Foreword

Abstracts for the 30th Bioelectromagnetics Society Annual Meeting
June 8-12, 2008 San Diego, California.

The following abstracts were reviewed by the Technical Program Committee and approved for presentation at the Thirtieth Annual Meeting. While the Technical Program Committee reviewed the content of these abstracts, they may not present completed work nor were they formally peer-reviewed for technical content.

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P1-1 THE PROBLEM OF ANTIBIOTIC-RESISTANT BIOFILMS:
ANTIBIOTIC-RESISTANT BIOFILMS, CLINICAL CONSIDERATIONS AND
AVAILABLE TREATMENTS

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Summary of Abstract. Biofilms are a unique state of existence preferentially employed by microorganisms in nature. Biofilms are ubiquitous in the environment and are estimated to be involved in two thirds of human infections seen in modern clinical practice, rendering them of enormous public health relevance.

Objectives. Examples of biofilm-associated human infections include, but are not limited to, intravascular catheter-related infections, prosthetic joint infections, prosthetic valve endocarditis, and cerebrospinal fluid shunt infections. In the United States alone, it is estimated that approximately 1 million nosocomial infections per year are related to biofilm formation on indwelling medical devices.

Methods. Growth in a biofilm state protects microorganisms from environmental stresses, currently available antimicrobial agents, and host immune defenses.

Results. Antimicrobial agents in use in clinical practice have been developed to have activity against bacteria in their planktonic (i.e., free-floating, non-biofilm) state. And, the majority of antimicrobial agents in use in clinical practice have been shown to have little activity against the same bacteria when they are grown in a biofilm state.

Conclusions. Clinically, many biofilm-associated infections (see above), do not respond to treatment with antimicrobial agents alone. Often, the associated device must be removed to effect cure. Novel strategies to treat biofilm-associated infections, without the need for device removal are needed.
THE USE OF ELECTROMAGNETIC FIELDS TO AUGMENT THE EFFICACY OF ANTIBIOTICS USED TO CONTROL BACTERIAL BIOFILMS FOUND IN PROSTHETIC KNEE IMPLANTS

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Summary of Abstract. Prosthetic implant surgery, in which total knee joints, hip joints, heart valves, shunts, catheters etc. are implanted in patients, is being done in clinics and hospitals worldwide. Tens of millions of these devices are implanted yearly in the United States and, in most cases, successfully. Unfortunately, long term and very difficult infections occur in an estimated 1.3 million patients (in the United States alone) sometime after an implant operation. Prosthetic knee implant surgeries are becoming more and more common as the U.S. population ages and physicians are also replacing damaged knees in younger patients due to the improvement in artificial knee designs (and hence the expected lifetime of the implant). If a prosthetic knee develops a recalcitrant infection, the base cause is probably a biofilm (quite likely with Staphylococcus epidermidis being the bacteria) on some surface of the knee and, if this is the case, there is virtually no means of clearing the infection without removing and re-implanting the knee. The cost in dollars, career time lost and pain caused by a second surgery is enormous for the unfortunate patient and the risk of re-infection and possibly even amputation of the limb is dramatically increased if a second surgery is necessary. The aim of the reported work is to develop a technique for clearing a bacterial biofilm infection in a prosthetic knee by using induced currents in the knee to enhance the efficacy of an antibiotic sufficiently to achieve sterilization of the prosthetic. In order to establish some of the basic biofilm growth processes and experimental protocols, the first efforts were directed to showing that small dc currents could be used to enhance the efficacy of ciprofloxacin against Staphylococcus epidermidis biofilms grown on a variety of materials including ASTM-F75, a common metal used in prosthetic knee implants. The results of these experiments are summarized below.

Results. The graph shows the killing trend lines with (dotted line) and without (solid line) the antibiotic ciprofloxacin in the support medium. The data points marked as (x) are for experiments without ciprofloxacin in the medium and the points (o) are for experiments with the antibiotic in the medium with all experiments having a 24 hour exposure time. The cross section of the experimental chamber was 239 square mm so, for instance, 5 mA dc current represents 20.9 microamps/square mm. The focus of the work is now being shifted to applying ac magnetic fields to S epidermidis biofilms in a new exposure setup that is designed to allow up to seven levels of antibiotic (or seven different antibiotics) to be used at a given set of ac magnetic field parameters. The biofilms are grown on half inch diameter disks in a standard CDC reactor using the protocol developed in the dc work. Each of the eight holders in the CDC reactor contains three coupons and the exposure setup is designed to allow the CDC holders to be removed from the CDC reactor and placed directly into individual wells in the exposure setup. After the biofilm coupons are placed in the experimental setup, the entire unit is placed inside an eight inch diameter, 24 inch long solenoid which produces the desired magnetic fields. Calibration measurements of the ac magnetic fields show excellent agreement to theoretical calculations. Measurements also indicate that the variation of the magnetic field, as a function of the distance from
the center line of the solenoid (the z axis) is about one percent (1%). The solenoid was designed to have three separate (non-overlapping) coils wrapped on the coil form. This was done to allow further flexibility in choosing the magnetic fields that will be used in the experiments. The entire experimental setup (solenoid plus the exposure chamber) is operated in a non-magnetic incubator. Standard incubators not only contain large amounts of magnetic materials, but they also exhibit large and uncontrollable ac magnetic fields generated by their built-in motors and pumps. There was some concern that ac magnetic fields applied to a prosthetic knee could pose a safety issue due to the fact that the metal parts of the knee might heat sufficiently to damage bone cells that are in close proximity to the metal (inductive heating). Theoretical calculations indicate for the fields anticipated to be effective in biofilm control that heating will not be an issue. Direct measurements of the heating will be done as part of the ac experiments that will confirm the calculations.

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![Graph Image]

**Figure 1.**
**P1-3 ISCHEMIC STROKE: PATHOGENESIS OF CELL INJURY**

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**Summary of Abstract.** The cellular and molecular pathogenesis of ischemic stroke is highly complex and well beyond the scope of this brief presentation. The focus of this abstract and presentation will be a discussion of the systems pathophysiology involved in stroke with the intent of identifying a limited number of fundamental targets for treating acute stroke.

**Objectives.** The key event in triggering stroke brain damage, known as cerebral infarction, is the loss of cellular energy to drive crucial molecular pathways involved in cell function and structure. Unlike most other body organs, the brain metabolizes glucose almost exclusively and does so without maintaining large carbohydrate stores in the form of glycogen or other high energy compounds/substrates. The brain is critically dependent on preserved blood flow to provide glucose and the oxygen necessary for glucose’s complete oxidation. The conscious human brain utilizes approximately 1000 $\mu$ mole/100 gm/min of high energy phosphates, e.g. ATP. Carbohydrate substrates and high energy organic phosphates (ATP, PCr) stores in brain total approximately 2500 $\mu$ mole/100 gm. Accordingly, with the loss of blood flow and substrate/oxygen supply the brain will deplete its energy reserves within two to three minutes. All energy dependent functions cease at this point and importantly all brain cells lose their transmembrane ion gradients and the cells depolarize. A complex, yet fully to be defined, set of events ensues that rapidly leads to cellular necrosis and tissue infarction unless blood flow is restored.

**Methods.** An important consideration for understanding ischemic brain injury and the development of treatment approaches is the anatomic pattern of blood flow reduction caused by occlusion of a single brain blood vessel. Because of extensive collateral blood vessels, occlusion of a single brain vessel produces an area of severe blood flow loss within the central tissue zone served by this vessel. This central core of severe ischemia is surrounded by areas of increasing flow until the zone of an adjacent vessel is reached where blood remains normal. This halo of partial blood flow reduction surrounding the severely ischemic core is known as the ‘penumbra’.

**Results.** Over twenty years ago various researchers discovered that brain tissue lying within this penumbral zone of partial ischemia survived the ischemic insult for several hours longer than the ischemic core. This several hour delay in cell death within the penumbra provided the clinician with a reasonable opportunity to initiate treatment to reestablish blood flow and preserve the penumbral tissue. The use of clot dissolving drugs, such as tissue plasminogen activator, exploits this approach and is effective in improving the outcome of patients with acute stroke when given within 3 hours of symptom onset. However, other efforts to develop ‘neuroprotective’ drugs to expand the reperfusion treatment window have been unsuccessful. Several laboratories including ours have studied the pathophysiology of the penumbra looking to clarify the cellular and molecular events that allow this tissue to remain alive for hours longer than the core ischemic zone. What we have found is that in contrast to the ischemic
core where brain cells depolarize and equilibrate their ions within minutes, penumbral tissue experiences recurrent bouts of brief depolarization/repolarization occurring five to ten times per hour. Each of these ‘recurrent depolarizations’ places stress on the cell, depleting energy stores, allowing toxic ion shifts to occur, and triggering intracellular systems that lead to cell death.

**Conclusions.** One treatment strategy that requires additional vigorous testing is to develop drugs that suppress these recurrent depolarizations through stabilization of the cell membranes. The ability to halt these recurrent depolarizations applied in conjunction with brain reperfusion methods stands an excellent chance of improving stroke treatment over that which is currently available.

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**P1-4 SURFACTANT CHAPERONE THERAPEUTICS FOR NEUROPROTECTION**

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**Summary of Abstract.** Each year approximately 1% of the American population suffers traumatic brain injury (TBI) resulting from mechanical, electrical or thermal trauma resulting in more than 100,000 new disabling injuries. In addition, disabling TBI resulting from IED blasts is a major problem among U.S. soldiers returning from Iraq. Conventional medical care for TBI are directed at preventing progression of injury and rehabilitation. Until recently, therapies for to reverse the molecular alterations associated with TBI have been unknown. However, promising new therapies involving use of surfactant copolymers or highly polar polymers are in preclinical and clinical testing phases of development. At the molecular level, physical trauma causes disruption of bilayer lipid membranes structure and conformational alteration in protein structure, leading to secondary cellular degeneration processes and acute tissue inflammation. Restoring membrane structure and disaggregating/refolding denatured proteins in the immediate post-trauma phase is essential to neuroprotection. Once considered impossible, it has been well demonstrated that this type of molecular repair is quite possible. This reports reviews the scientific development of this technology over past 15 years, particularly as its relates to electrical injuries. In addition, the challenges now faced by the university scientist engaged in making the technology commercially available will be discussed.
SYMPOSIUM: THERMAL MEDICINE

S1-1 TODAY’S THERMAL THERAPY: NOT YOUR FATHER’S HYPERTHERMIA - CHALLENGES AND OPPORTUNITIES IN APPLICATION OF HYPERTHERMIA FOR THE 21ST CENTURY CANCER PATIENT

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Summary of Abstract. Hyperthermia is the application of heat in a therapeutic setting. When cells are moderately heated they can become sensitized to therapeutic agents such as radiation and chemotherapy. The clinical field of hyperthermia emerged in the 1970’s on a foundation built upon compelling radiobiologic evidence that hyperthermia was an ideal complementary treatment to radiation and certain chemotherapeutic agents. Unfortunately this well deserved enthusiasm quickly become tempered due to the inability to effectively heat tumors, particularly deep seated ones with cumbersome first generation technology coupled with still emerging understandings of thermal biology. Today as before, both challenges and opportunities remain in the application of hyperthermia for cancer patients. The lessons learned from the introduction of hyperthermia a generation ago are providing focus for application of this still promising modality in today’s clinic. These areas of challenge and opportunity include: thermal biology; treatment planning, delivery and monitoring; successful high quality clinical trials; and integration of thermal therapy with emerging technologies and therapeutic strategies both established and evolving. Examples of advancements over the past quarter century in each of these areas will be discussed. The progress made in understanding of thermal biology, physics and bioengineering, coupled with advances in complementary clinical treatment modalities have all contributed to the next generation of clinical thermal therapy.

Introduction. If cells are heated to still higher temperatures the heat will cause irreparable damage resulting in cell death, a process referred to as thermal ablation. The clinical field of hyperthermia emerged in the 1970’s on a foundation built upon compelling radiobiologic evidence that hyperthermia was an ideal complementary treatment to radiation and certain chemotherapeutic agents. This well deserved enthusiasm quickly became tempered by the realization that available technology for clinical hyperthermia treatment delivery was both cumbersome and limited in ability to provide effective treatment. The lack of meaningful quality assurance guidelines and treatment goals provided further roadblocks to wide spread use.

Today as before, both challenges and opportunities remain in the application of hyperthermia for cancer patients. These areas include thermal biology, treatment planning, delivery, and monitoring, successful high quality clinical trials, and integration of thermal therapy with emerging technologies and therapeutic strategies both established and evolving. The progress made in understanding of thermal biology, physics and bioengineering, as well as advances in complementary clinical treatment modalities have all contributed to the next generation of clinical thermal therapy.
1-1 THE EFFECT OF ASSESSMENT SCHEMES AND RF EVALUATION UNCERTAINTY ON SAFETY COMPLIANCE PROBABILITIES

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Summary of Abstract. National and international (IEEE, IEC, CENELEC & ITU) RF safety compliance standards generally specify exclusion zones around RF radiators where human exposure exceeds permissible exposure limits (PEL). When setting the boundaries of these zones, operators rely on RF exposure evaluations (measured or calculated) that always entail an uncertainty error. Accordingly, there is a finite probability that the true level of RF exposure at the boundary of the operator’s exclusion zone will actually exceed the PEL. This probability can be reduced by assessment schemes such as adding a penalty margin (e.g. 3 dB) to the operator’s RF evaluation level.

In countries where government regulators conduct evaluation audit checks of the operators’ exclusion zone boundaries, the probability of a non-compliance assessment decision is further affected by the added uncertainty in the regulator’s RF exposure evaluations as well as any compensating scheme to account for that uncertainty. It is important that regulators and standards committees which are drafting rules for RF compliance and non-compliance assessments have a clear understanding of the probabilities for non-compliance assessment decisions, and making errors in those assessments.

Objectives. For a range of operator/regulator assessment schemes and evaluation uncertainties this presentation provides probability estimates for the following events:
1) The regulator finds that RF exposure at the operator’s exclusion zone boundary is non-compliant with the PEL;
2) The regulator commits a compliance error - i.e. the regulator decides that the operator’s exclusion zone boundary is compliant with the PEL when it really isn’t;
3) The regulator commits a non-compliance error - i.e. the regulator decides that operator’s exclusion zone boundary is non-compliant with the PEL when it really is compliant.

Methods. The event probabilities were calculated using Monte Carlo analysis over 10,000 trials for various combinations of operator and regulator assessment schemes, and for RF evaluation expanded uncertainties (95% CI) ranging from 1 to 6 dB. For each trial, a random outcome for both the operator and regulator evaluations was generated from a normal probability distribution based on the presumed expanded uncertainty, and then compared to determine if the events listed above had occurred. The corresponding probabilities for each event were then simply obtained by dividing the event count by the total number of trials. The analyses were implemented in Microsoft Excel using the VBA macro language to conduct and record the repeated trials.

The following operator assessment schemes were considered in the analyses:
1) Operator uses the best estimate of his RF exposure evaluation to set exclusion zone
boundary.
2) Operator sets a target range of 4dB for the difference between the upper bound of his 95%CI and his best estimate. Any excess above the target range is added to the best estimate level when setting the exclusion zone boundary.
3) Operator uses the upper bound of his 80%CI or 95%CI to set exclusion zone boundary.

The following regulator assessment schemes were also considered:
1) Regulator decides non-compliance if the best estimate of his audit evaluation exceeds the PEL at the operator’s exclusion zone boundary.
2) Regulator sets a target range of 4dB for the difference between his best estimate and the lower bound of his 95%CI. Any excess above the target range is subtracted from the best estimate level when assessing non-compliance at the exclusion zone boundary.
3) Regulator decides non-compliance if the lower bound of his 80%CI or 95% CI exceeds the PEL at the exclusion zone boundary.

Results. The event probabilities were found to vary substantially for different operator and regulator assessment schemes, as well as for varying combinations of operator and regulator evaluation uncertainties.

Predictably, the simplest assessment scheme where both operator and regulator use best estimates of their evaluations leads to a 50% probability of a non-compliance decision for all combinations of evaluation uncertainties. However, the probability of compliance and non-compliance error ranges from 3% to 23% for operator and regulator evaluation expanded uncertainties ranging from 1 to 6 dB. The event probabilities for when both operator and regulator use the 4dB target range schemes are identical to the aforementioned simple scheme when the expanded uncertainties are no more than 4 dB. However, for high regulator expanded uncertainties (5 or 6 dB), the compliance error probabilities can increase up to 34%.

When the operator uses the upper 95% CI and the regulator uses the lower 95% CI, the probability of a non-compliance decision falls to less than 1.3%. The probabilities for compliance error (<2.7%) and non-compliance error (<1.2%) are also very low. However this approach leads to larger exclusion zones than those based on best estimate evaluations. Smaller exclusion zones result if 80% CIs are used, though the probability ranges for non-compliance decisions, compliance errors and non-compliance errors increase - 3 to 7%, 3 to 10% and 1 to 6% respectively.

The Excel spreadsheet containing the detailed probability results data is available from the author on request.

Conclusions. These probability results help to enable more informed choices about RF compliance assessment schemes for operators and regulators. Other important considerations are: a) whether PELs incorporate any safety margin for evaluation error; b) what standard of evidence is required to show non-compliance (‘balance of probabilities’ or ‘beyond reasonable doubt’?), and; c) the economic cost of larger exclusion zones when adding penalties to the operator evaluation levels.

The above considerations entail value decisions that are open to debate. In the author’s opinion the best option is the last one described above where the operator uses the upper bound of the 80%CI of his evaluation, and the regulator uses the lower bound of his 80%CI
when conducting audit checks. It leads to reasonably low probabilities for the undesirable events listed above with modest compliance level penalties that can be reduced by high quality (i.e. low uncertainty) operator evaluations.

1-2 ARE THE LIMITED BENEFITS OF RESEARCH USING FMRI WORTH THE EMF EXPOSURE RISK TO HUMAN “VOLUNTEER” SUBJECTS?

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Summary of Abstract. The issue of Functional Magnetic Imaging EMF exposure risk to “volunteer” human subjects is approached from a neuronal dosimetry viewpoint.

Objectives. To assess potential risks from the EMF exposure to human subjects used in Functional Magnetic Resonance Imaging (FMRI) based studies and subsequently use that information to explore the risks vs limited benefits of such studies.

Methods. The use of Functional Magnetic Resonance Imaging (FMRI) on human volunteer subjects has become quite fashionable in neural and psychological research. For example at the last Neuroscience Society meetings (November, 2007) over a thousand (of the nearly 30,000) papers presented were based on, or referred to, FMRI studies. Human “volunteer” subjects used in these studies often have little understanding of the biophysical basis and possible side effects of FMRI — including the physiological action of the magnetic and RF fields applied to the brain (and adjacent body parts). Such possible effects should be of particular concern to those “volunteers” who undergo repeated exposures as part of protracted studies. However, often such subjects have little understanding of the biophysical basis of the FMRI and the exposures involved. There also appears to be widespread misunderstanding among researchers and their subjects as to the limits in spatial and temporal resolution inherent in the FMRI technique. In fact, in order to gain more useful resolution, FMRI technology is evolving towards using higher and higher field strengths — sometimes approaching the level at which “magnetostimulatory” effects would be seen. At such levels, the FMRI is clearly dangerous and its use on humans is proscribed. Field levels somewhat below this still produce EMF within the brain which may be of a “neuromodulatory” nature. Given even the possibility of such effects, it seems that more attention needs to be paid to assessing potential risks to human subjects in FMRI studies — and this should be weighed against the limited benefits of using that technology.

Methods. Our current study focuses on the risk side of the issue and is based on calculating the EMF fields that are imposed by FMRI exposure at the neuronal level where it might be influencing ongoing neural activity. For that purpose, we used an approach similar to that in our earlier studies of the cellular impact of Extra Low Frequency (ELF) fields from power lines and other sources. First the brain is viewed as a “macro-conductor” of, more or less, uniform conductivity and the average current densities (say for cubic mm sized “voxels”) is
estimated. The “microdistribution” of these currents at the cellular level is then calculated using non-uniform models of neuron interiors, neural membranes and intracellular spaces. Finally, the likely impacts of these induced “micro currents” are assessed by comparing their magnitude and frequency content with those of endogenous neuro-electric currents produced by normal brain activity.

**Results.** Our dosimetry estimates indicate that neuronal level fields (current densities) induced by exposure of the human brain to FMRI field are far greater than those produced by endogenous neural activity. By comparison, they are also far stronger than cellular level fields we had previously calculated for humans exposed to fields from “High Current Configuration” power lines and other EMF sources.

**Conclusions.** Induced neural fields from FMRI are not likely to produce direct “neurostimulatory” effects but they could potentially alter the pattern of ongoing neuro-electric activity and could also burden neural metabolic functions (as a result of higher demand on the active transport of ions). Such neuromodulatory and metabolic outcomes may not produce profound changes in neural vitality for single exposures but such impacts may be cumulative – and they should be considered, along with limited benefits of FMRI research, when adjudging risks vs benefits balance.

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**1-3 ELECTROMAGNETIC FIELD MEASUREMENTS IN SCHOOLS AND HOSPITALS**

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**Summary of Abstract.** In this work, the results of Electromagnetic Field (EMF) measurements campaigns performed in so called sensitive locations, like Schools and Hospitals, carried on by the monIT Project team in Portugal are presented. 47 schools and 10 hospitals were measured using broadband equipment, results showing that the measured values are in conformity with the human exposure reference level (HERL) in all analysed locations. Also, in hospitals, the Electromagnetic Compatibility Reference Level (EMCRL) are analysed, being satisfied in all locations with sensitive equipment.

**Objectives.** The objectives of all the performed measurements are twofold. The first objective is to study if HERL is complied in the so called sensitive locations, like schools and hospitals. The second objective is specific for hospitals scenarios, where one must also guarantee that the EMCRL is complied in all locations where sensitive equipment, i.e., life support and monitoring equipment, is present, e.g., Intensive Care Units (ICU) or surgery services.
Methods. All the measurements were performed in cooperation with the national health and education authorities. The first stage was the selection of schools and hospitals to be measured. The schools (47) were mainly selected by their vicinity to mobile communications Base Station (BS) antennas. Parameters like the distance to the antennas or the existence of other transmitters in the surrounding neighbourhood were also taken into account. For the hospitals, because of their characteristics, a different procedure was followed. The hospitals (10) were selected to represent various scenarios: larger and smaller ones, with and without mobile communication BS or with other wireless communication systems, specialised (e.g., maternity wards) or general hospitals. All the measurements performed by the monIT Project team are carried out using broadband equipment (0.1 to 3000 MHz). By using broadband equipment, one must compare all the measured values with the lowest reference levels inside the considered frequency band (28 V/m and 3 V/m, for the HERL and the EMCRL, respectively). The considered HERL is the one recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the EMCRL one derived from the electromagnetic compatibility standard of the International Electrotechnical Commission (IEC). If these reference levels are complied, then, it is certain to have a full compliance within the entire frequency band. Measurements were performed following a standard procedure developed by the monIT Project team, which is based on internationally accepted procedures. This procedure takes several aspects into account, like the installation topology of the antennas, the geometry of the surrounding buildings, and the location of other transmitters, if any, to select the points where the measurements are performed, for 6 minutes. The root mean square value of these 6 minutes is then compared with the considered reference levels. In the hospitals, the procedure was updated in order to take the EMCRL compliance into account. However, one should take notice that this procedure for hospitals only takes BS signals into account and not those from portable equipments from any given wireless system.

Results. The core result from the measurement campaigns is that no locations were found with values above the HERL. These values are even more significant when one considers that the measurements were wide band ones, and that the considered reference levels are the lowest within the considered frequency band. In addition, in all of the analysed hospitals no values were found above the EMCRL.

Regarding just schools, 214 points were measured in total, in all the 47 schools analysed. Looking at the results, the large majority of the measured points are several times below the strictest reference level, within the considered frequency band. More than 85 % of the points are at least 1 000 times below the HERL, in terms of power density. The highest observed value is around 27 times below, and it was measured in a location with conditioned access.

Regarding hospitals, 109 points were measured in all the 10 evaluated hospitals. Again, all measured points were also below the HERL, with the vast majority of points (more than 80 %) more than 1 000 times below the HERL. Concerning the highest observed value, it was about 18 times below the reference level. On the other hand, the EMCRL compliance was also verified in all points measured in location with life support and monitoring equipment. The EMCRL value is very small when comparing to the HERL, but even so, the majority
(more than 85%) of these points are at least 10 times below. The highest value observed in these locations was about 1.6 times below the EMCRL.

**Conclusions.** This document describes measurements campaigns performed in Portugal by the monIT Project in so-called sensitive locations, like schools and hospitals. 47 schools and 10 hospitals were measured in order to analyse if the HERL are complied in these locations. In hospitals, there is also the question regarding the EMCRL compliance in locations with life support of monitoring equipment.

Results show that the HERL is complied in all the measured points in both hospitals and schools, as no points were observed above the reference levels. A total of 214 points were measured in all schools and the majority of the points (85%) are at least 1,000 times below the HERL. Concerning hospitals, a total of 109 were measured, and the results are similar, i.e., more than 80% of the points are at least 1,000 below. Concerning the locations with life support and monitoring equipment, all the points measured there are in compliance with the EMCRL.

**Acknowledgements.** One would like to thank the Portuguese health and education authorities for all the support provided.

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**1-4 EMF POLICY: A COMPARISON OF RECENT PUBLIC HEALTH AND EMF POLICY EVALUATIONS OF ELECTROMAGNETIC FIELDS**

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**Summary of Abstract.** This presentation will address the policy attributes, similarities and differences in EMF policies from state, national and international proceedings of the United States, the United Kingdom, the World Health Organization, the European Commission, and the European Environmental Agency.

Several decades of scientific research on electromagnetic fields and possible health consequences have resulted in intermittent efforts to assess EMF public health issues and EMF public policy impacts. In 1992, a comparative analysis of then-recent EMF Policy Statements from the Keystone Center Transmission Line Siting Dialogue of 1992 and the California Public Utilities Commission EMF Consensus Group 1992 were presented at the 1992 US Department of Energy Contractors Conference in San Diego, CA by this author. Important scientific and health policy proceedings convened between 1992 and 2008 have resulted in new EMF policy directions which are relevant to current transmission line siting and in setting new public safety guidelines and standards. Various public policy approaches to precautionary and preventative actions have evolved, based on continuing public concern, and the constellation of new science and public health policy developments.

**Objectives.** To compare and contrast several new scientific reviews leading to development of EMF policy and public health policy criteria.
**Methods.** Review, analysis, interview and participation in proceedings leading to new EMF policy.

**Results.** A comparative analysis of new national and international EMF policy documents and conclusions.

**Conclusions.** There are multiple proceedings and reviews that have resulted in new EMF policy at the national and international levels.

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**1-5 BODY IMPEDANCE MEASUREMENTS OF ELECTRICAL UTILITY WORKERS**

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**Summary of Abstract.** Body impedance is an important component in determining the current that can flow through a shock pathway in the event of an accidental electrical fault. This project measured the body and dry contact impedance of hand-to-hand, hand-to-foot and foot-to-foot pathways for 231 electrical utility workers.

**Objectives.** These measurements will contribute to an ongoing evaluation of the efficacy of personal safety grounds during work on de-energized and grounded power lines by providing statistical distributions for the body impedance of contemporary workers. The impedance distributions for line workers will be incorporated into a statistical risk model for electrical hazards during performance of specific types of tasks.

**Methods.** Volunteer subjects were recruited through employee newsletter announcements and visits to training and work sites. Recruitment emphasized workers who participated in power line maintenance, but was directed to all interested employees from other occupations. Measurements were performed in both indoor and outdoor work locations. Prior to measurements medical electrodes were affixed to the ankles and wrists of the volunteers and connected to a differential voltmeter (EPRI contact-current meter) by thin wire leads. Twenty-microampere 64-Hz currents produced by a constant-current source were injected through large dry-skin contacts: viz., gripped copper pipes and copper foot plates into selected hand-to-hand, hand-to-foot and foot-to-foot pathways. Voltage differences across the various pathways were measured between wrist and/or ankle electrodes by the contact-current meter that served as a differential voltmeter referenced to the subject’s body. The impedance was determined from the voltage difference across the pathway for the 20 µA current. In addition, the total pathway (body plus contact) impedance was determined from the known current and the output voltage of the constant-current source. Both the applied current and voltage (∼0.1 V) were below perception thresholds for the subjects.
Pathway voltage measurement data were stored on a memory card in the contact-current meter. These data were combined with concurrently recorded information on subject, pathway and applied voltage prior to analyses. Protocols and consent procedures for this project were approved by an Institutional Review Board (IRB) convened by Independent Review Consulting, Inc. of Corte Madera, CA.

**Results.** Measurements were performed on 191 male and 40 female employees of Southern California Edison over a four-month period. The internal impedances for male subjects were generally lower than those for women: median hand-to-hand impedance of 530 Ω for men versus 690 Ω for women and 570 Ω versus 660 Ω for median hand-to-foot impedance. Body impedance measurements for both genders were log-normally distributed for all pathways. Differences between genders were statistically significant and attributable to the generally smaller physical size of the women subjects: median body mass index (BMI) was 24.9 for women versus 28.1 for men. The pathway total impedances were also significantly larger for women. This is reflected in the hand contact resistances derived from the total impedances. The mean and standard deviation for hand contact impedances included in the total impedances were 2250 ± 830 Ω for men and 3040 ± 1200 Ω for women. For both genders the hand-to-hand pathway impedances were larger than those for other pathways and the distributions for all pathways were log-normal. Correlation coefficients between internal pathway impedance and subject height, weight and BMI indicated a higher correlation (negative) with BMI than weight for both genders, with the highest correlation coefficients occurring for females. The range of Pearson product-moment correlation coefficients between internal pathway impedance and BMI was -0.49 to -0.60 for men and -0.68 to -0.74 for women. There was no correlation with height. Total pathway impedance depends primarily on contact resistance and was not related to BMI. Multiple repeat impedance measurements performed on three subjects at intervals of up to six months indicated a pooled coefficient of variation for both internal and total impedance pathways of about 11%. The average standard error for all three repeat subjects was 5.5%, when expressed as a percentage of the mean.

The measured impedances varied somewhat from those cited by the IEC*. The latter are based on historical data from cadavers and living subjects from the 1930s and 1980s. The contemporary internal impedances are lower than those cited by the IEC, while the total body impedances for dry contacts were higher in our data than in the IEC’s. Direct comparisons are difficult because of the lack of physical characteristic and gender data for the IEC data and the use of very low voltages for the contact-current meter measurements. Part of the difference in internal impedance between the two data sets could be due to historical changes in average BMI. Increases in the average BMI of adult males has been approximately 2 units since the 1980s and 3 units since the 1930s. The correlation between impedance and BMI in our data indicates a linear relationship with a slope of approximately −27 Ω/BMI unit. Thus, these changes could account for a 5 to 8% decrease in internal pathway impedance over these time periods. Applied voltage does not have a significant effect on internal impedance. On the other hand, differences in applied voltage, but not BMI, would affect the total pathway impedance which includes skin resistance. Results for the low applied voltage (∼0.1 V) used in this study are expected to be valid up to a few volts, and possibly as high as 15 V. However, at 25 V, which is the lowest voltage for which
impedance data are reported by IEC, the skin contact resistance has begun to decrease and the total pathway impedance falls below that at lower voltages. Median internal impedance values for all pathways for men ranged from 530 to 560 Ω, which is only slightly higher than the often used value of 500 Ω for internal body impedance.

Conclusions. This survey of body impedance within a worker population demonstrated efficient and practical protocols to collect reproducible body impedance data in non-laboratory work environments with low-current, low-voltage measurements. Internal and total body impedances are negatively correlated with body mass index. The internal impedance values may be valid for extrapolation and use in the statistical risk models. However, before the total impedance distributions can be used in such models it is necessary to further investigate their extrapolation to higher contact voltages.


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1-6 SUMMATION FORMULAS - FACTS AND FICTION

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Summary of Abstract. The use of “summation formulas” as a common concept for the assessment of a simultaneous exposure to multiple frequency fields or to multiple sources is checked for a lack of guidance, misunderstandings and erroneous contents. Based on the shortcomings, mistakes and errors detected a new framework and set of rules to properly deal with these exposure scenarios is developed.

Objectives. The assessment of a simultaneous exposure to multiple frequency fields or to multiple sources is the most misunderstood concept in the whole framework when it comes to ensure safety in electric, magnetic and electromagnetic fields. In the ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields it is clearly stated, that “it is important to determine whether, in situations of simultaneous exposure to fields of different frequencies, these exposures are additive in their effects.” This important sentence is not taken into account in most cases and often intentionally neglected. Several international and national guidelines, standards and regulations, as well as many people, derive from the pure existence of these so called “summation formulas” that their use is mandatory in every exposure situation where multiple frequencies or sources are present. Especially in the workplace environment this severe mistake often leads to unnecessary measures or prohibits the use of technologies and work
processes while not improving the safety of the workers at all. The ICNIRP Guidelines also state, that “the (...) summation formulae assume worst-case conditions among the fields from the multiple sources. As a result, typical exposure situations may in practice require less restrictive exposure levels than indicated by the above formulae for the reference levels.” Because no further guidance is given this information is often neglected, too, resulting in extensive consequences. The ICNIRP Statement on Guidance on Determining Compliance of Exposure to Pulsed and Complex Non-Sinusoidal Waveforms Below 100 kHz with ICNIRP Guidelines improved the situation to some extent, because now phase relationships were introduced in the summation formulas. However, even this improved approach leads to a large overestimation of the actual exposure, with all negative consequences.

Methods. Based on physical mechanisms of interaction of electric, magnetic and electromagnetic fields with biological tissue and physiological data different scenarios of simultaneous exposures to multiple frequency fields or to multiple sources are analyzed both in the low and high frequency range covering stimulation effects and thermal effects of those exposures.

Results. In the low frequency range a simultaneous exposure to multiple frequency fields or to multiple sources is not additive in its effects, if not a series of parameters are perfectly matched. From a theoretical point of view those additive scenarios do exist, however, they can hardly be found in the everyday life environments for both occupational and general public exposures.

Even in the high frequency range it is not true that thermal effects of electromagnetic fields are always additive.

Conclusions. A newly developed framework and set of rules gives clear guidance on how to deal with simultaneous exposures to multiple frequency fields or to multiple sources both in the low and high frequency range. The new data presented could also be taken into account for future safety guidelines or standards.

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**2-1 REVIEW OF 44 ANIMAL STUDIES INVESTIGATING EFFECTS OF RADIOFREQUENCY EXPOSURE ON CANCER, SURVIVAL AND GENERAL HEALTH**

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**Summary of Abstract.** The scientific weight of evidence in 44 cancer studies in laboratory animals shows no adverse effect of RF exposure up to two years in duration at dose rates up to 10 times the occupational limit (0.4 W/kg) on a) survival, b) body mass, an indicator of general health status, and c) carcinogenic processes (initiation, promotion and co-promotion).

**Objectives.** To present a review of 44 studies examining whether radiofrequency (RF) energy causes/promotes cancer or affects survival and general health of laboratory animals.

**Methods.** In three tables, this report summarizes 44 studies of cancer in laboratory animals exposed to RF energy published since 1962. The first table indicates whether or not a statistically significant increase was observed in tumor incidence as well as effects on survival and body mass, if reported. For each of the studies, information is provided on animal species (primarily mice and rats), frequency (and modulation), dose rate (specific absorption rate, SAR), exposure conditions, cancer model, number of animals per group and reference. A second table summarizes the 22 studies in which animals were exposed for 11-25 months. Thus, 50% of the studies employed long-term exposures of 11 months or longer; in 18 studies, animals were exposed for 18-25 months. Significantly, 10 publications describe lifetime exposure studies in which mice and rats were exposed for 24-25 months, the average lifetime of these animals. A third table lists the studies by cancer model (spontaneous tumors, genetically-modified animals, chemically-induced tumors, ionizing radiation-induced tumors and models employing injected tumor cells).

**Results.** Two studies (Preskorn et al., J Surg Oncol 10:483, 1978; Adey et al., Rad Res 152:293, 1999) reported that RF exposure had a “protective” effect on cancer development but such results are not supported by the overall evidence. Likewise, the results in five papers (Szmigielski et al., Bioelectromagnetics 3: 179, 1982; Chou et al., Bioelectromagnetics 13:469, 1992; Rephacholi et al., Rad Res 147:631, 1997; Anghileri et al., Int J Radiat Biol 81:205, 2005; Hruby et al. Mutation Research 649:34, 2008) describing carcinogenic effects in RF-exposed animals are not supported by the weight of evidence in the 44 studies. Three follow-up studies to the Chou et al. study failed to confirm an association between RF exposure and an increase in cancer incidence (Toler et al., Rad Res 148:227, 1997; Frei et al., Bioelectromagnetics 19:20, 1998; Frei et al. Rad Res 150:568, 1998). Two follow-up investigations of the Rephacholi et al. (1997) experiment by Utteridge et al. (Rad Res 158:357, 2002) and Oberto et al. (Rad Res 168:316, 2007) used many more animals and multiple exposure levels from 0.25-4 W/kg and did not confirm an increase in tumors. The description of the exposure conditions in Anghileri et al. is inadequate and a small number
of animals were used. Hruby et al. concluded that “chance effects remain the most plausible interpretation for the differences observed” because there was no exposure response relation and the results were inconsistent with an almost identical study (Yu et al., Rad Res 165:174, 2006). Two studies reported changes that could not be replicated in the same laboratory (Bartsch et al., Rad Res 157:183, 2002; Anane et al., Rad Res 160:492, 2003). The survival and body mass data are consistent because 26 of 27 studies since 1983 reported no significant change in survival and all 27 studies reporting body mass observed no significant change.

**Conclusions.** The scientific weight of evidence in 44 cancer studies in laboratory animals shows no adverse effect of RF exposure up to two years in duration at dose rates up to 10 times the occupational limit (0.4 W/kg) on a) survival, b) body mass, an indicator of general health status, and c) carcinogenic processes (initiation, promotion and co-promotion). The findings are consistent with the lack of any established mechanism of interaction (other than thermal) of RF energy with biological systems. Furthermore, the results offer a strong challenge to studies reporting potential health effects from RF exposure in vitro. More importantly, the results of the animal cancer studies contribute significantly to our understanding of safe levels of RF exposure.

**Acknowledgements.** (Supported by Motorola)

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**2-2 LONG-TERM EFFECTS OF EXPOSURE OF MICE TO UMTS ELECTROMAGNETIC FIELDS: A MULTI GENERATION STUDY**

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**Summary of Abstract.** Continuous exposure to UMTS electromagnetic fields of SAR values up to 1.3 W/kg did not affect ferility parameters or development in mice over 4 generations.

**Objectives.** Although the new mobile phone telecommunication standard, UMTS, has been introduced years ago, only little information is available regarding possible biological effects, especially with respect to long-term effects in animals. Within the German Mobile Phone Research Program, a study was therefore initiated which addressed this topic.

**Methods.** Male and female mice (C57BL6) were exposed continuously to UMTS frequencies at SAR values of 0 (sham), 0.08, 0.4, and 1.3 W/kg in a blinded fashion. Per SAR value and generation, 32 cages with one male and two females were placed in special radial waveguides (for details see Reinhardt et al., Radiation Protection Dosimetry 2007; doi:
Water and food consumption were measured once for each generation at a fixed day. One female was humanely killed 18 days after pairing, and the number of intact fetuses and macroscopically visible malformations were estimated. Additionally, the weights of uteri, and the numbers of resorption sites and follicles were counted. The number of pups of the second females’ litters and their weight gains were recorded, as well as the time point of eye opening. At the age of 7 days, a simple reflex test was performed. After weaning, the second females of each pair and the males were killed. In the males’ testes, the numbers of normal and malformed sperm were investigated microscopically. The next generation was recruited from the pups which were exposed already in utero. This procedure was repeated in the same way for three more generations (F1 – F3). In F3, the experiment was terminated 18 days after pairing.

**Results.** Neither the fertility-related parameters nor the development of the pups were negatively affected by exposure. One exception was a significantly ($p<0.01$) higher rate of malformations in fetuses of the F0 mice at 0.08 and 1.3 W/kg. This effect, however, was most likely due to very low malformation rates found in the respective sham group of this generation. Food consumption was significantly ($p<0.001$) lowered by exposure. This effect was most pronounced in the last generation at 0.4 W/kg.

**Conclusions.** The results of these experiments show that even long-term, life-long exposure to UMTS electromagnetic fields does not affect fertility or development in mice. Since there were no negative effects seen in the four generations tested it is safe to say that in mice UMTS electromagnetic fields at non-thermal SAR values have no adverse effects on the parameters investigated, even at levels above limits for public and occupational exposure. The effects seen on food consumption are interesting and should be analyzed in more details in future studies.

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2-3 BIOLOGICAL EFFECTS OF HIGH POWER MICROWAVES

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Summary of Abstract. Summary of abstract: Rats were exposed to 2 different sources of high power microwaves (HPM). This study shows small behavioural effects, some biochemical changes after an acute exposure (GFAP increase), and an increased cancer incidence after chronic exposure. If the observed increased risk of cancer is not due to residual X-rays, this study suggests that behavioural tests are not helpful to detect long-term effects of a chronic exposure, maybe with the exception of rotarod, performance of which is paradoxically improved.

Objectives. High power microwaves can be used to inhibit electronic systems or to neutralise people. The goal of this study was to look for effects of high power microwaves on the central nervous system, mainly on behaviour and effects on a marker protein of astrocytes indicating some inflammatory process: the glial fibrillary acidic protein GFAP. A long term follow up was also performed after a chronic exposure.

Methods. Six-week rats were exposed to two different sources with pulse trains emitted at a repetition rate of 100 pps.
Performed behavioural tests were: avoidance to test perception, beam-walking and rotarod to test balance and motricity, and T-maze to test exploratory behaviour and learning. Besides that, astrocyte labelling in the brain was assessed through quantification of GFAP filaments labelled by immunohisto-chemistry.

For each test, a group of 12 exposed animals was compared to a group of 12 sham-exposed animals, set at the same place and in the same ambient conditions as the exposed animals, but without emission by the source.

For the avoidance test with source 2, the emission was closer to the antenna output, with two pulse trains of 8 minutes spaced by 10 minutes. The number of alternations between the two compartments, one of which was protected from MW, was the parameter of interest.

Exposure parameters were: peak SAR=90MW/kg; av SAR: 22 W/kg.

In the beam-walking, a 2 m-long, 2 cm-large rod was placed in front of the rat homecage. The rat was placed at different distances from the cage and the success to reach the cage was noted. In the rotarod, the ability of the rat to stay on the turning axis was recorded. In the T-maze, the rat learned to go in a first task to go in one single open arm (right or left). The consecutive task was to go in the second arm when both arms were opened. Beside astrocyte density that would reflect some inflammatory process was assessed in different brain structures through quantification of GFAP filaments labelled by immunohisto-chemistry (IHC). This labelling was tested either 2 days after exposure (D+2), either 7 days after exposure (D+7). For each test, a group of 12 exposed animals was compared to a group of 12 sham-exposed animals, set at the same place and in the same ambient conditions as the
exposed animals, but without emission by the source.
A chronic exposure was also performed on two groups of 24 animals, one was truly exposed, the second one was sham-exposed. This exposure lasted 20 minutes a day, 5 dys/wk for 8 weeks. Peak SAR: 3.3 MW/kg; av SAR: 0.8 W/kg. Residual X-rays: 20 mGy/day (total 0.8 Gy).

**Results.** Avoidance was significantly altered at a thermal SAR. Amongst other behavioural tests, only rotarod showed an effect on exposed animals, which was an increased performance.
With source 1, GFAP expression was not increased on D+2, but increased on D+7 (+40%); with source 2, GFAP expression was strongly increased on D+2 (+70%), probably reflecting the higher average SAR allowed by a continuous emission instead of spaced 10 s pulses. Effect at D+7 has not been tested with this source 2.
In the one year after the exposure, 8 from chronically exposed animals deceased with various tumours, as only one sham-exposed animal died, without any tumour. Histopathology is ongoing.

**Conclusions.** In summary, HPM exposure showed short term effects (pain, motor excitation) as well as long term effects (cerebral tissue inflammation, tumour). Although rotarod results suggest that rat motricity may be stimulated by the exposure, the increase in cancer incidence tells this stimulation is not indicative in this case of a long-term beneficial effect after chronic exposure It also shows that the other behavioural tests that we used are not helpful in detection of a chronic risk. GFAP could be a marker of a long-term risk in cases of animal experimentation, but this needs complementary work to be confirmed.
If the observed important risk is not due to residual X-rays, this study suggests that a health risk could be produced by a chronic exposure at a average SAR below the known level of health threshold of 0.08 W/kg, given that the peak SAR is of the order of 3.3 MW/kg (E-field 1.5 MV/m). Further investigations are necessary to determine the threshold for such a risk.

**Acknowledgements.** This study was funded by DGA, and by the MEDAD research program Pr189 – Neurotox DRC07-AP05
**Figure 1.** Time spent in non protected side – Source 2 (Mean ± SEM)

**Figure 2.** GFAP expression in different brain areas at D+2 (Mean ± SEM)
**Summary of Abstract.** Introduction. The recent increasing interest in the biological effects of magnetic fields, specially those modulated at extremely low frequencies (ELF), can be attributed to the widespread application of modern equipment inducing such fields. There are numerous experiments showing the influence of exposure to ELF-EMF on behavior and neurotransmitter systems. Recently, greater interest in this aspect has been associated with attempts to apply ELF-EMF as a therapy for human movement disorders. Treatment with electromagnetic fields has been reported to attenuate motor symptoms of Parkinson’s disease (PD). However the influence of social influences have not analyzed in these studies.

**Objectives.** The aim of this study was to determine the effect of whole body exposure to ELF-EMF on motor behavior of rats with 6-OHDA lesions. Compare the behavior responses of rats isolated versus grouped.

**Methods.** Adult male Wistar rats (200-220 g) were lesioned unilaterally in nigrostriatal via by 6-OHDA. To evaluate the degeneration rotational behavior were induced with amphetamine injections each two weeks. After three evaluation the animals were divided (n=4 for each group): Group A: lesioned and maintained in cages individually, Group B: lesioned and grouped in the same cage; Group C, similar to A plus daily stimulation with ELF-EMF and Group D: similar to B plus ELF-EMF stimulation. ELF-EMF stimulation was applied for two hours daily (10:00-12:00) during two months with a pair of circular Helmholtz coils located above and below the acrylic cages. The coils produce a vertical sinusoidal 60 Hz magnetic field at 2.4 mT. Each week before and after the stimulation the animals were evaluated for different motor behavior: open field activity (resting time, rearing, stereotypic activity and locomotor activity), induced rotational behavior, curling and balance beam tests.

**Results.** Our results showed: (1) changes induced by ELF-EMF stimulation on motor behaviors are more strong in the animals grouped that these maintained individually, (2) ELF-EMF improved the rotational behavior induced by amphetamine, (3) no differences were observed in stereotypic activity, rearing and curling tests between any of group studied, (4) increase in locomotors activity and balance beam test were observed in animals with ELF-EMF stimulation.

**Conclusions.** Electromagnetic exposure induces motor changes of animal model of Parkinson disease. The changes observed were amplified when the animals are maintained in group versus the individual animals. These results showed the influence of the social environments in the recovery of motor activity in this model. The mechanisms involved in this result could be some changes in described hormonal and neurotransmitters involved in social behaviors.
2-5 KCL EUTHANASIA CAUSES NEARLY IMMEDIATE CHANGES IN INTRACRANIAL LOSS TANGENT AT MULTIPLE FREQUENCIES FROM 100 MHZ TO 3 GHZ

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Summary of Abstract. Using a probe placed on exposed calvariae of 7 anesthetized rats, we previously acquired serial complex reflection coefficient measurements at 51 frequencies from 100 MHz to 3 GHz during physiological maneuvers. From these data we have calculated the loss tangent (\(\tan\delta\)) at 7 of these frequencies. We report an abrupt change in \(\tan\delta\) at multiple frequencies occurring less than \(\frac{1}{2}\) minute after the start of KCl administration, demonstrating that serial reflection coefficients can be used to monitor changes in passive electrical properties of tissue that accompany physiological changes.

Objectives. Physiological changes in brain\textsuperscript{(1,2,3)}, kidney\textsuperscript{(2)}, and heart\textsuperscript{(4)} cause changes in tissue permittivity that can be measured with in situ coaxial probes. Also, measurements obtained with a probe placed on the brain have been used to calculate changes in conductivity and loss tangent (\(\tan\delta\)) associated with KCl or CaCl\textsubscript{2} euthanasia \textsuperscript{(1,2)}. In a pilot study, after placing a probe on exposed rat calvaria, we used a network analyzer to apply microwaves at 51 frequencies and measure the reflections. Previously we showed that reflection coefficient changes with hypercapnia and IV infusion of KCl\textsuperscript{(5)}. We have now used the prior data to calculate \(\tan\delta\) (the ratio of the imaginary component of permittivity to the real component). We now report the effects of KCl infusion on \(\tan\delta\).

Methods. Animal preparation and data acquisition were as previously described \textsuperscript{(5)}. The calvaria of each of 7 rats was surgically exposed. A hole was drilled into the calvaria that penetrated to or just through the inner table. A coaxial probe made from 3.6 mm (0.141 in) outer diameter semirigid coaxial cable, with a \(\sim\)0.6 mm protruding inner conductor, was placed on the calvaria such that the outer conductor, which terminated in a ground plate, was fixed in contact with the outer table of the skull, while the inner conductor (diameter = 0.9 mm) fit into the drilled hole. The probe was connected to an HP/Agilent 4191A network analyzer, from which the complex reflection coefficient at 51 different frequencies from 100 MHz to 3000 MHz was obtained every \(\sim\)2.3 - \(\sim\)2.6 seconds. The rats were euthanized by intravenous injection of KCl. Measurement of reflection coefficient was continued during KCl administration and afterwards. Complex reflection coefficient data at 100, 506, 1028, 1492, 2014, and 3000 MHz were used to calculate \(\tan\delta\).
Results. Change in tanδ, often pronounced, promptly followed administration of KCl (see figure). Deflection from the baseline was typically evident in much less than $\frac{1}{2}$ minute. For example, in the case of 100 MHz data the tanδ of the point nearest the start of KCl was considered to be the t=0 point. The magnitudes of difference between it and all other points from $\frac{1}{2}$ min before to $\frac{1}{2}$ min after were calculated. For clarity we will designate as “befores” the magnitudes of difference from data points from before KCl on the one hand to the data point nearest the onset of KCl infusion on the other, and designate as “afters” the magnitudes of differences of data points from after the onset of KCl to the value obtained at onset of KCl. In the case of 6 out of 7 rats there was a significant difference between the “befores” and the “afters” (t-test, p<0.005, 2-tailed). In each of those 6 rats the mean “afters” were greater than the mean of ”befores.” After about a minute the rate of change typically diminished. In some but not all cases the initial direction of change of measured tanδ reversed. These reversals occurred at times varying from ~0.25 to ~13 minutes after t=0.

Conclusions. An abrupt and obvious change in the electrical properties of brain tissue is observed at all frequencies examined. These findings indicate that changes in tissue electrical properties associated with physiological changes can be monitored with good temporal resolution by measuring the reflection coefficient at RF/MW frequencies. Our findings confirm similar past results, but with a probe that does not affect results by pressing on soft tissues.

There are various potential limitations of the work. Because the volume of interrogated tissue at a given frequency is unknown, it is not known whether the brain (as opposed to more superficial entities) is sampled to any meaningful degree. Multiple instrumentational factors can affect results, potentially introducing substantial error into calculated tanδ values. Potential physiological confounders, such as body temperature and the identity and concentration of anesthetic, could have exerted unappreciated effects. Positioning of the probe with respect to major superficial veins was not controlled.

It is unknown exactly what causes the tanδ changes, though presumably they are caused largely or entirely by changes in water content in the interrogated volume. We do not know the extent to which the tanδ changes in the first $\frac{1}{2}$ minute resulted directly from sudden reduction of vascular blood volume beneath the probe from cardiac arrest versus shrinking of the brain (and increase in interrogated cerebrospinal fluid) from vascular collapse. Causes of more delayed changes could include brain swelling.

Our results indicate that dosimetry based on dead tissue permittivity may not be exactly correct in living tissue (though it is unclear whether the difference is important). Finally, the results hold open the eventual possibility of imaging physiological change with high temporal resolution through changes in tissue electrical properties.

REFERENCES:


**Figure 1.** Example of changes in measured tanδ at 7 frequencies.

x-axis: minutes after start of KCl infusion (chart displays values ranging from -5 min to +7 min)

y-axis: tanδ
**2-6 AMYLASE: A NEW TARGET FOR INVESTIGATING ALTERATIONS IN THE MAMMARY GLAND OF FEMALE FISCHER 344 RATS AFTER EXPOSURE TO ELF MAGNETIC FIELDS?**

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**Summary of Abstract.** In previous experiments, Fischer 344 rats showed a marked decrease in amylase gene expression after MF exposure of 2 weeks (50 Hz, 100 µT), but there was no change in MF-exposed Lewis rats. In order to get first information about the role of amylase in the breast tissue and its impact on MF effects, we determined amylase in the mammary gland of F344 and Lewis rats. The present results demonstrate that MF exposure altered amylase in the rat breast tissue, but the MF effects were not restricted to F344, because an increased amylase enzyme activity was observed in F344 and LEW.

**Objectives.** For many years, we are investigating the effects of extremely low frequency (ELF) magnetic fields (MF) on the breast tissue of juvenile female rats in order to get to know if MF exposure enhances the risk for mammary gland tumors. We found tumor-promoting effects after prolonged MF exposure in the DMBA breast cancer model with female Sprague-Dawley (SD) rats (Thun-Battersby et al., Cancer Res., 1999). Moreover, cell proliferation in the mammary gland of juvenile SD rats was increased by MF-exposure (Fedrowitz et al., Cancer Res., 2002).

In line with the varying outcomes of MF experiments performed by other groups, we also detected differing MF effects in cell proliferation and tumor promotion in the mammary glands among different rat strains or substrains, e.g., two SD substrains from the same breeder varied in their response to MF exposure (Fedrowitz et al., Cancer Res., 2004). In inbred rat strains, only Fischer 344 (F344) rats showed an enhanced cell proliferation in the breast tissue after MF exposure (Fedrowitz and Löscher, Oncology, 2006). MF exposure also significantly increased tumor development in female Fischer rats in the DMBA breast cancer model (Fedrowitz and Löscher, Carcinogenesis, Oct 4 [epub ahead of print], 2007). Altogether, MF responses in F344 rats were comparable to the effects in the MF-sensitive SD substrain that we used over years in our experiments.

Recently, we investigated gene expression in the breast tissue of sham- and MF-exposed F344 rats and compared the results with Lewis rats (Lew) that are considered MF-insensitive. Unexpectedly, the most striking result was a marked decrease of amylase gene expression in MF-exposed F344, but not in Lew (Fedrowitz and Löscher, 28th Annual BEMS Meeting, 2006). These results indicate that the F344 inbred rat serves as a MF-sensitive rat strain and that the genetic background plays an important role in the effects of MF exposure.

In order to get first information about the role of amylase in the mammary gland tissue and its impact on MF effects, we determined amylase in the breast tissue of F344 rats after MF exposure, stress, and administration of the synthetic estrogen diethylstilbestrol (DES). For some experiments, Lew rats were included and compared to F344.

**Methods.** In the present study, we obtained F344 and Lew rats from Charles River, Sulzfeld, Germany. Rats were allowed to acclimatize to the environmental conditions for at
least one week and were MF- or sham-exposed at an age of about 52 days. F344 were MF-
exposed over different periods, the insensitive Lew rats only over 2 weeks. After 1 day, 1,
2, or 4 weeks (100 µT, 50 Hz), rats were sacrificed, the mammary gland complexes excised,
and stored in liquid nitrogen. DES served as a substance with known effects on proliferative
activity in the mammary gland and was administered to F344 rats at different dosages and
time points. In one experiment, rats were exposed to stressful situations like taking blood
samples. Amylase enzyme activity was measured colorimetrically with Starch Azure as a
substrate and the protein content of amylase was determined by western blotting. The
grade of differentiation of the breast tissue was checked up by whole mount analysis.

Results. MF exposure significantly increased amylase enzyme activity in F344 rats that
were exposed for 2 or 4 weeks. The amylase activity in the breast tissue of F344 was also
significantly increased by DES (30 µg, 6 times) and stressful situations.
Results of amylase protein measurements corresponded to enzyme activities. Differentiation
of the breast tissue was not altered in MF- compared to sham-exposed F344 rats. DES
application in F344 increased the appearance of more differentiated structures in the breast
tissue in a dose-dependent manner. However, the effects of MF exposure on amylase activity
were not restricted to F344, but an increased enzyme activity was also observed after 2 weeks
of exposure in LEW rats.

Conclusions. These data demonstrate that MF exposure altered amylase activity in the
rat mammary gland tissue. In contrast to the marked decrease of amylase gene expression,
amylase enzyme activity was increased after MF exposure. This could be explained by
different changes on RNA level and protein over time.
Although F344 and Lew rats varied in their responses to MF exposure with the F344 showing
alterations in mammary gland cell proliferation and amylase gene expression, amylase
enzyme activity was increased in both rat strains in the recent study. This seems to indicate
that amylase cannot be the explanation for the differing MF effects in strains with different
genetic background.
In literature, only few associations between amylase and tumor development are described
though the underlying mechanisms are not known. Amylase is well known as an enzyme
of the salivary glands and the pancreas. The main function is the cleavage of carbohy-
drates with special structure, e.g., starch, and amylase is used as an indicator for diseases
of the pancreas or the salivary glands. Previous publications introduced amylase as a potent
stress parameter for activation of the adrenal system (e.g., Nater et al., Psychoendocrinol-
ogy, 2006). Information about amylase in the breast tissue is very rare. There are only
few reports about amylase in the mammary gland, dealing with the appearance in certain
breast tumors (Shimao et al., Breast Cancer, 1998). Moreover, Novak and Trnka showed
that application of amylase increased survival of tumor bearing mice in a chemical tumor
model and had further antimetastatic and antitumor effects in vitro (Novak and Trnka,
In summary, some facts suggest that amylase is involved in regulative mechanisms to prevent
loss of cell cycle control or maybe participates in stabilization of cell proliferation. Assuming
that is the case, then amylase activity could be increased in MF-exposed rats as a kind
of defense or control mechanism. In contrast to Lew rats, in F344 this route might be less
effective indicated by the decreased gene expression, thus leading to detectable MF effects. Of course, for the moment this must be considered speculative but further experiments are planned to study the potential association of amylase and MF effects.

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**2-7 TIME DEPENDENCE OF STATIC MAGNETIC FIELD ACTION ON EXPERIMENTAL INDUCED ACUTE INFLAMMATION AND PAIN PERCEPTION IN RATS - IN VIVO**

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Summary of Abstract. Through many decades a lot of scientific peer review papers, concerning static magnetic field action it has been dedicated of the investigations of unfavorable effects and small amount on beneficial effects of SMF. Results of static magnetic fields action on rats with preliminary induced acute inflammation are present in current abstract. At this work we propose pilot investigations of possible beneficiary effects of static magnetic fields, as well anti-inflammatory and pain relief actions. The main idea of this work is to investigate possible complex role of static magnetic fields on pain relief and diminishing of consequences by inflammation.

Objectives. Experimental induced acute inflammation in rats is a good model system because there are a lot of well defined markers for following and estimation of changes at observed system. Inflammation is the complex biological response of vascular tissues to harmful stimuli, such as pathogens, damaged cells, or irritants. It is a protective attempt by the organism to remove the injurious stimuli as well as initiate the healing process for the tissue. Acute inflammation is the initial response of the body to harmful stimuli and is achieved by the increased movement of plasma and leukocytes from the blood into the injured tissues. A cascade of biochemical events propagates and matures the inflammatory response, involving the local vascular system, the immune system, and various cells within the injured tissue. Inflammation and induced pain stress for the investigated organism are tightly related. By tissue and blood plasma, markers could be possible to be followed at in vivo system on molecular level any possible changes or the lack of it at the model system after SMF action. The outcome of this work could be, as follow: Elucidation of possible beneficial effects on inflammation healing and pain relief, in regards to physiotherapy, Elucidation of the possible SMF time and intensity dependence - effects on inflammation and pain relief in biological systems.
Methods. Animals: The experiments were carried out on male Wistar rats (180-200g)-n=240 kept under normal conditions at ambient room temperature (22°C). Ethical guidelines of the International Association for the Study of Pain in conscious animals were followed. Animals were divided by groups Control group (SMF=0) 1-st day (n=20), 2-nd day (n=20),3-rd day (n=20) (at the end of each day of exposure the animals are decapitate and the blood samples are investigated), Exposed groups: 25 mT, for 10 min 1-st day (n=20), 2-nd day (n=20), 3-rd day (n=20) (at the end of each day of exposure the animals are decapitate and the blood samples are investigated, 3-rd day mean three consequence days of exposure by 10 min 25 mT), 25 mT, for 20 min 1-st day (n=20), 2-nd day (n=20), 3-rd day (n=20), (at the end of each day of exposure the animals are decapitate and the blood samples are investigated, 3-rd day mean three consequence days of exposure by 20 min 25 mT), 25 mT, for 30 min 1-st day (n=20), 2-nd day (n=20), 3-rd day (n=20), (at the end of each day of exposure the animals are decapitate and the blood samples are investigated, 3-rd day mean three consequence days of exposure by 30 min 25 mT). Total number of used animals n=240. Reagents: Radio immune assay analysis (RIA) kits for stress markers (Corticosteroids, and ACTH)

Lipid peroxidation was asses by the measurement of quantity of formation of malondialdehyde (MDA) in blood plasma, which was estimated by Spectrophotometry (UV-VIS Spectrophotometer, Shimadzu UV-250 (190-900 nm range)).

SOD Assay Kit (Fluka), for luminescent detection of catalase and SOD activity in blood plasma In vivo have been used (Luminometer Shimadzu UV-1050).

Fibrinogen Assay Kit (SIGMA) for UV-VIS Spectrophotometry of blood plasma samples.

Results of this investigation present preliminary plasma levels of the stress markers and screening of susceptibility of antioxidant system of living organism after SMF action. Antioxidant system play a central role as a mediator in many stress induced and stress promoters reactions, therefore investigations of SMF effects on oxidative stress reactions, play key role in understanding of complex character of SMF effects on living systems.

Statistical method: Non-linear Regression analysis and Friedman test

Results. Complex approach to investigation of possible effects of SMF action on artificial induced acute inflammation in rats (by measurements of the levels of specific stress markers), is important in understanding of possible inflammatory mitigation effects, pain relief, and oxidative stress state of organism. SMF (25 mT at 10, 20 and 30 min exposure time), itself cannot induce energetically transformations in the systems, but usually in the environment SMF usually interact with dynamical processes in biological systems in combination with other environmental factors which can cause modification of existed dynamic regulation.

SMF may affect biological systems by increase of life span of active oxygen forms. To test this hypothesis, we have investigated whether SMF (25 mT, 10, 20 and 30 min), can induce or deminish lipid peroxidative stress in blood plasma in rats. A marker for lipid peroxidative stress in vivo, are Malondialdehyde (MDA) and antioxidant enzyme superoxide-dismutase (SOD). In parallel with this we investigate the levels of stress markers such a COR and ACTH, after SMF action. For better understanding of inflammatory pathology and process of inflammation healing during investigated period of time 3 consequent days we measured Fibrinogen plasma levels. Compared with the control group, products of lipid peroxidation such as MDA level was significantly increased in blood plasma of rats respectively with
concomitant increase of SOD at the early stages (1-st and 2-nd day after initiation of inflammation), this tendencies diminished with different degree at the 3-rd day after 30 min exposure time at 25 mT SMF. However there was no significant alteration in COR and ACTH among the groups. Levels of Fibrinogen in blood plasma consequently decreased up to 3-rd day and have a maximum at the 2-nd day in comparison with the control.

**Conclusions.** These results indicate that SMF $B=25$ mT for 30 min induces diminishing of the inflammatory process and decrease levels of inflammation markers into the blood plasma in rats. The exact mechanism by means SMF, induces fasten inflammation healing and decrease of inflammation markers in blood plasma in rats still remain unclear. We can suppose that two possible mechanisms exist, direct interaction of SMF with free active oxygen forms and affecting of membrane processes and some physiological functions and indirect mechanism through dynamic regulation of inflammation healing process.

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**2-8 EFFECTS OF DURATION AND DELAY AFTER EXPOSURE TO A STATIC MAGNETIC FIELD ON AUDIOGENIC SEIZURES IN BLACK SWISS MICE**

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**Summary of Abstract.** A one hour exposure to static magnetic fields but not shorter times increased the seizure latency in Black Swiss audiogenic mice. Delaying testing for up to eight hours after field exposure demonstrates a dose response on this timescale.

**Objectives.** About 30% of epilepsy patients have inadequate control over their disease using anti-epileptic drugs (AEDs). New drugs on the market tend to be more tolerable but does not appear to change this fraction of intractable epilepsy. This state of affairs suggest a role for alternative therapies, including therapies that could augment pharmacological treatments. We have previously shown that static magnetic fields (SMFs) may be just such an intervention. Now we report on some physical dose responses to SMF treatment in Black Swiss audiogenic mice.

**Methods.** Black Swiss mice (Tac:N:NIHS-BC; Taconic, Germantown, NY) were housed under a 12 h/12 h light/dark cycle with food and water ad libitum. Mice were exposed to magnetic fields produced by a single cuboidal permanent magnet (Neotexx; Berlin, DE) made of N52 neodymium-iron-boron (NdFeB). The magnets measured 25 mm x 10 mm x 10 mm and were magnetized through the 10 mm dimension. The flux density was measured at the surface of a magnet to confirm numerical models of the field around the magnets. At a distance of 5 mm from the surface of the magnet, the flux
density and perpendicular gradient component were about 220 mT and 40 T/m, respectively. At 15 mm, the corresponding values were about 30 mT and 4 T/m.

Mice were studied between 21 and 30 days of age, the period of maximum susceptibility to audiogenic seizures. To minimize movement during exposure to SMF, mice were restrained in 35 ml syringes that had been perforated for ventilation and the plunger was advanced until the nose of the mouse was near a hole produced by cutting the hub off the end of the syringe. Exposure to the SMF was accomplished by attaching the magnet to the syringe tube with a rubber band. The magnet was positioned above the head of the mouse inside.

Auditory stimulation: After pretreatment, mice were removed from the syringe tubes one at a time and placed in a plexiglass cylinder with a speaker centered in the lid. Seizure latency (time from onset of auditory stimulation to seizure initiation) and seizure stages exhibited by each mouse during each session of auditory stimulation were tabulated during the experiment by an observer.

**Results.** A one hour exposure induced a significant shift to longer latency before onset of epileptiform activity as compared to unexposed controls. Fifteen and 30 minute exposures shifted the latency to longer times, but not enough to be statistically significant with the number of subjects used (see Figure 1). In order to test how persistent the effect of the magnetic field exposure was, we introduced a delay between the control/field exposure and the sound stimulation. The results are summarized in Figure 2. The effect of the magnetic field is persistent out to 8 hours after exposure. Our results suggest that the increase in latency is greatest not immediately after exposure but about one hour after removal from the exposure and restraint although the difference between zero delay and 60 minutes delay before sound stimulation is not statistically significant.

**Conclusions.** The Black Swiss mouse has now proven to consistently respond with longer latency to seizure onset after magnetic field exposure. It was not possible to mask the control/exposure condition to the experimenter in this work. Care has been taken to perform matched control experiments for every field condition tested in this series. We observe a consistent dose response with respect to exposure duration and field amplitude: The effect size of the latency shift decreases monotonically with lower field amplitudes as compared to our canonical largest exposure.
Figure 1. Exposure duration. A pronounced shift to longer latencies before seizure onset occurs when mice are exposed to a magnetic field for 60 minutes as compared to unexposed controls (p<10e-6). Exposures of 30 minutes or 15 minutes caused a shift towards longer latencies but the difference to the control distribution was not statistically significant in this experiment.

Figure 2. Summary of delay after exposure. In order to evaluate the persistence of the protective effect of magnetic field exposure, auditory stimulation was delayed for increasing periods of time (1 h, 2 h, 4 h, and 8 h). “D (KS)” is the maximal distance between two cumulative distributions. It is a measure of effect size and is the parameter used for statistical evaluation using the Kolmogorov-Smirnov (KS) statistic.
3-1 MAGNETOSOME GENE EXPRESSION FOR CANCER CELL TRACKING BY MRI

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Summary of Abstract. To impart magnetic properties to mammalian cells, we have expressed the MagA gene, a putative iron transporter from magnetotactic bacteria. These microorganisms respond to the earth’s magnetic field through magnetosomes: membrane-enclosed iron biominerals. Overexpression of MagA in cancer cell lines enhances intracellular contrast for magnetic resonance imaging (MRI). Analysis of iron retention in transfected cells by inductively coupled proton mass spectrometry (ICP-MS) shows that MagA lowers the concentration of extracellular iron required for efficient uptake. Overexpression of a dominant negative mutant MagA both decreases the sensitivity of cells to extracellular iron and lowers the MRI signal to background levels. Molecular imaging with MagA provides a reporter gene expression system for non-invasive cell tracking by MRI. Multiple medical applications pertain, including tracking cancer cell growth and metastasis.

Objectives. Magnetotactic bacteria derive their magnetic properties from magnetosomes: membrane-bound iron biominerals. As the genes responsible for magnetosome formation are identified so too is the possibility of conferring magnetic character to mammalian cells for the purpose of non-invasive molecular imaging. Toward developing reporter gene activity for MRI, we have transfected cancer cells with the iron transporter MagA, from Magnetospirillum sp. AMB-1. Characterization of MagA-expressing cells correlates intracellular contrast with iron uptake and retention.

Methods. MRI was performed on mouse neuroblastoma (N2A) and human breast cancer (MDA MB 435) cells, stably expressing MagA or its E137V mutation. Cloning under standard procedures provided either green fluorescent protein-MagA fusion protein from pEGFP-C3 or unlabelled MagA from pcDNA3.1/Zeo+. Cells were cultured under selection in the presence or absence of 250 $\mu$M ferric nitrate unless otherwise specified. 3D MRI was acquired at 11T with a dual echo: spin echo at TE=5 ms and gradient echo at TE=15 ms, TR=1000 ms, 128x128x8 with 8 averages, 137 minutes, 65x65x75 cubic $\mu$m resolution. The gradient echo image in figure 1C was subtracted from the spin echo image in panel E to produce the positive contrast image in panel D. Iron retention in cell lysates was quantified by ICP-MS. Cellular protein was measured using the BCA assay.

Results. Overexpression of MagA increases cellular contrast in cancer cells (Figure 1). Correlation of gradient echo and positive contrast images confirms that signal voids are due to cells. In serial planes, MagA expression allows detection of cells in adjacent layers, resolving cellular detail from a mixed population of cells. In contrast, the signal from
overexpression of mutant MagA is comparable to background. Analysis of cellular iron indicates that MagA expression lowers the threshold of mammalian cells for uptake of extracellular iron (Table 1).

**Conclusions.** MagA expression is well suited to reporter gene activity for MRI. MagA increases intracellular contrast in mammalian cells and decreases the threshold at which extracellular iron may be imported. Comparison of MagA to its V137E mutation suggests that the bacterial iron transporter utilizes iron more effectively for the generation of cellular contrast. Multiple applications exist for MagA reporter gene expression, including in vivo tracking of cancer cell growth and metastasis by MRI.

**Acknowledgements.** This project was funded through the Cancer Imaging Network of Ontario (CINO) supported by Cancer Care Ontario.

![Figure 1](image-url)

**Figure 1.** Molecular MRI of MagA Expression in N2A Cells. MagA-expressing cells were cultured in media supplemented with iron for 7 days prior to mounting live cells in gelatin/phosphate buffered saline and imaging by MRI at 11T. Panels A and B are gradient echo images showing an axial cross section through the gelatin phantom and gelatin containing 1 million cells expressing vector alone, respectively. The plane of focus is marked by human hair. Panels C-E are gradient echo, positive contrast (difference) and spin echo images of a single, axial cross section through gelatin containing 1 million MagA-expressing cells.
Table 1. ICP-MS Analysis of Iron in MagA-Expressing Cell Lysates

<table>
<thead>
<tr>
<th>Iron Supplement (micromolar)</th>
<th>Amount of Cellular Iron (pg iron/μg protein)</th>
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<tbody>
<tr>
<td></td>
<td>MagA Expression</td>
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<tr>
<td>0</td>
<td>7.82</td>
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<tr>
<td>31.25</td>
<td>8.41</td>
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<td>62.5</td>
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<td>250</td>
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3-2 ELECTROPORATION THERAPY WITH BLEOMYCIN DESTROYS MALIGNANT BUT NOT NORMAL TISSUE

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Summary of Abstract. We have investigated the responses of normal and malignant tissue, respectively, to Bleomycin-Electroporation Therapy (B-EPT). While histological changes to normal tissue in response to B-EPT are relatively mild and of limited duration, malignant tissue is generally destroyed. Thus, performing B-EPT in combination with surgery promises to preserve valuable functional tissue and enhance tumor control relative to surgery alone. Molecular studies to elucidate the relatively selective destruction of malignant tissue by B-EPT have yielded initial results and are ongoing.

Objectives. 1. To quantitatively investigate the effect of electroporation (EP), with or without the anticancer drug Bleomycin (B), on various normal tissues in various animal models. 2. To clinically evaluate the effect of B-EPT on apparently normal tissue surrounding malignant tumors. 3. To explore in animal and clinical studies the feasibility and potential advantages of combining B-EPT with surgery to achieve superior local tumor control. 4. To explore the molecular mechanism underlying the surprisingly different effects of B-EPT on normal and malignant tissue, respectively.

Methods. Histological changes including inflammation, hemorrhage, necrosis and fibrosis have been scored by severity at various time points up to 40 days after tissues were subjected to EP, with or without prior injection of B. These studies included effects on skin and muscle (in rodent and porcine models) and on prostate, nerves and blood vessels in canine models. In humans, clinical and histological effects in response to B-EPT of tumor tissue and surrounding normal tissue, respectively, were recorded. In a mouse model, tumors and
surrounding tissue were first treated with B-EPT, followed by surgical removal of the tumor; alternatively, tumors, but not surrounding tissue were first removed surgically, followed by treating the wound bed with B-EPT. Also in a mouse model, responses to B-EPT were investigated by histological, immunohistological and gene expression analysis.

**Results.** In animal models, B-EPT treatment caused histological changes of only low severity in normal tissues. These changes were transient and essentially non-existent 40 days after treatment. EP alone (without B) caused even less severe changes than B-EPT. The severity of changes increased with increasing pulse number, applied voltage and field strength. In humans, up to over 80% of tumors were destroyed by B-EPT, while adjacent normal tissue was much less affected and generally healed well. Combination treatments with B-EPT and surgery achieved significantly better tumor control (up to 100%) than treatment by either method alone. Gene expression results indicated activation of apoptosis pathways very early after B-EPT, as well as activation of other gene clusters.

**Conclusions.** We confirmed and analyzed the surprising effect of B-EPT on tumor tissue (destruction) and normal tissue (transient and mild changes), respectively, both in animal models and clinical studies. Initial histological and gene expression studies are encouraging to eventually determine the mechanisms underlying the selective destruction of malignant tissue by B-EPT. Studies on combining B-EPT and surgery demonstrated the feasibility and potential benefits of such an approach, namely preservation of functional tissue and low tumor recurrence rates not attainable with either single method.

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**3-3 PROSPECTIVE VIEW OF THE MEDICAL APPLICATIONS OF RF ENERGY IN THE BAND 0.15-100 GHZ**

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**Summary of Abstract.** We now have a history of more than 50 years of searching for low-level non-thermal radiofrequency (RF) effects in biological systems. Analysis of this database and an evaluation of proposed mechanism of interactions suggest that the probability of finding such effects between the frequencies of 150 MHz and 150 GHz is vanishingly small and most likely that such effects do not exist between 10 MHz and 200 GHz. These low level non-thermal RF fields can find application, for example, in the telemetry of physiological parameters and the timely delivery of medical assistance, application unrelated to biochemical interactions. However, studies using fields at much lower frequency (e.g. ELF) with amplitude on the order of or exceeding endogenous fields, development of THz spectroscopy and medical imaging at THz frequencies and RF fields that can cause temperature elevation have proven and are proving to be fruitful areas of research.
Objectives. We review the state of the science of biological and biochemical responses to RF exposure beginning with a discussion of proposed mechanisms to determine whether theoretical and/or experimental support exists for low-level non-thermal effects (LLNT) t. Biological effects have been reported [1] to occur from high peak energy pulses with low power averaged over the period of the pulse train. These responses are briefly discussed; however, we do not apply the term LLNT mechanisms or effects to the response from high peak energy or field strength exposures with low average power. There is no firm basis to distinguish between the terms athermal and non-thermal, both of which are widely understood to involve no measurable temperature increase.

Results. It is recognized that non-thermal effects do exist below a few MHz and maybe at frequencies up to 150 MHz [2]. Those wishing to develop low-level non-thermal medical application of RF energy will find the frequencies between 150 MHz and about 200 GHz fruitful only for application to telemedicine in all its various application (monitoring and delivery). The majority of research funding in this frequency range has been driven by concerns for adverse health effects and not by inherent scientific interest or a search for beneficial applications. This adverse health effect related objective has served the interest of health regulators and those interested in developing safety standards but has not necessarily served well the scientific community. The prevalence of no effect or non-repeatable findings may be useful for risk evaluation but has not lead to advancements in science and may have driven or fostered dead end research lacking original hypotheses. Historically, less expensive microwave sources have been available at frequencies widely used by consumer products such as microwave ovens, cell phones etc and have promoted use of selected frequency bands for research. Available funds and RF sources are necessary ingredients for research but allowing such items to drive research seriously restricts the scientific investigation process. The proper simile is: looking under the street lights for a lost coin because the illumination is better.

The areas of bioelectromagnetic research that have been or are fruitful include not only hyperthermia but applied DC or ELF fields that exceed endogenous fields promoting bone and wound healing, high peak short pulses that are on the order of membrane potentials and THz signals for spectroscopy and medical imaging. The physics behind these applications is sound and investigations should lead to repeatable findings providing a fruitful body of data for building analytical and predictive theories. This contrasts sharply with the lack of theoretical or experimental support for LLNT biological effects between about 0.1 and 150 GHz other than then those molecular interactions leading to immediate transfer of energy to the thermal bath.

Conclusions. Studies of effects on free radical formation below a few MHz may be fruitful for a general understanding of a possible LLNT interaction but the usefulness for medical applications is still open [2]. We find no experimental or theoretical support for LLNT biological effect between about 150 MHz and 200 GHz other than then those molecular interactions leading to immediate transfer of energy to the thermal bath. Continued efforts to use ELF fields exceeding endogenous fields and studies at THz frequencies are promising.

Acknowledgements. M. Swicord thanks Motorola for partial support of this work.

3-4 IMMUNE STIMULATION IN FISH AND FARM ANIMALS THROUGH WEAK LOW FREQUENCY ELECTROMAGNETIC FIELDS

Jan Cuppen. Immunent BV, Veldhoven, Netherlands.

Summary of Abstract. A method is presented for enhancing the immune competence of fish and farm by means of weak Low Frequency Electromagnetic Fields (LF EMF). Results are shown and a hypothesis is proposed how exposure can stimulate an immune response, based on recent insights in immunology.

Objectives. To investigate the value of LF EMF as means to stimulate immune competence and reduce the costs of infections.
To investigate the effects of LF EMF on feed efficiency and growth in fish and farm animals.

Methods. Signals were generated by an Immunent® signal generator, capable of generating field strengths between 0.15 µT and 1.5 mT in the exposure area, with a composite LF EMF signal containing shaped waveforms with base frequencies between 250 and 5,000 Hz. This generator is available from Immunent BV (www.immunent.com).
Coil systems were used according to the different experiments performed: Ferrite C-arm systems for exposing cell cultures, Solenoid coils around the complete exposure area for fish experiments, and simple current loops for covering large areas in the chicken and piglet experiments in practical farm houses.
Dosimetry was done by first calibrating the current through the coil systems to the field strength using an FW Bell 5180 Tesla meter and then digitally monitoring the rms current continuously. Since there are no attenuation issues at such low frequencies, this is considered a valid and accurate approach.

Results. In a first series of experiments in vitro common carp head kidney-derived phagocytes were used to determine Reactive Oxygen Species (ROS) production as a measure for immune activation. Exposure to LF EMF signals led to 42% or 33% increase in immune activity, respectively, compared to negative control values. Significance of increase in ROS production in the total series was: p<0.0001.
In a second series of experiments in vivo commercial goldfish were used. The fish suffered from a combination of infections due to natural causes and high density transport. Groups
of fish were housed under equal conditions in at least 4 control tanks and 8 to 16 EMF-exposed tanks.
Without treatment mortality was about 50% after 18 days, while the treatment reduced it to 20% on average.
In a third series, in vivo experiments were done with 708 commercial broiler chickens in groups of 8 exposed to infection pressure from coccidiosis. EMF exposure at 6.5 µT reduced intestinal lesions by 40% and improved feed conversion by 8%.
Finally full scale experiments were started in commercial chicken houses (with 48,000 and 28,000 chicken broilers respectively), piglet houses (with 100 piglets per division) and shrimp ponds (1 hectare, 200,000 shrimp). These experiments are done against control groups, but they need many repetitions to obtain statistical significance. Preliminary results include: 50% faster growth in shrimp for the same feed, 7% less feed in chicken broilers for equal growth, 8% less feed in piglets for equal growth.

Conclusions. We hypothesize that the EMF treatment induces mild stress to cells, which then produce cytokines that function as alarms or so called danger signals for the immune system. In this way EMF treatment takes the place of multiplying pathogens, and the damage these cause, in the triggering of an immune response.
Feed conversion in farm animals, defined as the quotient feed kgs / growth kgs, is the most important parameter in animal husbandry today. Feed conversion is in practice improved by hygiene, feed additives and, before that was outlawed, preventive antibiotics. Our results show similar or better results for EMF treatment than any of the usual approaches.
This research indicates that the ELF EMF treatment with the Immunent signal is capable of stimulating the immune system, with significant positive effects on survival, damage reduction due to infectious disease, and feed conversion. These results support the hypothesis that LF EMF improves the immune competence of the animals
Because of the low field strengths required, and the surprisingly large effects on animal health, the results indicate that practical application with important economic advantages in Animal Husbandry is possible.

Acknowledgements. Important contributions to this work have been made by Huub Savelkoul and Geert Wiegertjes from the Cell Biology and Immunology group of Wageningen University, by Anton Beynen and Mohammed Elmusharaf of Utrecht University, veterinary department, and by Willem Smink of FIS BV, The Netherlands. The help and advice of Marko Markov has been very valuable to achieve our results.
Figure 1.

Figure 2.
Figure 3.
3-5 THE ELECTRIC FIELD AT HUMAN SKIN WOUNDS DECLINES SHARPLY WITH AGE

Rich Nuccitelli¹, Pamela Nuccitelli¹, Changyi Li¹, Suman Narsing¹, David Vendt³, David Pariser³,², Antoinette F. Hood². ¹BioElectroMed Corp., Burlingame, CA, USA. ²Eastern Virginia Medical School, Norfolk, VA, USA. ³Virginia Clinical Research, Inc., Norfolk, VA, USA.

Summary of Abstract. We have used a newly developed non-invasive Dermacorder® to measure the electric field near human skin wounds in two age groups. The field is twice as large in adults 18-29 years of age as in adults 65-80 years of age.

Objectives. 1. Use a new, non-invasive Dermacorder® bioelectric field imager to measure the electric field near human skin wounds; 2. Determine if the electric field near lancet wounds in adults 28-29 years old is significantly different from that near such wounds in adults 65-80 years old.

Methods. The fundamental principal employed by the Dermacorder® is that the skin surface potential can be determined by a capacitative coupling method. We hold a small flat metal sensor very close to the skin, forming a parallel plate capacitor. One plate of this capacitor is the conductive surface of the epidermis which has a certain voltage value that we want to detect. If we oscillate the metal sensor along an axis perpendicular to the skin surface, the distance between it and the skin will oscillate. The capacitance between the two surfaces is inversely proportional to this distance so this capacitance will also oscillate. This can be detected by measuring the charging current that flows on and off of the metal sensor as the capacitance oscillates. We can control the voltage on the metal sensor and if we hold it at the same voltage as that on the skin surface, there will be no charge movement. Therefore, we can determine the unknown potential of the skin surface next to the sensor by finding the voltage at which no charging current flows.

Results. We sponsored a blinded study at Virginia Clinical Research in Norfolk Virginia. They measured the lateral surface wound field between the stratum corneum and epidermis near a lancet wound on one arm and leg in 40 adults. Ten women and ten men in the 18-29 year old age group exhibited a mean electric field of 163±59 mV/mm in the space between the stratum corneum and the epidermis. Ten women and ten men in the 65-80 age range exhibited a mean field of 78±15 mV/mm. Therefore the mean electric field of individuals in the older age group is half that of the younger group. It is important to realize that this electric field just beneath the stratum corneum is very different from that expected to exist within the epidermis. Not only will the field direction be opposite in the epidermis with current flowing toward the wound, but also the current density will be much lower because there are more paths for the current to follow between each of the 7 layers of cells comprising the epidermis. Since the electric field is proportional to the current density, we predict that the average field within the epidermis would be between 1/2 and 1/7th of
that measured by the Dermacorder® Thus we would expect the intra-epidermal field to be about 24-80 mV/mm in young adults and only 11-40 mV/mm in older adults.

**Conclusions.** It is well known that the rate of wound healing declines with age. Could this be due in part to the reduced electric field at the wound site? Previous work that we have done with human keratinocytes in vitro has shown that they will actively migrate to the negative pole of an imposed electric field that is greater than 5 mV/mm with an optimal response at 100 mV/mm [1]. These data would suggest that the stronger electrical field near skin wounds in young adults would result in a stronger stimulus to keratinocytes in the region to migrate towards the wound than would be expected in older adults. A role for endogenous electric fields in wound healing has been established in another mammalian system, the rat cornea. Pharmacologically enhancing or decreasing wound-induced ionic currents has been shown to increase or decrease wound healing rates, respectively [2]. Therefore it is very likely that the electric field lateral to wounds in human skin plays a role in wound healing.

Reference List


**Acknowledgements.** This work was supported by NIH GM069194 to RN.
Methods. Sprague-Dawley rats were exposed at $8 \mu T$ 60 Hz in a custom made exposure cage for 30 minutes prior to I-R. Ischemia was induced by ligation of left anterior descending coronary artery (LAD) for 30 minutes, followed by 30 minutes of reperfusion. Blood and heart tissue samples were taken at 10 minute intervals for hsp70 detection by Western blot and RNA detection by rt-PCR. Quantification: density of the bands on the films was measured using image analysis software (ImageJ v1.38, NIH). Statistics: Continuous variables were expressed as Mean ± standard error and compared using two-tailed t-testing. Paired t-testing was used to evaluate significance within groups at multiple time points. A p-value of less than 0.05 was considered statistically significant.

Results. A clear effect on systolic contractile function in EMF-treated animals was found after reperfusion, as shown by significant increases in contractile function, such as, left ventricular (LV) maximum power and cardiac output. These changes occurred without evidence of concurrent LV hypertrophy or at the expense of reduced diastolic function, which might have been expected with pressure-volume overload seen after ischemic injury. EMF induced significantly high levels of both HSP70 RNA transcription and hsp70 within thirty minutes after initial exposure. These elevated levels persisted for more than three hours. Additionally, ventricular diastolic function (relaxation at constant volume), was markedly improved in EMF-treated animals. Significant recovery of myocardial function was seen in EMF treated rats after 10 minutes of reperfusion and survival was sustained for more than 120 minutes.

Conclusions. In the experiments reported here we applied EMF to increase hsp70 levels and improve survival following I-R. While stress proteins in cells and tissues have been previously utilized as diagnostic markers and prognostic indicators, a safe, non-invasive method of augmenting endogenous defense mechanisms as a therapeutic tool, such as EMF exposure, has significant clinical potential. The data indicate that exposure with EMF prior to reperfusion, in a mammalian model, induces upregulation of the HSP70 gene and subsequent increased levels of hsp70 protein and, most importantly, improved ventricular function after ischemia-reperfusion.

Acknowledgements. The Robert I. Goodman fund
MEASUREMENTS OF THE CURRENT IN THE GRADIENT COILS IN A MRI SCANNER


Summary of Abstract. The occupational exposure to the magnetic field from the gradient coils of MRI scanners is very complex, and can sometimes exceed international guidelines. In order to get a better understanding of this exposure the currents in the gradient coils have been measured for several different pulse sequences.

Objectives. Measure the current in the gradient coils of a MRI scanner to get a better understanding of the occupational exposure of the staff being near the MRI machine during scanning.

Methods. The Magnetic Resonance Imaging (MRI) technique makes use of a strong static and a radio frequency magnetic field, and to make it possible to scan to whole body a set of gradient coils are used. There is one coil for each of the three axes: x, y and z, and these are fed with a complex time varying current in order to create the picture. In the simplest case the coil in the z-axes is along the long axes of the body in the scanner and the pulsed magnetic field in this coils is termed slice selection. The other two axes, x and y, are for scanning the selected slice.

Results. We have measured the currents in some typical pulse sequences. Depending on what contrast the radiologist select, a specific pulse sequence is selected. These can be very different in pulse repetition frequency and amplitude. Below is an example of one of the most commonly used sequences, a so called T2weighted sequences. In this presentation several examples will be given. We have made the recordings with a 4 channel Picoscope directly attached to the oscilloscope outlet from the amplifiers for the gradient coil currents. Figure 1. T2weighted sequence. The current monitors are set to give 1 V/100 A of current. The oscilloscope was attached so that the axes were from top to bottom according to:

X axes blue color
Y axes red color
Z axes green color

Conclusions. When the staff are present in the room during scanning, or as they in some instances bent into the scanner while in operation, the occupational exposure can be quite high. The gradient field is often of the order 10-40 mT/m with a rise and fall time of 100-400 µs (microsec), which can give rise to time derivative of the order of several tens of T/s, which should be viewed in perspective to the ICNIRP guideline of 0.22 T/s. As can be seen from the current recordings some of the pulses are dominating and thus the ones that are limit setting.
PLANT DERIVED MELATONIN AS A RADIO-PROTECTIVE AGENT: RESULTS OF A PLACEBO-CONTROLLED CLINICAL TRIAL

Roger W. Coghill. Coghill Research Laboratories, Pontypool, United Kingdom.

Summary of Abstract. Certain plants are rich in melatonin ("MLT"), an indoleamine normally produced in the pineal and regulated by light. There is some evidence that MLT synthesis is inhibited by exposure to EMFs, and that living near sources of radio frequency radiation ("RF/MW") can lead to sleep disturbance. Most MLT tablets available over the counter are at concentrations thousands of times more than the physiological levels provided via pineal synthesis, and may in some cases be inflammatory. Physiological doses however are reported as more bio-effective. In this crossover trial subjects living near EMF sources were provided with plant-derived MLT or a placebo and their sleep patterns monitored objectively by means of accelerometric devices ("Sleeptracker Pro"), as well as subjectively by completing a sleep quality diary. The results show that melatonin from plants can be used equally well to supplement normal melatonin, and that it significantly improves sleep quality among a population exposed to RF/MW radiation from vicinal cellphone masts.

Objectives. To investigate the effects of supplemental plant-derived melatonin on sleep quality among a healthy population living near cellphone masts.

Methods. Plant-derived MLT was prepared in capsule form from Festuca arundinacea, known to be rich in natural MLT, at a dose level equal to that of the peak concentration in a normal adult. An identical capsule format was also developed containing a placebo.
Healthy subjects were given either the treatment or placebo for consecutive periods of two weeks with a one week washout period. Neither the administrators nor the subjects knew which format was being administered. At the end of the trial the codes were broken and the data compared, to see if there were any significant differences between baseline, the placebo, and the treatment.

**Results.** There was a significant improvement in sleep pattern among subjects when taking the treatment compared with baseline and the placebo group.

**Conclusions.** Plant-derived melatonin may prove to offer significant improvement in sleep patterns amongst populations living near cellphone masts.

**Acknowledgements.** We acknowledge the financial assistance of Asphalia Food Products and the University of Glamorgan Spin out Programme, financed by the Welsh Assembly Government.
PLENARY 2: INTERACTIVE ROUNDTABLE: INTERPHONE RESULTS

P2-1 SPECIAL EPIDEMIOLOGY SESSION: CELLULAR TELEPHONE USE AND BRAIN TUMORS

Joachim Schüz\textsuperscript{1}, Martha S. Linet\textsuperscript{2}, Lennart Hardell\textsuperscript{4}, Elisabeth Cardis\textsuperscript{3}, Jørn Olsen\textsuperscript{5}. \textsuperscript{1}Institute of Cancer Epidemiology, Copenhagen, Denmark. \textsuperscript{2}National Cancer Institute, Rockville, MD, USA. \textsuperscript{3}International Agency for Research on Cancer, Lyon, France. \textsuperscript{4}University Hospital of Örebro, Örebro, Sweden. \textsuperscript{5}UCLA School of Public Health, Los Angeles, CA, USA.

Summary of Abstract. In this special session, the most influential epidemiological studies on cellular telephone use and the risk of brain tumors will be presented by their principal investigators. Conclusions are drawn by a renowned expert in epidemiology and discussed in plenary.

Objectives. Cellular telephones and brain tumours – is there a risk or not? How controversial is this topic? A number of epidemiological studies have been completed until now. Time to draw an interim result. But this is not so easy to draw, as the studies differ in methodology and details obviously matter, and quite a number of publications provide an abundance of effect estimates.

Methods. The more than original 30 peer-reviewed papers originating from epidemiological studies on cellular telephone use and brain tumours can be subdivided into four categories. There is category 1 of independent case-control studies based on brain tumor cases diagnosed in the late 90’s with the two biggest studies conducted in the USA. There is category 2 with a case-control study series from Sweden. Category 3 contains the cohort studies on this topic, which are the Danish retrospective cohort of cellular telephone subscribers and the multinational prospective cohort study (Cosmos) which just started in Denmark and is about to start in Sweden, the UK, and Finland. There is category 4 with the Interphone study, which is a pooled analyses of 16 case-control studies conducted in 13 countries. Several of the national studies have already been published.

Results. Each category as defined above will be presented by a principal investigator of the respective studies. Dr Martha Linet, Chief of the Radiation Epidemiology Branch of the National Cancer Institute (NCI), USA, will present the category 1 studies focusing on the large NCI study published in 2001. Dr Lennart Hardell, Professor at the Department of Oncology of the University Hospital of Örebro, Sweden, will present the Swedish case-control study series. Dr Joachim Schüz, Head of the Department of Biostatistics and Epidemiology at the Institute of Cancer Epidemiology, Copenhagen, Denmark, will present the cohort studies. Dr Elisabeth Cardis, Head of the Radiation Group at the International Agency for Research on Cancer (IARC), Lyon, France, (but about to move to the Centre for Research in Environmental Epidemiology, Barcelona, Spain) is the coordinator of the Interphone study and will present all Interphone results that are published before the BEMS meeting.
Conclusions. To aid the audience in the overall interpretation of the four presentations, Dr Jørn Olsen, Professor and Chair at the Department of Epidemiology, UCLA School of Public Health, USA, will present his view and summarize the available findings. After this final talk, the session will commence with a plenary discussion with the five speakers.
Tuesday

PLENARY 3: INTERACTIVE PLENARY:
RF/ELF EXPOSURE STANDARDS

P3-1 REVIEW OF ICNIRP STANDARDS


Summary of Abstract. Present ICNIRP standards cover the whole electromagnetic spectrum from static fields up to 300 GHz. The development of such standards started in the ’80s within IRPA/INRC, and the first guidelines on RF fields were issued in 1984. Subsequent revisions extended the frequency range and updated the recommendations to the most recent results of scientific research. It is worth noting however that such updates concerned the scientific database on which the recommendations were based, rather than the basic approach and the numeric values of exposure limits.

The protection system developed by ICNIRP has been from the very beginning quite well harmonized with national standards existing in some countries such as UK (NRPB recommendations), Germany (DIN standard), Canada (Health Canada code) and USA (ACGIH). While some discrepancies existed in the numerical values, the standards were consistent with respect to the scientific rationale, the two-level structure based on primary and derived limits (though termed differently in different standards, and the frequency dependence of exposure limits.

A guiding principle of ICNIRP guidelines is that only established health effects may form the basis to derive quantitative, science-based exposure restrictions. In the absence of a convincing evidence of long term effects, ICNIRP maintains its recommendation for limits based on acute effects only, with the critical effect as the reference. Therefore, the process of development of guidelines requires the identification of the critical effect and its frequency dependence.

However, while interaction mechanism and related effects are well established in some frequency ranges, in some frequency ranges (static magnetic fields, intermediate frequency electric and magnetic fields), limited data are available in others. That requires different approaches, based on the maximum field level at which no effect is evident, or on extrapolation from other frequency regions.

ICNIRP is in the process of revising the full set of its guidelines. The related tasks are carried out separately for static magnetic fields, ELF electric and magnetic fields, and RF electromagnetic fields. The status of advancement is different, depending on the one side on priorities that ICNIRP itself has established and the other side on the availability of fundamental input documents from WHO (Environmental Health Criteria, to which ICNIRP collaborates) and IARC (classification and related monographs), whose preparation requires in turn the completion of some important epidemiological and biological studies.
The revision of ICNIRP guidelines is not expected to be limited to an update of the supporting literature. It will rather imply a critical review of the whole process, including the choice of the most appropriate dosimetric quantities, the justification and magnitude of reduction factors, the possibility of relaxation of limits in special circumstances. Given the lack of convincing evidence for their existence, and of any indication of an exposure-effect relationship, it is unlikely that long-term effects may form a basis for the revised guidelines. However, the possibility to provide some advice through other documents than exposure guidelines is discussed.

P3-2 REVIEW OF THE IEEE ICES EMF EXPOSURE STANDARDS.
Chung-Kwang Chou. Motorola Labs, Fort Lauderdale, FL, USA.

Summary of Abstract. IEEE International Committee on Electromagnetic Safety (ICES) develops standards for the safe use of electromagnetic energy in the range of 0 Hz to 300 GHz relative to the potential hazards of exposure of humans, volatile materials, and explosive devices to such energy. Technical Committee (TC) 95 develops standards based on established adverse effects and incorporates safety margins for human exposure to electric, magnetic and electromagnetic fields, including induced currents from such fields. TC34 deals with methods for the assessment of human exposure to such fields, and develops compliance standards for products that emit electromagnetic energy by design or as a by-product of their operation.

Objectives. To review the IEEE ICES TC95 EMF exposure standards C95.6.1 and C95.12 covering the frequency range of 0 to 300 GHz. The limits and rationale of the two exposure standards will be discussed.

Methods. C95.6-2002: This standard covers the frequency range of 0 to 3 kHz, and is based on protecting against established adverse health effects to humans such as electrostimulation (nerve stimulation, muscle excitation, cardiac excitation, etc.) and magneto-hydrodynamics which are generally associated with blood flow. Although the committee considered the results of epidemiological studies that reported associations between long-term exposure to magnetic fields and disease, including childhood leukemia in residential environments and chronic lymphocytic leukemia in occupational environments, these results were not useful for determining the basic restrictions and exposure limits defined in this standard for the following reasons: a) the evidence is not sufficiently reliable to conclude that long-term exposure to electric and magnetic fields at levels found in public or occupational environments are adverse to human health, including cancer; b) the associations are not supported by the results of animal studies; and c) there is no confirmed mechanism that would support a scientifically-defensible basis for predicting adverse effects from long-term exposure at levels below the limits in contemporary standards and guidelines. Differences
between the IEEE standard and the ICNIRP (1998) guidelines will be discussed, including the difference in basic restrictions between C95.6 (in situ electric field) and ICNIRP (in situ current density).

**Results.** C95.1-2005: The first U.S. human RF safety standard (USAS C95.1-1966) limited exposure at 10 MHz to 100 GHz to 10 mW/cm² averaged over any 0.1 h interval. The standard, based on a simple thermal model, was designed to be protective against adverse thermal effects. In the 70’s, dosimetry data, showing that the interaction of RF energy with biological bodies is complex, were one of the major reasons for revising the frequency-independent limit. ANSI C95.1-1982, the third revision of the 1966 standard, included frequency-dependent limits from 300 kHz to 100 GHz. These limits were derived from the basic restriction for whole-body-averaged specific absorption rate (SAR) to protect human beings from harm by any mechanism. Behavioral disruption in laboratory animals was identified as the most sensitive adverse effect. For the first time, basic restrictions in terms of peak spatial-average SAR were included for localized exposure. Each of these standards consisted of a single set of limits applicable to both the public and workers. The next revision effort produced a two tier standard (IEEE C95.1-1991) and extended the frequency range from 3 kHz to 300 GHz. The upper tier included a 10-fold safety factor; the lower tier had an additional factor of 5, i.e., a total safety factor of 50 below the threshold for effects considered adverse. Although the IEEE C95.1-1991 basic restrictions for whole-body-averaged SAR are harmonized with those of the ICNIRP guidelines in the resonance region, i.e., 0.4 W/kg and 0.08 W/kg for the upper and lower tiers, respectively, the basic restrictions in terms of peak spatial-average SAR limits for localized exposure differ, both in magnitude (1.6 vs 2.0 W/kg) and averaging volume (1 vs 10 g). These differences in peak SAR values were resolved by the publication of IEEE C95.1-2005 in April 2006.

**Conclusions.** Both the basic restrictions and maximum permissible exposures of C95.6 and C95.1 are based on protecting against established adverse effects associated with human exposure to electric, magnetic and electromagnetic fields. Safety margins are included to address biological and other uncertainties. A lack of credible scientific and medical evidence that demonstrates adverse health effects for EMF exposures within the limits of these standards supports their protective nature. ICES has initiated work on a single safety standard that will combine C95.6-2002 and C95.1-2005 to cover the frequency range from 0 Hz to 300 GHz. Following the best scientific information to update the standard and harmonization with ICNIRP guidelines will continue. One single world harmonized EMF exposure standard will be the ultimate goal.

**Acknowledgements.** 1. C95.6-2002, ”IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz”, Published by The Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, New York, NY 10016-5997, USA 2. C95.1-2005, ”IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz”, Published by The Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, New York, NY 10016-5997, USA 3. ICNIRP, (International Commission on Non-Ionizing Radiation Protection), ”Guidelines
for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz),” Health Physics, Vol. 74, 1998, pp. 494-522.

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**P3-3 ISSUES FOR CONSIDERATION FOR CURRENT AND FUTURE EXPOSURE STANDARDS**

James Lin. University of Illinois-Chicago, Chicago, IL, USA.

**Summary.** In the established exposure guidelines, reference levels expressed in terms of physical quantities are introduced for practical exposure assessment purposes, although the basic restrictions are often specified as dosimetric quantities that may be impractical to measure. The dosimetric quantity SAR and current density and their determinations are tissue-type dependent and require a region of specific tissue mass for averaging and for correlation with any induced biological response. Thus, a smaller averaging region is scientifically more relevant and precise. Furthermore, most exposure guidelines are promulgated on a 4 W/kg (SAR) and to prevent any whole-body exposure from raising the body temperature to 1°C above the norm at 37°C. Special guidance may be needed for higher ambient temperature and humidity variations. Existing guidelines are mostly based on results from acute studies. Biological effects from repeated or life-long exposure at low power levels have not been systematically included. Moreover, differences in philosophical approach and scientific interpretations would have profound influence on and lead to different safety standards.
CONDUCTANCE AND IONIC SELECTIVITY OF THE PLASMA MEMBRANE IN CELLS EXPOSED TO 600-NS ELECTRIC PULSES.

Andrei G. Pakhomov, Bowman M. Angela, Shu Xiao, Karl Schoenbach. Old Dominion University, Norfolk, VA, USA.

Summary of Abstract. We found that cell plasma membrane permeabilized by nanosecond electric pulses (nsEP) retains high selectivity to K$^+$ ions, as compared to either larger or smaller cations or Cl$^-$ anions. This result suggests that activation of potassium ion channels, rather than membrane electroporation, is the principal reason for the prolonged increase in resting membrane conductance (Gm) in nsEP-exposed cells.

Objectives. Although long-lasting Gm increase after nsEP exposure has been well documented in different cell lines, its nature remains unclear. In general, transmembrane passage of ions requires formation of aqueous conductance pores (CPs), either by opening of endogenous ion channels, or by damage to the lipid bilayer (e.g., by electroporation). In the latter case, the CPs are likely to allow passage of any small enough ion species, and the size of the largest permeable ion will be a measure of CPs’ diameter. On the contrary, many endogenous ion channels are equipped with a selectivity filter that restricts passage to certain ion species only. Hence, studying ion permeabilities of CPs in nsEP-exposed cells may help to establish the underlying mechanism of long-lasting Gm increase.

Methods. The experiments were performed in GH3 cells (rat pituitary) attached to poly-l-lysine-treated glass cover slips. NsEP were delivered to individual cells via a pair of tungsten rod electrodes. The E-field values between the electrodes were obtained by simulation using Amaze-3D software. Shortly after nsEP or sham exposure, a glass micropipette was brought in contact with the cell to form a whole-cell patch clamp recording configuration. Membrane currents (I) elicited by incremental voltage steps (V) were recorded using a MultiClamp 700B amplifier, Digidata 1340 digitizer, and pCLAMP-10 data acquisition software. Resting Gm was determined as slope of the I-V curve by a linear fit in the region from -90 mV to -60 or -50 mV. The reversal potential (Erev) was determined as an intercept of the best fit line with the abscissa. Relative permeabilities of different ions were calculated from Erev and ion concentrations inside and outside the membrane using the Goldmann-Hodgkin-Katz equation.

Results. Measurements were performed in about 100 cells exposed to a single 600-ns pulse at 0 (control), 2.4, or 4.8 kV/cm. As expected, control cells were some 5- to 10-fold more permeable to K$^+$ than to either smaller or larger monovalent cations, or to the chloride anion. This selectivity is a result of ion flow through voltage-independent leak-type potassium channels. Surprisingly, nsEP exposures had little effect on relative permeabilities, even though the resting Gm could increase more than 10-fold. K$^+$ remained the most permeable ion; relative permeabilities of other ions decreased (Cs$^+$), slightly increased (NMDG$^+$), or remained practically unchanged (Li$^+$, Na$^+$, Rb$^+$, TMA$^+$, TEA$^+$, Cl$^-$).
Conclusions. Overall, the ionic permeability profile of hypothetical CPs in nsEP-exposed cells was essentially the same as of leak-type potassium channels in control cells. This finding suggests that nsEP-induced prolonged increase of the resting Gm reflects opening of endogenous ion channels (probably, K⁺ channels) rather than formation of electroporative defects in the lipid bilayer (because such defects are unlikely to be highly selective for K⁺ compared to a similarly-sized Cl⁻ anion and tested monovalent cations). Note, however, that this conclusion applies to long intervals (minutes) after nsEP exposure, and does not exclude possible electroporative damage on a shorter time scale.

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4-2 PERMEABILIZATION OF PLASMA MEMBRANE BY NANOSECOND-DURATION ELECTRIC PULSES IS DETERMINED BY THE ABSORBED DOSE.

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Summary of Abstract. Plasma membrane effects of 60- and 600-ns pulses at different E-field levels were found to be determined by the absorbed dose, with the threshold at or below 10 mJ/g.

Objectives. In contrast to conventional electroporation by micro-and millisecond electric pulses, nanosecond-range pulses can decrease plasma membrane electric resistance without creating large pores. Even more interesting is that this reduction in membrane resistance remains present minutes after exposure, slowly recovering towards normal. In this study, we compared the effects of 60- and 600-ns pulses, and analyzed the dependence of the biological effect upon physical parameters of the exposure.

Methods. The experiments were run in parallel using two separate but similarly designed patch clamp rigs, one at ODU (600-ns pulses) and the other one at Brooks (60-ns pulses). We used GH3 cells (rat pituitary) attached to poly-l-lysine-treated glass cover slips. Nanosecond electric pulses (nsEP) were delivered to an individual cell via a pair of tungsten rod electrodes, which were precisely positioned next to the selected cell by means of a micromanipulator. The E-field values between the electrodes were obtained by simulation using Amaze-3D software. Shortly after the nsEP or sham exposure, a glass micropipette was brought in contact with the cell, to form a whole-cell patch clamp recording configuration. Bath and pipette buffers imitated the natural composition of extra- and intracellular media. Membrane currents were recorded in 100-150 sec after the exposure using MultiClamp 700B amplifier, Digidata 1340 digitizer, and pCLAMP-10 data acquisition software. The
membrane resistance (Rm) and capacitance were measured in voltage clamp mode by the Membrane Test utility, by applying a 10- or 15-mV positive pulses from the holding level of -80 mV. The resting membrane potential (MP) was measured by briefly switching to current clamp mode at I=0.

**Results.** Both 60- and 600-ns pulses decreased Rm and caused the loss of MP. The threshold for these effects was at less than 6 kV/cm for 60-ns pulses, and at less than 1 kV/cm for 600-ns pulses. Further analysis established that nsEP at both tested pulse durations produced equal bioeffects when the absorbed dose (AD) was the same. In other words, it was AD rather than any other single parameter of exposure (E-field; pulse width; specific absorption rate; exact pulse shape or rise time) that determined biological effectiveness of nsEP. The threshold AD to produce plasma membrane effects in GH3 cells was found to be at or below 10 mJ/g. At higher doses, the nsEP-induced change in Rm was best fit by the function Rm(exposed)/Rm(control) = 5.5AD-0.74, where AD is in mJ/g.

**Conclusions.** It is important to note that changes in Rm and MP were evoked by nsEP at E-field intensities far lower (at least 5-10 fold) than other known nsEP effects (e.g., induction of apoptosis and calcium bursts). Moreover, these effects at higher E-fields were typically determined by charge transfer rather than by AD (data in press), which might be an indication of essential differences in mechanisms that underlie nsEP bioeffects at “low” and “high” E-field intensities. In either case, an equation similar to the one given above can be useful to compare and quantify nsEP sensitivity of different cell types and of cells in different physiological conditions. It can further be employed to predict E-field thresholds at various pulse durations; these threshold values could serve as science-based guidance in determining safety limits for pulsed electric field exposures.

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**4-3 INHIBITION OF VOLTAGE-GATED CALCIUM CHANNELS OF CELL PLASMA MEMBRANE BY NANOSECOND ELECTRIC PULSES**

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**Summary of Abstract.** Whole-cell patch clamp recordings established significant inhibition of currents through L- and T-type calcium channels in 2-3 min after exposure to a single 600-ns pulse at 1.2-4.8 kV/cm.
Objectives. Our experiments reported earlier established long-lasting plasma membrane permeabilization by 60-ns electric pulses (nsEP). This effect was accompanied by the loss of resting membrane potential and inhibition of some voltage-activated currents. The objectives of the present study were (1) to test if longer (600-ns) pulses suppress currents through calcium channels, (2) to separate effects of nsEP on low-threshold (T-type) and high-threshold (L-type) calcium channels, (3) to check if the effect on the channels correlates with membrane permeabilization and with the E-field intensity.

Methods. Calcium channel currents in cultured rat pituitary tumor cells (GH3) were recorded using a whole-cell patch clamp technique in a 2-3-min interval after exposure to a single 600-ns pulse (1.2 to 4.8 kV/cm), or after a sham exposure. To deliver nsEP to an individual cell, a pair of electrodes (100-µm diameter, 110-µm gap) was positioned precisely next to the selected cell by means of a micromanipulator. The E-field values between the electrodes were obtained by simulation using Amaze-3D software. The bath solution contained (mM) 136 TEACl, 2 MgCl₂, 10 BaCl₂, 10 HEPES, and 10 glucose. A patch pipette filled with (mM) 20 TEACl, 120 CsCl, 10 Cs-EGTA, 1 BaCl₂, and 10 HEPES was brought in contact with the cell within several seconds after exposure. Calcium channel currents (as carried by Ba²⁺ ions, Iₜₐ₃) were elicited by incremental voltage steps from the holding potential of either -78 mV (to activate both L- and T-types of calcium channels) or -48 mV (to activate L-type channels only). Resting membrane conductance was determined as the slope of the current-voltage curve by a linear fit in the region from -100 mV to -70 mV. The data were collected and processed using a MultiClamp 700B amplifier, Digidata 1340 digitizer, and pCLAMP-10 data acquisition software. All values of the membrane potential reported here have been corrected for a junction potential of -8.5 mV.

Results. Exposures at 1.2, 2.4, and 3.6 kV/cm caused no increase in the resting membrane conductance, probably because of blockage of potassium channels by TEA (see an accompanying abstract by Pakhomov et al. for more detail). Inward Iₜₐ₃ had a threshold between -60 and -50 mV and peaked at about -20 mV both in the exposed and control cells. At the same time, the peak amplitude of Iₜₐ₃ typically was lower in the exposed cells (e.g., about 3-fold lower than in the control after exposure at 3.6 kV/cm, p<0.01). The sensitivity of different types of calcium channels to nsEP and the dependence of the inhibitory effect upon the applied E-field have yet to be analyzed. In cells exposed at the highest E-field tested (4.8 kV/cm), the resting membrane conductance was sharply increased (to 3.7 nS vs 0.6 nS in the control group), and no voltage-activated Iₜₐ₃ could be reliably detected.

Conclusions. This study demonstrated that a single 600-ns pulse, even at a relatively low amplitude of 1.2-3.6 kV/cm, can cause long-lasting inhibition of voltage-gated calcium channels in the cell plasma membrane. This effect can be reliably detected in the absence of any increase of the resting membrane conductance (i.e., without any change in the leak current); this observation suggests that the inhibition of calcium channels and plasma membrane permeabilization are two separate effects of nsEP.

Acknowledgements. The study was supported in part by internal funding from the Frank Reidy Research Center for Bioelectrics.
4-4 NANOSECOND ELECTRIC PULSE STIMULATES CATHECHOLAMINE RELEASE FROM CHROMAFFIN CELLS

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Summary of Abstract. The results of studies examining the effect of nanosecond electric pulses on catecholamine release from bovine adrenal chromaffin cells are described.

Objectives. Our previous studies have shown that a single 4 ns electric pulse at field intensities ranging from 2 MV/m to 8 MV/m elicits a rapid, transient increase in intracellular calcium levels $[\text{Ca}^{2+}]_i$ in electrically excitable bovine adrenal chromaffin cells that is due to Ca$^{2+}$ influx via voltage-sensitive L-type Ca$^{2+}$ channels [Craviso et al., 2006; 2008]. Because secretion of catecholamines from chromaffin cells is a Ca$^{2+}$-dependent process that is triggered by activation of L-type channels, the present work was undertaken to determine whether the influx of Ca$^{2+}$ elicited by a single nanoelectropulse is sufficient to cause catecholamines to be released.

Methods. Bovine adrenal chromaffin cells were isolated, cultured and disaggregated into single cells and cells in small clusters as previously described [Craviso, 2004]. Approximately 50,000 cells in 100 $\mu$l of a balanced salt solution (BSS) were placed into standard electroporation cuvettes (1 mm gap) that served as the exposure chambers. The cells were exposed at room temperature to 4 ns pulses at a field intensity of 5 MV/m delivered by a magnetic compression diode-opening switch pulse generator. Two minutes after the pulse was applied, the cuvettes were cooled on ice, centrifuged at 850 x g at 4 $^\circ$C for 5 minutes to pellet the cells, and the amount of norepinephrine (NE) and epinephrine (EPI) released into the BSS quantified by high performance liquid chromatography coupled with electrochemical detection, as described in Craviso et al. [2003]. Control samples consisted of identically handled samples that had not been pulsed, and positive controls for NE and EPI release comprised parallel cell samples stimulated for two minutes with a submaximal concentration (5 $\mu$M) of the nicotinic receptor agonist dimethylphenylpiperazinium (DMPP). All experiments were conducted using triplicate cell samples for each condition. Data are expressed as the percentage of NE and EPI released into the BSS relative to the total cellular NE and EPI content of each cell sample.

Results. A single 4 nanosecond pulse stimulated the release of both NE and EPI from chromaffin cells to a similar degree. In six independent experiments that utilized cells at different times in culture and from different cell preparations, the mean ± S.E.M. for NE release was 3.45 ± 0.41% of the total cellular NE content and that for EPI release was 3.49 ± 0.81% of the total EPI content. At the concentration of DMPP used in these studies,
NE release was comparable to that elicited by the nanoelectropulse, \(4.05 \pm 0.38\%\) of the total cellular NE content. EPI release, however, was less (\(2.87 \pm 0.32\%\) of the total EPI content), a finding consistent with previous reports by us and others of differences in the secretion of NE and EPI in response to nicotinic receptor stimulation. Additional experiments will investigate further whether NE-releasing and EPI-releasing cells are affected by the nanoelectropulse to the same extent. When experiments were carried out with calcium omitted from the BSS, no stimulation of NE and EPI release occurred in response to either the nanoelectropulse or DMPP. These results demonstrate that the secretory response of the cells to the nanoelectropulse requires extracellular calcium. To explore the basis of the requirement for extracellular calcium, a nanoelectropulse was delivered to the cells in the presence of the fluorochrome YO-PRO-1 (5 \(\mu\)M), a compound that is excluded from cells with intact membranes and which has been used as an indicator of plasma membrane permeabilization after nanosecond pulse exposure [Vernier et al., 2006]. Detectable uptake of the dye into the cells did not occur after the application of a single 4 ns, 5 MV/m pulse, suggesting that plasma membrane electroporation does not appear to be a significant factor in the secretory response of chromaffin cells to a nanoelectropulse. Experiments utilizing specific blockers of plasma membrane voltage-sensitive channels are presently being carried out to elucidate the mechanism involved.

**Conclusions.** The \([\text{Ca}^{2+}]_i\) response previously observed in electrically excitable adrenal chromaffin cells in response to a single electric pulse appears to have physiological significance since NE and EPI are released from the cells.

**References.**


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PHOSPHATIDYLSERINE TRANSLOCATION DETECTED ON HELA CELLS EXPOSED TO INTENSE BURST SINUSOIDAL ELECTRIC FIELD

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Summary of Abstract. This paper describes one of the biological reactions of HeLa cells induced by a narrow frequency band and moderate electric field using an intense burst sinusoidal electric field (IBSEF). The IBSEF enables to generate a well-defined electric field in terms of frequency, amplitude and exposure time. A 50 MHz, 200 kV/m IBSEF, which is supposed to cause an intracellular electric field, was applied to HeLa cells, and the phosphatidylserine (PS) translocation, which is one of the indications of apoptosis activity, was investigated. The apoptotic reaction was determined by a double staining method using Annexin-V-FITC and propidium iodide. The experiment shows the 0.2 ms long IBSEF, which is supposed to be a non-thermal pulsing, caused the PS externalization to HeLa cells, and the number of cells with the PS externalization was increased gradually.

Objectives. In the last decade biological effects of wide and narrow band electrical pulses have been intensively investigated. It is known that pulsed electric fields (PEFs) with a pulse duration exceeding 1 µs cause the increase in the permeability of cell membrane, i.e. electroporation. As the duration and the rise time of PEF are decreased to nanoseconds range, the cell response changes. Schoenbach et al. have reported that nanosecond pulsed electric fields (nsPEFs) causes intracellular effects and they used nsPEF for melanoma remediation on mice. We have proposed the use of Intense Burst Sinusoidal Electric Field (IBSEF) as a narrow frequency band electric field instead of rectangular pulses of which the frequency spectrum is rather broad. The IBSEF enables to give a well-defined electric field in terms of frequency, amplitude and exposure time to biological targets. In our previous work we have experimentally demonstrated that non-thermal 50 MHz IBSEF with the moderate amplitude on the order of 100 kV/m and the burst duration of 0.2 ms causes the denaturalization of intracellular DNA for Chinese hamster ovary cells. The frequency of 50 MHz is sufficiently high for the electric field to penetrate through the cell membrane. Our interests are now focused on the mechanisms of the DNA denaturalization by the intracellular electric field in addition to the possibility of the apoptosis induction by using IBSEF for the purpose of cancer therapy. This paper describes the phosphatidylserine (PS) translocation, which is one of the indications of apoptosis, was investigated on HeLa cell (human cancer cell) exposed to the IBSEF.

Methods. IBSEF generator consists of signal generator, pulse generator, and RF amplifier, each controlling the frequency, burst duration and amplitude, respectively. The system was connected to an application cell via a 50 Ω coaxial electrode. An application cell consists of
two parallel platinum plate fixed on a glass plate by using heat resistant resin. The cell, of which the electrode separation and the cross section are 1 mm and 10 mm², respectively, is regarded as a 66 Ω resistive load. We have performed the detection of phosphatidylerine (PS) externalization. PS is a phospholipids nutrient usually hidden in the inner-leaflet cell membranes. In an early phase of apoptosis reaction, the PS transports to the outer-leaflet of the plasma membrane. Labeling the PS by Annexin-V with FITC enables to visualize cells in the early- to-mid-apoptotic states. Propidium Iodide (PI), a fluorescent dye which is permeable to the cell, was used simultaneously to detect dead cells.

**Results.** 50 MHz, 200 kV/m IBSEFs with various burst durations from 0.2 to 5 ms were applied to HeLa cells (human cervical cancer cell), and observed by fluorescent microscope. Cells were stained with both Annexin-V and PI either immediately (0 hour) or 5 hours after IBSEF application. The double staining results were classified into three cases (1) Annexin-V negative and PI negative as living cells, (2) Annexin-V positive and PI negative as apoptotic cells, (3) Annexin-V positive and PI positive as dead cells. The percentage of the dead cell and the cells in the apoptotic process were evaluated by counting the cell number. As the result of the experiment, the control cells showed 0 % apoptotic reaction for both 0 and 5 hours later analysis, and less than 1 % of the cells were dead in both cases. In the case of long burst duration of 5 ms 4 shots, which is accompanied by the instantaneous temperature increase, approximately 40 % of the cells showed the apoptotic reaction immediately. After 5 hours the apoptosis ratio was decreased as the result that immediately activated apoptotic cells were dead. On the other hand, the application of 0.2 ms IBSEF with the slight temperature increase less than 1 K did not cause the PS externalization just after the pulsing, while the occurrence percentage of the apoptotic process was gradually increased to be approximately 10 % after 5 hours. The delayed occurrence or the PS externalization implies that the non-thermal IBSEF does not directly cause the PS externalization, or apoptosis reaction, but is likely to trigger the biological process related to the PS externalization.

**Conclusions.** Intracellular intense electric fields achieved by 50 MHz burst sinusoidal wave produces the intracellular biological effect and is capable of initiating the apoptosis process. It would be interesting to explore how the intracellular electric fields actually link to the apoptotic process.

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REAL-TIME QUANTIFICATION OF ELECTROPORATIVE UPTAKE KINETICS AND ELECTRIC FIELD HETEROGENEITY EFFECTS IN CELLS


Summary of Abstract. We have conducted experiments to quantitatively characterize uptake kinetics of a fluorescent plasma membrane integrity indicator, propidium iodide (PI), in HL60 human leukemia cells when exposed to 40 µs pulsed electric fields (PEFs). These experiments were possible through fluorescence microscopy calibration and the development of a microcuvette—a microfabricated device designed for exposing cell cultures to PEFs under real-time microscopy. A finite-element electrostatic simulation was performed to assess the degree of field non-uniformity within the microcuvette’s exposure chamber allowing us to correlate trends in cellular response to field heterogeneity. Analysis of experimental data identified two distinctive fluorescence signatures: one characterized by low-level, decelerating fluorescence beginning immediately after PEF exposure and the other by an accelerating fluorescence that is manifested sometimes hundreds of seconds after PEF exposure. These fluorescence signatures were used to discriminate between transient and irreversible electroporation and to discuss electropore stability and persistence. A transient electroporation window was identified for HL60s under our experimental conditions existing between 1.6 and 2 kV/cm. Quantitative analysis was used to determine that transient electroporation resulted in 88.3 ± 20.9 million internalized and bound PI molecules/cell. Finally, data on the microcuvette’s field non-uniformity was exploited to elicit asymmetric electroporative PI uptake in individual HL60s.

Objectives. The research described achieves important objectives in experimental electroporation research. First, we have developed techniques required to quantitatively monitor electroporative uptake kinetics of fluorescent molecules. Obtained data were used to identify a range of PEF intensities resulting in exclusively transient electroporation. Second, we have analyzed the electric field heterogeneity in our microcuvette in order to relate the distribution in post-PEF cell response to the variation in field intensity. Such treatment of field heterogeneity has not previously been examined. Finally, we have exploited field heterogeneity to elicit heterogenic PI uptake demonstrating that field non-uniformity may be used to spatially control molecular uptake.

Methods. HL60s were suspended in HBSS with [PI] = 30 µM, placed between a microcuvette’s electrodes, and monitored under fluorescence microscopy (Fig 1(a)). The microcuvette was connected to our high-voltage pulsing electronics capable of administering square PEFs as short as 60 ns with maximum intensities of 90 kV/cm (pulse rise and fall times were 64 and 70 ns, respectively). Fluorescence levels were calibrated by cataloging the fluorescence of saponin-lysed HL60s in the presence of known quantities of PI (see Fig. 1(b) for resulting calibration curve). The microcuvette’s field non-uniformity was assessed for the case of 1 V excitation. The computed field pattern conveniently divides the microcuvette’s exposure chamber into two regions: Region I, where the field strength is slightly lower than the nominal field strength ($E_n$) (defined as the voltage across the electrodes divided by the electrode separation), and Region II, where the field strength is slightly higher than $E_n$. 
Results. Fluorescence vs. time curves for individual HL60s are shown in Fig. 2. Cells lying in the microcuvette’s Region I are plotted in solid lines whereas cells lying in Region II are plotted in dashed lines. The calibration curve was used to estimate the number of internalized and bound PI molecules per cell based on their fluorescence intensity (see right vertical axis of Fig. 2). It can be seen that cells lying in Region II respond more dramatically in given electroporation experiments. We attribute this to the slightly higher field intensities found in Region II. We observed a qualitative change in the fluorescence vs. time curves as field levels increased. For instance, in Fig. 2(b), some of the curves—primarily those in Region I—are consistent with transient electropore formation (i.e., their negative second derivative and eventual plateau suggests initial electropore formation, reduction in electropore number and/or size over time, and eventual resealing). Other curves—primarily those in Region II (cells labeled 1-4)—are consistent with permanent electropore formation (i.e., their positive second derivative suggests an increase in electropore number and/or size over time). Using the quantitative estimates provided on the vertical right axis, cells with fluorescence vs. time characteristics consistent with transient electroporation internalize $88.3 \pm 20.9$ million nucleic acid-bound PI molecules.

Conclusions. We have produced data quantitatively characterizing electroporative uptake kinetics resulting from 40 µs PEFs. The curves for PEFs between 1.6-2 kV/cm are consistent with uptake expected from transient electroporation and the curves from PEFs above 2 kV/cm are consistent with uptake expected from permanent electroporation. Cells exhibiting transient electroporation fluorescence signatures internalize approximately 88.3 million nucleic acid-bound PI molecules per cell. We have shown that electroporative response is highly sensitive to the field variations found in our microcuvette’s exposure chamber. This sensitivity is exploited in order to induce PI uptake preferentially near the microcuvette’s electrodes (see Fig. 1(a)).

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Figure 1. (a) Microcuvette images. (b) Fluorescence calibration curve.
Figure 2. PI uptake versus time data for electroporation experiments using 40 μs PEFs
**Summary of Abstract.** [1] has presented a technique to simulate the impact of individual vessels on EM induced temperature increase. This technique is extended to enable the simulation of thin, highly thermo-conductive structures and 1D boundary conditions without having to resort to extremely fine meshes and small stable time-steps. The proposed method has been extensively validated and applied to realistic example cases (implanted wire in MRI birdcage coil, internally cooled RF ablation catheter) illustrating the significant impact (in terms of accuracy and speed) provided by this approach.

**Objectives.** This study aims at developing a general model to simulate the thermal impact of thin, nearly 1D structures. This covers vessels (incl. flow effects), highly thermo-conductive wires as well as 1D boundary conditions (Dirichlet, Neumann and convective).

**Methods.** The Pennes bioheat equation which is commonly used to model EM induced temperature increase does not consider the impact of discrete blood vessels (and the directness of blood flow). This led [1] to introduce a ‘finite differences’ based method to couple a pseudo-1D simulation of the vessel tree with a 3D simulation by estimating the local heat flux through the vessel surfaces based on the temperature of voxels (unit of spatial discretization) in the vicinity of the vessel and (analytical) knowledge about the dependence of the local temperature on the distance to the vessel center. This technique can be extended by adding a heat conduction term in the pseudo-1D simulation, by imposing boundary conditions at the ‘vessel’ surface and by considering the impact of microvasculature and arterial bleed-off on the local temperature profile in the vessel vicinity. Stability criteria can be determined for these extended models by performing a von Neumann stability analysis. And it is possible to analytically determine equilibration lengths for simple setups.

As the pseudo-1D simulation can have a considerably larger ‘voxel’ size, the new approach offers a way of getting around the requirement of using a very small time step (which would otherwise be necessary to assure stability for a simulation featuring thermally relevant, thin structures and highly thermo-conductive materials). And using an (improved) analytical model of the temperature distribution in the vicinity of the thin structure results in better accuracy even for larger grid steps in the 3D simulation.

**Results.** The models have been extensively validated using analytically solvable example cases and the accuracy of the models with respect to voxel size as well as orientation and position of the thin structure relative to the grid has been studied for various structure radii. Subsequently the technique has been applied to model the heating caused by the
presence of wires in a phantom during exposure in an MRI birdcage coil and the temperature distribution in the vicinity of an internally water cooled RF ablation catheter. Up to a factor 400 speed increase is obtained with the presented technique and important differences are found when comparing the simulation results with results obtained using standard boundary conditions instead of explicit modelling of the thin structures.

Conclusions. A unified method based on [1] has been developed to simulate the thermal impact of thin, nearly one dimensional structures with the finite differences technique. The presented method is both more accurate and faster than the standard approach. It has been extensively validated and proved to be stable and accurate for a large range of parameters. The importance of the technique has been illustrated with two realistic example cases. It is ideally suited to study thermal effects caused by implants exposed to EM fields. Extensive experimental validation using an MRI bird-cage, a gel phantom and embedded thin structures is being performed.


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Figure 1. Temperature isosurface in simulation of RF ablation. The internally cooling of the ablation catheter is a) not considered, b) considered using a fast and accurate 1D boundary condition approach, c) considered using a conformal boundary condition method.
5-2 FAST SAR AND TEMPERATURE FIELD (RE-)OPTIMIZATION FOR HYPERTHERMIA: BRINGING TREATMENT PLANNING INTO THE TREATMENT ROOM

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**Summary of Abstract.** A new, fast optimizer for hyperthermia treatment planning is presented. It optimizes the antenna parameters (phases and amplitudes) of a phased array applicator to ideally focus the energy deposition into the tumor, while reducing the exposure of healthy tissue. Both temperature and SAR optimization can be performed. By using efficient optimization techniques, selecting a functional that can be largely precomputed and for which the contributions of individual patient regions can be calculated and weighted individually, it becomes possible to take patient feedback into account and to quickly generate a new treatment plan based on patient complaints (unpleasant heat/pressure sensation).

**Objectives.** Hyperthermia is a relatively novel treatment modality for various types of cancer. EM energy is used to heat the tumor with curative intent. Due to the large number of antenna parameters that have to be optimized and the difficulty of predicting the resulting field distribution in the patient treatment planning is required to properly heat the tumor and avoid hot-spots in healthy tissue. The objective is to develop a tool that permits optimization at high resolution, and subsequently fast reoptimization during treatment based on patient feedback.
**Methods.** An optimization functional has been selected that can be split both according to region contributions and according to antenna contributions. These contributions can be individually precomputed and weighted before being combined in a fast operation to obtain the functional value for given antenna settings. This means, that it becomes possible now to quickly adapt the weights for individual regions based on patient feedback and that any iterative optimization method suitable for large parameter spaces (genetic, particle swarm, tree based...) can be applied to optimize the problem. Because of its speed and the option of considering constraints (such as a balanced power load on the different antennas) the ‘Estimation of the Population Density of Probability using Dependency Trees’ method [1] has been used.

In the presented implementation, it is possible to define multiple, arbitrarily shaped target region that do not necessarily have to correspond to specific solids (e.g. tumor + 2cm safety margin). Heating priorities can be assigned to the individual target regions and sensitivities can be specified for the healthy tissues. A first optimization can be performed to identify likely hot-spots and underexposed tumor regions (cold-spots) that can then be assigned increased weights in a second optimization run (similar to [2]). Additional thresholds can be imposed for sensitive tissues.

Because of the speed at which the functional can be reevaluated, it becomes possible to perform a Monte-Carlo stability analysis to study the sensitivity of the proposed treatment to uncertainties in phase and amplitude of the individual antenna excitations.

**Results.** After precomputing the EM (or thermal) fields at high resolution (16 million voxels) optimization can be performed in about 10 min for a 12 antenna applicator (the optimization time scales roughly linearly with the number of antennas for EM based optimization and quadratically for temperature based optimization). Reoptimization with modified weights takes about 50 s (or 20 s if only the antenna parameters and not the resulting field distribution has to be recomputed). The method has been tested using data from a series of patients and produces considerably improved treatment protocols. Iterative hot- and cold-spot reduction can be helpful. The Monte-Carlo stability analysis helps identifying phase and amplitude accuracy constraints when designing new applicators.

**Conclusions.** The presented approach allows fast (re-)optimization taking into account patient feedback and allowing flexible constraints to be imposed on the possible antenna parameters. The presented tool permits bringing treatment planning into the treatment room.


5-3 REAL-WORLD LOW FREQUENCY SIMULATIONS OF FULL BODY INTERACTIONS WITH ELECTROMAGNETIC FIELDS

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Summary of Abstract. Because the FDTD method becomes inefficient at low frequencies, other numerical schemes have to be considered. This study investigates the electro and magneto quasi-static approximation in connection with the very detailed human body models (up to 84 distinguished tissues). The numerical kernel has proven to be efficient and robust for a wide variety of applications from statics up to 0.5 MHz.

Objectives. In the last decades, the finite-difference time-domain method (FDTD) has proven to be an efficient and powerful numerical tool. Especially for interactions of complex human body models and electromagnetic (EM) fields, the FDTD method is highly valuable to assess electromagnetic compatibility above 100 MHz. However, at lower frequencies the FDTD method becomes inefficient due to the explicit time integration scheme. Using quasi-static approximations of Maxwell’s equations can lower the computational burden considerably. A novel approach and effective implementation was therefore the objective of this study.

Methods. The electro and magneto quasi-static approximations (EQS and MQS) to Maxwell’s equations have been implemented using the finite element method (FEM) in frequency domain. The EQS model neglects the temporal change of the magnetic flux, whereas the MQS model neglects the temporal change of the displacement current. The

Figure 1. Optimized SAR distribution for patient in a head&neck hyperthermia applicator.
nonuniform but rectilinear computational grid of the FDTD method has been reused to benefit from the model discretization and postprocessing capabilities of the graphical user interface SEMCAD X (www.semcad.com). In addition, a variety of very detailed human body models for FDTD simulations are thus immediately applicable for the low frequency solver, which is a very interesting feature in the scope of this study.

**Results.** The new low frequency solver package was applied to highly complex human body configurations. The EQS model was used in assessing the impact of applicators during cancer treatement with thermal ablation. The MQS model is currently under investigation addressing the safety of workers operating close to a MRI machine (see picture).

**Conclusions.** The numerical approach of this study has proven to be very effective to assess interactions between detailed human body models and electromagnetic fields at low frequencies. Real-world simulation results in the range from cancer treatement (thermal ablation) to EM safety of MRI workers will be presented.

**Figure 1.** Young person inside two Helmholtz coils

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**5-4 SIMULATION STUDIES OF HIGH INTENSITY, ULTRASHORT ELECTRICAL PULSE EFFECTS ON EXCITABLE CELLS**

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**Summary of Abstract.** The interaction of electric and magnetic fields with biological systems has been of long standing scientific interest. Phenomena caused by exposures to strong fields include tissue heating, conformational changes of voltage-gated channels, electroporation and cell membrane permeabilization, possible Ca\(^+2\) release, self-organization and pattern forming at membranes, generation of action potentials, cell death via apoptosis,
and enhanced gene expression. A class of important considerations and applications that are beginning to emerge from electrical stimulation are the potential effects on neurons, including the possibility to block “Action Potential” propagation in nerves. Another fundamental aspect is the need to probe and understand the influences of such high-intensity electrical pulsing on the ion-channels embedded in excitable membranes. Detrimental effects include disruption of the voltage gating mechanism in sodium and/or potassium ion-channels. In this contribution, the effects of ultrashort, high-intensity voltage pulsing on the neural response is studied. Appropriate comparisons with experimental data are also presented, and the underlying physics and mechanisms discussed.

**Objectives.** There are two objectives of this modeling study. The first is the analysis for possible neuro-muscular incapacitation based on the application of high-intensity, ultrashort electric pulses. The analysis is applied to a rat, but the approach is general, can be extended to any whole-animal, and applies for any arbitrary pulse waveform. It is hypothesized that repeatable and reversible action potential blocks in nerves can be attained based on the electroporation mechanism. Second, we seek to model changes in the current-voltage (I-V) behavior of voltage-gated, ion-channels in based on a suitably modified Hodgkin-Huxley distributed circuit approach for nerves.

**Methods.** Our numerical studies are based on an integrated approach that includes three distinct aspects. The first component is a modified Hodgkin-Huxley (HH) distributed circuit representation of nerves that includes a shunt conductance Gsh, to account for pore-formation at nerve membrane. The time-dependent Smoluchowski equation is used to determine the density of pores on the cylindrical nerve membrane. This provides a time-varying area, which is then used to dynamically update the membrane conductance. The spatially integrated value over the membrane surface at the end of the ultrashort, external electrical pulse is then used for the Gsh parameter. The second aspect is the time-dependent calculations of the volumetric electric fields produced by the external electrodes. This requires inclusion of the electrical characteristics of all tissues within the whole-body, details of the electrode placement, and time-dependent voltage waveforms being applied. It yields the internal current distributions and equi-potential profiles. Finally, the HH model is transformed into the discrete domain to obtain a finite state model for evaluating the dynamic response of a collection of voltage-gated, ion-channels. In this context, the idea of electrically-induced, channel damage is incorporated via an “intermediate-idle” state lying between the open- and closed-channel conditions.

**Results.** It is shown in this simulation study that high-intensity, short-duration electrical pulses can provide for a quick-acting, localized, and reversible cessation of biological electrical signaling pathways. The concept of arresting action potential propagation is based on creating a large density of electro-pores on the membrane of both myelinated and unmyelinated nerves. Our predictions were compared against actual experimental reports on rats, where 600 ns, high- voltage pulses had been used [9]. The shunt conductance created through electroporation due to such a 600 ns pulse was shown to be adequate for arresting the neural signal through the rat spine, in very good agreement with the actual data. Our study also generated an effective ”strength-duration (SD)” curve, detailing the pulse duration necessary for attaining the requisite membrane shunt conductance for a given field.
amplitude. Finally, our time-dependent analysis of the ion-channel I-V characteristics was seen to match the available “patch-clamp” data fairly well. The results also suggest a role for the temporary blockage of ion-channel functioning at high applied electric fields.

**Conclusions.** This is a report on the theoretical study of possible neuro-muscular incapacitation based on the application of high-intensity, ultra-short electric pulses. The analysis was applied to a rat, but the approach is general and can be extended to any whole-animal. It is hypothesized that repeatable and reversible action potential blocks in nerves can be attained based on the electroporation mechanism. Our numerical studies are based on the Hodgkin-Huxley distributed circuit with suitable modifications. For self-consistency, the analysis includes three-dimensional, time-dependent calculations of the potentials in whole animals based on the external voltage waveforms and electrode placement. The predictions are compared to actual 600 ns experimental reports on rats, and shown to be in very good agreement. Effective strength-duration plots for neuro-muscular incapacitation are also generated. The conceptual possibility of disrupting the voltage-gated, ion-channel function is also introduced and discussed. Appropriate comparisons with “patch-clamp” data are made in this regard.

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**5-5 EFFICIENT AND VERSATILE IMPLEMENTATION OF DIFFERENT SPATIAL-AVERAGING SCHEMES FOR SAR**

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**Summary of Abstract.** This work presents an efficient implementation of three techniques for the spatial averaging of Specific Absorption Rate (SAR) values within highly inhomogeneous and complex tissue structures, as human bodies. The main purpose is to enhance the efficiency and accuracy of existing algorithms while meeting the recommendations of IEEE and ICNIRP. The cubical, contiguous and spherical spatial-averaging schemes for SAR have been implemented and integrated into the advanced simulation platform SEMCAD-X.

**Objectives.** Various organizations have established safety guidelines for electromagnetic (EM) wave absorption. In particular, for near field exposure, these standards are based on spatial-peak values of averaged SAR. In the process of SAR averaging, the adjustment of the averaging volume around every sample in the tissue constitutes the major computational burden in the method. Actually,
In the computation of large problems the time required for SAR averaging might even surpass that employed in the resolution of the EM problem itself. Some of the techniques presented so far [1, 2] overcame this problem by using approximations on the averaging volumes that took advantage of the imprecision of the tissue models. Nowadays, this scenario has changed since accurate numerical models of human bodies are now available [7]. Therefore, it would be desirable to perform an implementation that provides equivalent accuracy on larger models and without a loss in efficiency.

In this communication, we will present an implementation of algorithms that satisfies the following points:

1. Numerically efficient algorithms for the evaluation of three useful SAR averaging schemes: cubical (IEEE-compliant) [3], contiguous (ICNIRP-compliant) [4] and spherical.
2. Suited for any arbitrary highly inhomogeneous structures and any averaging mass.
3. Organ/tissue specific evaluation of SAR average.

User-friendly interface for configuration and visualization.

**Methods.** The computation of the SAR requires the knowledge of the power dissipated on the tissue as well as its density at every point. The evaluation of these quantities can be carried out by numerical simulation. Advanced implementations of the FDTD method have shown to be very convenient, in terms of efficiency and accuracy, for the computation of arbitrary highly inhomogeneous problems. Therefore, this is the method selected to estimate the EM fields induced on human bodies from RF sources.

The averaging of the SAR can be defined in several ways, leading to different possible schemes.

The IEEE standard [3] proposes a cubic region of a specific mass (typically 1 or 10g) as the averaging volume. This shape can be easily fit in the FDTD grid which simplifies the averaging procedure. The cube fitting consist first in a fast "coarse" expansion based on the grid voxels [2]. Finally, the resulting cube is fine tuned in order to fit the exact mass, within a specified tolerance [5].

Another useful scheme consists of the so-called contiguous SAR averaging [4]. In this case, the volume’s shape is not predetermined but only the mass. The shape is built by gathering contiguously the points in the tissue with maximum local SAR values until the required mass is reached. This procedure requires a high computational effort since the determination of the averaging volume shape implies the analysis of the entire problem. Therefore a segmentation strategy has been a key in the optimization of this algorithm.

Finally, a spherical volume has also been implemented for comparison since it seems to be a natural shape for averaging. This shape has the inconvenient that it does not fit well the Cartesian grid provided in the FDTD method. This has been overcome by interpolating different volumes from the cubic scheme.

**Results.** The algorithm has been integrated into the post-processing unit of the simulation platform SEMCAD-X [6] which incorporates an state-of-the-art EM technology based on the Finite-Difference Time-Domain (FDTD) method. SEMCAD provides all the features needed in order to generate and evaluate highly complex real world problems. It supports the generation of model specific, customizable
non-homogeneous grid generation together with a fast voxelizer for material assignment. Advanced local refinement schemes enable enhanced modeling within FDTD, even for setups with a large ratio between smallest and largest extensions. Preliminary results of the SAR averaging algorithms show a clear increase of the computation speed with respect to previous implementations while providing higher accuracy. The three averaging schemes are being applied to realistic scenarios involving the EM exposure of human bodies, outlining performance of the methods as well as specific average SAR variations based on the chosen scheme.

**Conclusions.** Three SAR averaging schemes have been implemented to meet the requirements in terms of efficiency and versatility that nowadays applications demand. The cubical and contiguous schemes follow the recommendations of standardization groups of IEEE and ICNIRP, respectively. On the other hand, the spherical scheme provides an alternative averaging definition. These solutions have been integrated into SEMCAD-X and will be available in coming versions of this simulation platform.

**5-6 DNA STIMULATION IS INITIATED BY CHARGE TRANSFER IN ELECTROMAGNETIC FIELDS**

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**Summary of Abstract.** The weak electromagnetic fields (EMF) that stimulate DNA do not appear to have sufficient energy to directly affect large biopolymers. However, even weak EMF have been shown to accelerate electron transport in the Na,K-ATPase, cytochrome oxidase and the Belousov-Zhabotinsky reactions. The weak fields would be expected to react strongly with electrons, because of their high charge to mass ratio. A redistribution of charges in biopolymers due to electron transfer could trigger large conformational changes, such as the well known disaggregation of hemoglobin tetramers into dimers with an increase in net charge. It appears likely that the direct effects of EMF on biopolymers can be initiated by charge transfer, while the large structural changes are driven by changes in the large hydration energies that stabilize macromolecular structures. Conformational changes that arise from alterations in charge distribution play key roles in the action of membrane transport proteins, including ion channel proteins. Many biological processes probably rely on this mechanism for control and amplification.

**Objectives.** To show that the direct effects of EMF on biopolymers are only initiated by charge transfer, while the large structural changes are driven by changes in the large hydration energies that stabilize macromolecular structures.

**Methods.** Calculate energies needed to affect electron transfer reactions and compare to energies of macromolecular structure changes.

**Results.** Electron transfer in DNA can lead to disaggregation of local DNA regions.

**Conclusions.** Electron transfer in DNA can lead to disaggregation of local DNA regions. This mechanism also plays a key role in the action of many membrane transport proteins.
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**6-1 P2X AND P2Y PURINERGIC RECEPTORS PLAY A ROLE IN KERATINOCYTE ELECTRIC FIELD-MEDIATED DIRECTIONAL MIGRATION**

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**Summary of Abstract.** An endogenous electric field (EF) is generated immediately upon wounding skin, with the cathode of the field located at the wound center. The EF could be the earliest signal that cells sense to initiate directional cell migration into the wound, but the sensing mechanism is unknown. Upon injury, keratinocytes at the wound margin migrate directionally towards the center of the wound bed to initiate repair and restore epithelial integrity. Nucleotides, released from platelets and wound-damaged cells, could play a role in regulating keratinocyte migration towards the electric guidance cues in the wound. Here we demonstrate that the ability to sense the electric field requires the nucleotide-mediated activation of both P2X and P2Y receptors to initiate and sustain keratinocyte galvanotaxis. Further characterisation will identify the purinergic receptors that play a role in sensing electrical guidance cues.

**Objectives.** Our objective was to determine if nucleotides, released from platelets and wound-damaged cells, play a role in regulating keratinocyte migration towards the electric guidance cues in the wound. Nucleotides act via the P2 family of receptors of which there are two subgroups: P2X receptors, which are ligand-gated ion channels and P2Y receptors, which are G protein coupled receptors. Keratinocytes express a range of P2X (P2X\textsubscript{1}, P2X\textsubscript{2}, P2X\textsubscript{3}, P2X\textsubscript{4}, P2X\textsubscript{5}, P2X\textsubscript{6}, P2X\textsubscript{7}) and P2Y (P2Y\textsubscript{1}, P2Y\textsubscript{2}, P2Y\textsubscript{4}, P2Y\textsubscript{6}, P2Y\textsubscript{11}, P2Y\textsubscript{12}, P2Y\textsubscript{13}) receptors, can release ATP through a variety of mechanisms and can interconvert nucleotides at the cell surface. In addition, purinergic agonists and antagonists are known to alter skin wound repair, keratinocyte proliferation and cytokine release. Finally, a number of P2X (P2X\textsubscript{4}) and P2Y (P2Y\textsubscript{2}, P2Y\textsubscript{6}, P2Y\textsubscript{11}, P2Y\textsubscript{12}) receptors are known to play a role in sensing chemical guidance cues. As the process of chemical guidance (chemotaxis) has similarities with the process of electrical guidance (galvanotaxis), it is possible that purinergic receptors play a role in sensing electric guidance cues.

**Methods.** Keratinocytes will migrate directionally towards the cathode of an applied physiological EF of 100mV/mm in vitro. We performed a series of one hour experiments, in the presence and absence of P2 agonists and antagonists, to determine if nucleotides play a role in initiating and sustaining keratinocyte galvanotaxis.

**Results.** Keratinocytes were treated with the non-specific P2 receptor antagonist, suramin, at the time of EF application. In the presence of suramin (10\textmu M), keratinocytes were incapable of detecting the applied EF, for the duration of the one-hour experiments, and migrated randomly. The application of apyrase (3.2U/ml), which will break down any ATP released from the keratinocytes, or the addition of exogenous ATP (100\textmu M) also decreased
galvanotaxis by 60% and 70%, respectively, while having no effect on migration speed. It appears, therefore, that P2 receptors play a role in the sensing of electrical cues.

To determine if P2X receptors play a role in keratinocyte electric guidance, experiments were initially performed in the presence of a P2X selective antagonist, isoPPADS. IsoPPADS (10µM) decreased keratinocyte galvanotaxis by 80% suggesting the involvement of P2X receptors in sensing electric guidance cues. To determine the identity of the P2X receptors that play a role in keratinocyte galvanotaxis, experiments were performed in the presence of a P2X₁ and P2X₃ selective agonist, αβ Me-ATP. αβ Me-ATP (1µM) decreased galvanotaxis by 74%, suggesting the involvement of P2X₁ and/or P2X₃ in keratinocyte galvanotaxis. Furthermore, a potent P2X₁ receptor antagonist, NF449 (100nM), also decreased galvanotaxis by 32%, while having no effect on migratory speed. It is likely, therefore, that P2X₁ plays a role in sensing electric guidance cues.

Purinergic receptors differ in their ability to respond to uridine and adenosine nucleotides and the potency of the nucleotide agonists can help to distinguish between receptor subtypes. UTP (100µM), UDP (100µM) and ADP (100µM) all decreased galvanotaxis within 30 minutes of EF application by 64%, 55% and 76%, respectively, while having no effect on migratory speed. The ability of UDP to reduce keratinocyte galvanotaxis supports the mechanistic involvement of one or more P2Y receptors, as it is not a P2X receptor agonist. Hopefully, future experiments with P2Y receptor-specific antagonists will reveal their identity.

Conclusions. In conclusion, it appears that the ability to sense the electric field guidance cue requires the nucleotide-mediated activation of both P2X and P2Y receptors to initiate and sustain keratinocyte galvanotaxis. Further characterisation will identify the purinergic receptors that play a role in sensing electrical guidance cues.

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that SVZ cells become reactive in response to different pathological cues, like trauma, ischemia, neurodegeneration, inflammation and demyelination (Nait-Oumesmar B., et al., 2007). Neurodegenerative diseases induce a substantial up-regulation or down-regulation of SVZ progenitor cell proliferation, depending on the type of disorder. Far from being a dormant layer, the SVZ responds to neurodegenerative disease in a way that makes it a potential target for therapeutic intervention (Curtis M.A., et al., 2007). Previous reports showed that exposure to Low Frequency Electromagnetic Fields (LFEMF) plays a key role in promoting the neuronal differentiation of neural stem/progenitor cells (NSCs) (Piacentini R., et al., 2007). By other side, several in vitro studies have established that LFEMF exposure induces biological changes that include effects increasing enzyme reaction rates in eukaryotic cells (Goodman and Blank, 2002) and catecholamine release in SVZ cells (Arias-Carrion et al., 2006).

**Objectives.** In this way, the aim of the present work was to determine the effect of LFEMF on primary cultures of rat SVZ cells over both cellular catecholamine release and apoptosis.

**Methods.** SVZ primary cultures were done using the SVZ of 75 g male Wistar rats. SVZ cells were exposed for 10 days, 4 hours per day (2 in the morning and 2 in the afternoon), to 60 Hz and 0.7 mT. Two control groups were done: 1) SVZ cells without treatment and 2) SVZ cells exposed to sham LFEMF. Culture media was analyzed for catecholamine content using HPLC-ED detection. Twenty microliters of sample were injected for analysis using a Rheodyne 712S autoinjector. Electrochemical detection was performed using a BAS 4C detector (EDC) prototype .65V vs Ag/AgCl, glassy carbon electrode. Gilson pump provided a flow rate of 1mL/min through the column and guard columns (nucleosil 100 (C18) 5 µ 150 X 4.6mm). Catecholamine assays were established after exposing SVZ cells for 5, 7, and 9 days to LFEMF. Apoptosis was evaluated using the TdT-mediated dUTP nick end labelling (TUNEL) method of in-situ labeling.

**Results.** Our results showed a two fold significant increase on SVZ noradrenaline release after both 5 and 9 culture days with LFEMF stimulation. Dopamine release did no showed significant differences during LFEMF treatment. Meanwhile, adrenaline was significant released (three folds) to the culture medium after 5 days of cellular culture; after that, on day 9 a 0.5 fold significant decrease was observed on adrenaline releasing of the LFEMF group. Serotonin was measured also by HPLC-ED and at day 5 (one fold), 7 (two folds) and 9 (one fold), significant differences were observed on SVZ cells exposed to electromagnetic fields. All the observed results have statistical analysis. Apoptotic results showed us significant differences between control and both sham LFEMF and LFEMF groups. When SVZ cells were exposed to LFEMF, 7.7% more of the cells were on an apoptotic stage, compared versus the control group. This finding is very interesting for us due the observed releasing increase on noradrenaline, adrenaline and serotonin.

**Conclusions.** Our results indicate that 1) Despite the fact that there are more apoptotic SVZ cells on our primary cultures, the surviving SVZ cells exposed to LFEMF suffer changes on specific catecholamine release after 10 days of treatment. 2) SVZ cells release more noradrenaline, adrenaline and serotonin after exposition to LFEMF; main observed differences were observed after 20 hours of electromagnetic treatment, and then after another 8 hours
of exposition. 3) SVZ cells presented specific changes at specific window times of LFEMF exposition.

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**6-3 STRONG STATIC MAGNETIC FIELDS AFFECT INSULIN-SECRETING CELLS**

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**Summary of Abstract.** The magnetic flux density of MRI for clinical diagnosis has recently become much higher. However, there remains very little biological data regarding the effect of strong static magnetic fields (SMFs) on human health. To evaluate the effects of strong SMFs on biological systems, we cultured insulin-secreting cells under exposure to sham and SMF conditions (3 to 10 T of magnetic flux density, and 0 to 41.7 T/m of magnetic field gradient) for 0.5 or 1 h, and analyzed insulin secretion and mRNA expression. Exposure to SMF with a high magnetic field gradient for 1 h significantly increased insulin secretion and insulin 1 mRNA expression. Our results suggested that MRI systems with higher magnetic flux density might not cause functional damages, and SMF with high magnetic field gradient might have a potential for the application of clinical use.

**Objectives.** The magnetic flux density of MRI for clinical diagnosis has recently become much higher. However, there remains very little biological data regarding the effect of strong static magnetic fields (SMFs) on human health. In this study, we evaluated the effects of exposure to strong SMFs on insulin-secreting cells.

**Methods.** Rat derived insulin-secreting cell line, INS-1, was cultured in RPMI 1640 medium supplemented with 10%FBS, 10 mM HEPES, 1 mM sodium pyruvate, 50 μM 2-mercaptoethanol, 100 U/mL of penicillin, and 100 μg/mL of streptomycin under exposure to sham and SMF conditions (3 to 10 T of magnetic flux density, and 0 to 41.7 T/m of magnetic field gradient) for 0.5 or 1 h, and analyzed insulin secretion and mRNA expression in INS-1 cells. For insulin secretion analysis, cells were seeded on 4-well-MultiDishes (Nalge Nunc No. 176740) at a density of 7.5 × 10⁴ cells/cm². After cells were washed once with fresh medium, the culture medium was changed to another 0.5 mL/well of fresh medium. After exposure, aliquot of culture medium was collected and insulin concentration was measured by ELISA kit. Insulin secretion was standardized to the cell number, which was counted by a cell and particle counter (COULTER Z1; Beckmann Coulter Inc.). For mRNA expression analysis, cells were seeded on 4-well-MultiDishes at a density of 1.5 × 10⁵ cells/cm². After exposure, cells were scraped and total RNA was isolated using an RNeasy® Mini kit (QIAGEN). cDNA synthesis was performed using random hexamers as primers and ExScript® RTase (TaKaRa Bio). Semi-quantitative PCR
was performed using a SYBER® Premix Ex Taq® kit (TaKaRa Bio) and a Smart Cycler® II System (Cepheid). β–Actin and GAPDH expression were used to normalize the amount of template cDNA in the semi-quantitative PCR reaction.

**Results.** Exposure to SMF for 1 h at the 6 T position increased insulin secretion significantly during the exposure. At the 3 T position, insulin secretion was slightly, but not significantly, increased by exposure for 1 h. At the 10 T position, exposure to SMF did not affect insulin secretion. As to mRNA expression, a significant increase in insulin 1 mRNA expression was detected after SMF exposure for 1 h at the 6 T position. A slight but not significant increase in insulin 2 mRNA expression was observed after SMF exposure for 1 h at the 6 T position. A slight but not significant increase in ins1 mRNA expression was observed after SMF exposure for 1 h at the 3 T position.

**Conclusions.** Exposure to strong SMFs increased insulin secretion from insulin-secreting cells. MRI systems with higher magnetic flux density might not cause functional damages, and SMF with high magnetic field gradient might have a potential for the application of clinical use.

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**6-4 EFFECT OF 100 MT STATIC MAGNETIC FIELD ON \([Ca^{2+}]_c\) RESPONSE TO ATP IN HL-60 CELLS FOLLOWING GSH DEPLETION**

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**Summary of Abstract.** Calcium is important to many biological systems, including systems where signal transduction cascades involve molecules such as ATP. Activation of surface receptors by ATP can lead to increased cytosolic free calcium ([Ca\(^{2+}\)]\(_c\)) levels through emptying of intracellular calcium stores. Changes in [Ca\(^{2+}\)]\(_c\) can be influenced by external factors such as exposure to a static magnetic field (SMF). One hypothesis suggests that SMF exposure affects the cell through an action on free radicals. By reducing the number of antioxidant molecules like glutathione (GSH) the proportion of free radicals in the cell is increased and may lead to a greater probability of a biological response to a SMF.

**Objectives.** The purpose of this study was to determine if the [Ca\(^{2+}\)]\(_c\) response to ATP was affected by depletion of GSH by diethylmaleate (DEM) and the absence or presence of a 100 mT SMF.
Methods. Undifferentiated HL-60 cells were loaded with Fura-2 AM and placed in a disposable cuvette. The cuvette was placed between the poles of a toroidal magnet within a circulating water bath. \([\text{Ca}^{2+}]_c\) was measured in real time using a ratiometric fluorescence spectroscopy system. Cells were acclimatized to the 37°C bath environment at a SMF strength of 0 mT for 1200 s prior to any experimental manipulation. At 1200 s, 24 µl of Diethylmaleate (DEM) was added directly to the cuvette to achieve final concentrations of 1 mM, 7.5 mM, 8.5 mM, 9 mM, 9.5 mM, 10 mM, 12 mM, or 15 mM. At 2700 s, the magnetic field either remained unchanged (i.e. 0 mT, sham), or was increased to 100 mT. At 3000 s, 10 µl of ATP was added to reach a final cuvette concentration of 1 µM followed by return of the magnetic field to 0 mT at 3480 s. The Fura-2 AM signal was calibrated using BR-A23187 and EGTA to obtain the \([\text{Ca}^{2+}]_c\). Four metrics were obtained from each \([\text{Ca}^{2+}]_c\) time series: (1) the average \([\text{Ca}^{2+}]_c\) before the addition of DEM, (2) the average \([\text{Ca}^{2+}]_c\) before onset of SMF, (3) the average \([\text{Ca}^{2+}]_c\) after the onset of SMF, but before ATP, (4) the peak \([\text{Ca}^{2+}]_c\) after ATP, and (5) the full width, half maximum (FWHM) of the \([\text{Ca}^{2+}]_c\) response to ATP. Five to eight replicates of sham and 5 - 8 replicates of 100 mT SMF exposed conditions were performed for each [DEM]. Statistical analysis was by ANOVA.

Results. In HL-60 cells, \([\text{Ca}^{2+}]_c\) was elevated following treatment with DEM with greater \([\text{Ca}^{2+}]_c\) at higher concentrations of DEM. The observed increases in \([\text{Ca}^{2+}]_c\) due to DEM was statistically significant (P < 0.001). The \([\text{Ca}^{2+}]_c\) response to ATP was significantly decreased as the DEM concentration increased (P < 0.001). However, there was no effect of the 100 mT SMF on the peak or FWHM of the \([\text{Ca}^{2+}]_c\) response to ATP (P > 0.6 and P > 0.4 respectively).

Conclusions. The results of this study showed that by increasing the concentration of DEM and thereby decreasing GSH, a significant increase in the level of \([\text{Ca}^{2+}]_c\) could be detected in real-time. It has been hypothesized that the increase in \([\text{Ca}^{2+}]_c\) following depletion of GSH results from the emptying of intracellular stores. Our observations support this hypothesis. We observed that as the concentration of DEM increased, the peak in the \([\text{Ca}^{2+}]_c\) response to 1 µM ATP decreased. This may have been due to a smaller release of calcium from intracellular stores, faster transport of calcium out of the cytoplasm, or a combination of the both mechanisms. The results also demonstrated that exposure to a SMF at 100 mT does not affect calcium homeostasis or the calcium response to ATP at any of the [DEM] examined. This finding suggested that the 100 mT SMF did not act on HL-60 cells through a free radical mechanism that involved the action of signaling pathways in control of calcium release from intracellular stores or removal of calcium from the cytoplasm. Since the action of SMF on free radicals is known in other systems to be highly dependant on flux density, future work could expand the experiments described here to include SMF flux densities both below and above 100 mT.

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6-5 GERMAN MOBILE TELECOMMUNICATION RESEARCH PROGRAMME: GENE REGULATION AT THE BLOOD BRAIN BARRIER IN VITRO FOLLOWING RF-EMF EXPOSURE

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Summary of Abstract. This study investigated the influence of RF-EMF on the blood-brain barrier of the rat in vitro. Differential gene expression was examined with genechip arrays and quantitative RT-PCR. We could identify several genes that were either up- or down regulated following EMF exposure and suggest them as potential candidates for further investigations.

Objectives. We have previously reported on the lack of effects of RF-EMF according to UMTS or GSM standards on the blood-brain barrier in vitro. As those studies focussed on selected parameters such as tight-junction proteins and barrier properties we aimed to extend the view by applying an hypothesis free approach. Therefore the focus of the actual study was to determine alterations in gene expression at the BBB in vitro following RF-EMF exposure in order to gain new insight in potential molecular targets and involved pathways affected due to RF-radiation.

Methods. Primary cultures of microvascular rat brain endothelial cells (RBEC) grown on Petri-Dishes were used as in vitro model of the BBB. These cell cultures were permanently exposed to either a generic GSM1800 or UMTS-signal for 72 hours. Four different SAR levels (0.4, 1.0, 3.0 and 8.0 W/kg) were applied consecutively with sham exposed controls performed in parallel experiments. For this purpose two radial waveguides were used, each allowing exposure or sham-exposure of the RBEC samples. Temperature of the cell culture medium and the field strength were permanently monitored during exposure. Positive controls were introduced by heating cell cultures to 38°C and to 40°C without EMF exposure for the same time. Immediately after exposure, the RNA was extracted from each individual cell sample using the Qiagen RNeasy Micro Kit, stored at -80°C and later hybridised onto the Affymetrix GeneChip® Rat Genome 230 2.0 Array. Quality control of RNA samples was carried out on Agilent Bioanalyzer LabChip-Kits. Data obtained after scanning the gene chips are evaluated statistically by means of bioinformatics software tools. Up- or down regulation of genes was quantified and the regulation of selected genes was additionally verified by quantitative real time RT-PCR on TaqMan® low density microarrays.

Results. An in vitro model of the BBB derived from rat brain endothelial cells was successfully established and characterized. After the exposure device was set up we could start exposing RBEC cultures to UMTS or GSM1800 RF-EMF. The exposure was typically started 5 days after isolation of the cells and continued permanently for 72h. The integrity of each cell monolayer could be verified by examination under a phase contrast microscope prior and after exposure. An excellent quality of the generated RNA samples was confirmed by RIN (RNA integrity number) values ranging from 8-10, mostly being close or equal to 10. RNA quantity was sufficient to conduct the genechip analysis without further amplification. Temperature surveillance revealed a negligible heating effect for the lower
SARs whereas exposure at 8 W/kg elevated the culture medium temperature to 38°C. For this reason we decided to include an additional control group of cells maintained at 38°C but without RF-exposure. Signal intensities from the chip arrays were processed and normalized by the MAS 5.0 algorithm and the evaluation of genechip data revealed lists of genes, that were at least 2-fold up- or down regulated at one or more exposure intensities but not in the positive controls. Using TaqMan® low density arrays we could select 47 genes from each group (UMTS and GSM) for qRT-PCR verification of the results from the genechip analysis. Although one third of these genes were present in both groups, the qRT-PCR experiments confirmed a significant regulation for 21 different genes, 14 in the UMTS group and 7 in the GSM1800 group.

Conclusions. In the present study we examined the influence of radio frequency electromagnetic fields emitted by mobile phones on the blood-brain barrier by screening for differential gene expression with chip arrays and quantitative PCR. By choosing this approach instead of selecting a hypothesis that had to be proven, we identified targets that can now serve as a basis that supports new hypotheses addressing functions of the proteins that are codes by the genes we could identify here. The goal of this study was to gain information on potential targets for interactions of a biological system (the BBB, which is frequently discussed in this context) and RF-EMF. Thus our results are actually only referring to the gene expression level of a cell culture from murine origin it is not correct to interpret these findings as a proof for adverse health effects on humans, which should be emphasized here.

Acknowledgements. This study is part of the German Mobile Telecommunication Research Programme and we would like to acknowledge financial support by the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS).

6-6 IN VITRO STUDY OF THE EFFECTS OF ELF ON GENES EXPRESSION
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Summary of Abstract. An acceleration of the differentiation at the expend of the proliferation is observed after the application of low frequency and low amplitude electromagnetic fields on various biological models. Following these biological results showing significant modifications we try to identify the biological mechanism involved at the cell level through the microarray screening. For this study, we use keratinocytes cultures harvested from human abdominoplasty. Two platinum electrodes are used to apply the electric signal. The application of ELF on keratinocytes cells produces a modification of the genes expression.
The results are in agreement with the already observed, an acceleration of the cell differentiation at the expend of the cell proliferation. The results obtained are also compared with current knowledge in Acute Lymphoblastic Leukaemia (ALL) characteristics.

**Objectives.** Our laboratory observed biological responses to the application of low frequency and low amplitude electromagnetic fields on various models of growing or healing bones tissues\(^{(1)}\)(\(^{(2)}\). The response to the low frequency electromagnetic fields for every model is an acceleration of the differentiation at the expend of the proliferation. Presently we use culture of keratinocytes on a deepidermized human dermis on air-liquid interface (very similar to *in vivo* physiological epidermic growth). Two platinum electrodes are used to apply the electric signal. This model of epidermal repair and electric signal provides simplified and well characterized substrate to study the biological effects of electromagnetic stimulation. The previous results on this model \(^{(3)}\) are the same than those obtained on the bones models.

Following these biological results, we try to identify the biological mechanism involved at the cell level through the microarray screening.

**Methods.** The keratinocytes cultures are harvested from human abdominoplasty. Decellularized dermis is used as supports. Wagner’s dermatome and punch biopsy are used to prepare the 3mm explants of epidermis placed on the dermic support. The model is completed by the culture medium and foam on which lies the dermic support. Two platinum electrodes are used to apply the electric signal. A part of samples was exposed daily to electrical field and the other part serve as control. All Petri dishes are put in the same incubator \((37^\circ\text{C}, 5\% \text{ CO}_2)\).

The output of the stimulating generator consists in an impulse charge balanced signal, with a frequency of 40Hz, the current amplitude is 20mA maximum, the stimulus is repeated during 4s followed by 4s break, 40min every day during 11 days.

Eighty-four explants of the same patient are distributed on 14 dermal supports. We realized 5 controls sampling at J\(_{-3}\), J1, J4, J7 and J12 and 3 stimulated sampling at J4, J7 and J12. The totRNA is extracted with a rotor-stator and a Qiagen\textsuperscript{®} extraction kit. We analyse the genes expressions with Affymetrix\textsuperscript{®} microarray U133 Plus 2.0 chips. We repeated the protocol on 3 different patients.

**Results.** We compare the expression of the stimulated (stim) and control group at different period. We obtain by making a t-test \((p\leq 0.05 \text{ and } 2\leq \text{Fold Change(FC)}\leq -2)\) on:

- J4 stim vs J1 control, 39 up and 265 down regulated genes
- J7 stim vs J1 control, 30 up and 190 down regulated genes
- J12stim vs J1 control, 237 up and 259 down regulated genes
- J4 stim vs J4 control, 315 up and 626 down regulated genes
- J7 stim vs J7 control, 228 up and 397 down regulated genes
- J12stim vs J12 control, 441 up and 505 down regulated genes

If we compare the genes list significantly up and down regulated \((p\leq 0.05 \text{ and } 2\leq \text{FC}\leq -2)\) of the 3 stimulated times compared with their 3 respective controls, we find only 3 genes up regulated present during all the experimental procedure:

- Thioredoxin Reductase 1 (TXNRD1):
  play a role in the diminution of the proliferation in embryo
- Activating Transcription Factor 3 (ATF3): increased concentration in the process of differentiation of the chondrocytes
- Membrane Metallo-Endopeptidase (MME): stop mitosis in G1 phase, play a role in diminution of the proliferation

A further comparison of the genes list of J4 stimulated vs J4 control, shows that one gene of the up regulated list is Dickkopf Homolog 1 (DKK1)(FC=4.42 p=0.01). DKK1 is regulated by SAPK/JNK Signaling Cascades. The SAPK/JNK is activated by a variety of environmental stresses, inflammatory cytokines and growth factors. DKK1 play a role in the negative regulation of Wnt receptor signalling pathway and the effect of the Wnt down regulation was a reduction of cell proliferation (4) and an induction of terminal cell differentiation (5)(6).

In the literature, some paper analysed a possible effect of the EMF on infantile leukaemia. The most frequent leukaemia in the child is the Acute Lymphoblastic Leukaemia (ALL). Several papers treating of this subject indicate in the ALL an activation of WNT signalling pathway (7) and an increase in the concentration of β-catenin (8). Other articles speak about the inhibition of the WNT signaling pathway as "an attractive target for the use of more specific therapies..." (9). In our result the β-catenin present in the WNT Signaling Pathway and the WNT Signaling pathway are inhibited with the presence of DKK1.

Conclusions. The application of our impulsed ELF signal by platinum electrodes on keratinocytes cells involves a modification of the genes expression.

The analyze of the gene expression at the 3 stimulated times compared with their 3 respective controls shows only 3 up regulated genes playing a part in cell proliferation and differentiation.

With is negative regulation on the Wnt pathway, the up regulation of the DKK1 expression is also in agreement with a reduction of cell proliferation and an induction of cell differentiation. SAPK/JNK regulated DKK1 expression and is activated by a variety of stress receiver. An ELF receiver could complete these categories.

In the Acute Lymphoblastic Leukaemia, the concentration of β-catenin and the activation of WNT Signaling Pathway seems increased. In our result the β-catenin present in the WNT Signaling Pathway and the WNT Signaling pathway are inhibited with the presence of DKK1.

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6-7 ANALYSIS OF GENE EXPRESSION IN TWO HUMAN-DERIVED CELL LINES EXPOSED IN VITRO TO A 1.9 GHZ PULSE-MODULATED RADIOFREQUENCY FIELD


Summary of Abstract. Increasing usage of cellular phones and their growing presence in our lives have aroused much public concern as to potential health risks associated with the radiofrequency (RF) fields emitted by these devices. Reports of associations between RF fields and cancer rates have created widespread concern among the public and prompted researchers to examine further the biological effects associated with exposure to RF fields. Clearly, it remains critical to resolve discrepancies in the existing literature to identify any potentially adverse biological changes that result from RF field exposure in order to prevent human health consequences before they arise. In the present study, we employed high-throughput DNA microarray analysis to investigate potential responsive genes in two human-derived cell lines after 1.9 GHz RF field exposure.

Objectives. The objectives of this study were to: 1) explore for possible late responding genes in human glioblastoma-derived (U87MG) cells at 6 h following a 24 h exposure to continuous 1.9 GHz pulse-modulated RF fields, and 2) investigate whether intermittent (5 min ON, 10 min OFF) RF fields could influence gene expression in human monocyte-derived (MM6) cells.

Methods. Cell culture: U87MG and MM6 cells were cultured in RPMI 1640 media supplemented with 10% fetal bovine serum, 2 mM L-glutamine, 100 U/mL penicillin and 100 µg/mL streptomycin. When the cultures were approximately 70% confluent, they were exposed to sham, RF, positive (heat-shock) control, or negative (incubator) control conditions. RF field exposure: Six circularly polarized cylindrical waveguides were used to expose the cell culture samples to 1.9 GHz pulse-modulated (50 Hz, 1/3 duty cycle) RF fields. U87MG cells were exposed for 24 h at mean SARs of 0 (sham), 0.1, 1.0 and 10.0 W/kg, while MM6 cells were exposed for 6 h at mean SARs of 0 (sham), 1.0 and 10.0 W/kg. Within the sample region, the maximum to minimum SAR ratio was approximately 4:1, while the SAR distribution in the plane of the cells was estimated to be ±24% of the mean SAR established for each RF treatment group. Temperature within the cell cultures was monitored at 60s intervals during RF exposure using non-perturbing thermistor probes. Both negative (incubator) and positive (heat-shock, 43oC) controls were run in conjunction with each of the five independent experiments.

RNA extraction/hybridization and microarray analysis: RNA was preserved using RNAeasy Minikit’s, according to the manufacturer’s instructions (Qiagen Inc.). An Agilent 2100 Bioanalyzer and a spectrophotometer (A260:A280) were used to assess RNA quality and
concentration for each sample. All samples included for analysis were determined to be of high quality RNA (OD260/280 = 1.8 - 2.1). Low RNA Input Fluorescent Linear Amplification Kits (Agilent) were used to generate fluorescently (Cy3)-labeled cRNA, which was subsequently hybridized to Agilent Human 1A (V2) oligonucleotide 22K microarray slides according to the manufacturer’s instructions.

Microarray Scanning and Data Analysis: Microarray slides were scanned using a Scan Array 5000 confocal scanner and ImaGene 6.0 (Biodiscoveries Inc) was used to quantify the 16-bit greyscale image files. The image files were read into SAS 9.1.3 (SAS Institute Inc), the background noise adjusted and the signal intensity data were then transformed in R using the variance-stabilization and normalization (VSN) method. The data were globally normalized using a mixed model following Wolfinger et al. (2001). The residuals from the mixed effect model were then treated as the normalized expression values and were analysed using the Microarray Analysis of Variance (MAANOVA) library in R. The James-Stein shrinkage estimator (Fs) F-test was used to test for an overall treatment effect. In this analysis the p-values for the Fs test was based on 10,000 permutations using residual shuffling. The Fs F-test p-values were then adjusted for the false discovery rate (FDR). Contrasts between the sham and other treatment groups in each analysis were conducted using the Fs testing procedure. The least square means were then used to estimate the fold change for each contrast that was tested. Differentially expressed genes were those that were significant (p < 0.05) by MAANOVA, present in at least 3 of 30 microarrays for U87MG cells and 3 of 47 microarrays for MM6 cells, and had a minimum fold change of ±1.35.

Results. A total of 30 independent hybridizations were performed on non-pooled RNA for U87MG cells, while 47 independent hybridizations were performed on non-pooled RNA for MM6 cells. Under these conditions, a relatively large number of independent biological replicates were included to reduce the probability of aberrant false-positive events resulting from chance and/or slight differences in culture conditions. Under the experimental conditions used in this study, we found no evidence that non-thermalizing 1.9 GHz RF field exposure affected gene expression in cultured U87MG cells at 6 h following a 24 h exposure or in MM6 cells immediately following a 6 h exposure or 18h post exposure, relative to the sham- or negative (incubator)-control groups. As with our previous study, the current study also included a positive heat-shock control group in our experimental design. Gene expression changes in this treatment group revealed changes in expression of a number of genes when compared to the sham- and negative (incubator)-control groups. For the U87MG cell-line, RT-PCR confirmed an increased expression of HSP27, HSP40, HSP70, HSP90 and HSP105 in the positive (heat-shock) control group, but also the lack of response in the RF-exposed groups relative to the sham control group. In the MM6 cell-line, HSP27 and HSP70 along with the proto-oncogenes c-fos, and c-jun were shown to be upregulated in the positive control group relative to the untreated controls.

Conclusions. In conclusion, we found no significant changes in gene expression in glioblastoma or monocytic cells resulting from 1.9 GHz RF field exposures. The data obtained from this study support our previous results where we found no evidence of altered gene expression at 6 h following a 4 h exposure of U87MG cells to RF fields. Future well designed
in vivo genomics and proteomics studies will assist in the ongoing evaluation of possible non-thermal bio-effects from RF field exposure.

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**6-8 EFFECTS ON BRAIN BLOOD BARRIER AND HEAT SHOCK PROTEINS OF WISTAR-HAN RATS EXPOSED HEAD-ONLY TO GSM-1800 OR UMTS SIGNALS.**

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**Summary of Abstract.** The occurrence of blood-brain barrier (BBB) damage and heat shock protein (HSP) expression in Wistar rats were tested immediately and 50 days after 4-week repeated head-only exposures to mobile telephony signals (GSM-1800 or UMTS) at different brain-averaged SAR (BASAR): 0.026-13 W/kg. Limited significant increases in BBB permeation were recorded mainly at the highest BASAR levels (50 days after repeated exposure). Experiments on HSP expression in the rat brain are on-going.

**Objectives.** The Swedish group of Salford (Salford et al. Environnemental Health Perspectives, 2003) reported the occurrence of brain damage, 50 days after a single 2-hour exposure of rats to a mobile telephony GSM-900 signal. However, new signals for mobile communication are being developed and their health effects have to be assessed. As part of the German Federal Ministry for Environment, Nature Protection and Reactor Safety project (BfS project), we investigated the effects of GSM-1800 and UMTS on BBB and dark neurons in rats. In this specific study, we describe the impact of repeated (2 hours/day, 5 days/week, 4 weeks) exposures to these signals on rat BBB and expression of heat shock proteins (HSP-25 and HSP-70).

**Methods.** Exposure and dosimetry: the characterization of the BASAR was performed at GSM-1800 and UMTS frequencies by experimental measurements and numerical simulations (FDTD), using head-only exposure to the loop antenna (Leveque et al. IEEE MTT, 2004).

Biological system and experiments: 6-week-old male Wistar rats (200-225 g) were housed under controlled temperature (22°C) and lighting conditions. After a one-week acclimation period, and progressive training to the rocket-type exposure setup during one week, rats were exposed repeatedly (2 hours/day, 5 days/week, 4 weeks). Four BASAR levels were used: 0.026, 0.26, 2.6, and 13 W/kg. Sham-exposed rats (restrained in a rocket), cage controls, and positive controls (cold-shock) were included in the protocol. The tested
time-points were performed immediately, and 50 days after exposure. Rats were ethically euthanized using isoflurane inhalation. The brains were fixed by intracardiac perfusion using a paraformaldehyde solution and frozen. To ensure blinding of the analysis, brains were coded before slicing. Serial 10-µm-thick brain sections were prepared from 3 different brain regions (between bregma -0.80 and -1.20 mm; -4.00 and -4.80 mm; -8.00 mm and -8.80 mm). Biological parameters: The BBB permeation was assessed by endogenous albumin leakage detection. Briefly, quenching of endogenous peroxidase was done with H2O2. Tissue sections were incubated with an anti-human albumin antibody (Dakocytomation) and revealed using an indirect immunoperoxidase method (Vectastain ABC kit, Abcys®). Endogenous albumin leakage around the vessels was counted for each brain zone (frontal Z1, median Z2 and posterior Z3). For HSP measurements, the sections were immunohistochemically stained with antibodies raised against Hsp25 and Hsp70. Pictures analysis was performed on the 3 brain zones in 12 different brain regions (Z1: the motor cortex and the medial forebrain bundle, Z2: the retrosplenial cortex, the auditory cortex, the cortical amygdaloid nucleus, the Cornu Ammonis field 1 (CA1), the Cornu Ammonis field 2 (CA2), the Cornu Ammonis field 3 (CA3), and the Dentate Gyrus (DG), and Z3: the dorsomedial periaqueductal gray, the retrosplenial cortex, and the Pontine nuclei using the Aphelion image software (ADCIS SA).

Statistics: For each exposure condition, two successive series of 8 rats per exposure condition (n=16 rats) were used allowing the detection of a significant difference (p<0.05) of 35%. Statistical analysis was made using the Kruskal–Wallis test with correction for multiple comparisons.

Results. The occurrence of BBB leakage in rodents was investigated up to 50 days after repeated exposures (2 hours/day; 5 days/week; 4 weeks) to RFR. Repeated exposures to GSM-1800 induced increases in BBB permeability 50 days after last exposure. BBB permeation was detected at 0.026 W/kg (1 brain zone) and 13 W/kg (all brain zones). No dose response was found. After a repeated exposure to UMTS, BBB permeation was sparse (0.26 W/kg, two zones of three brain zones) and reversible in the rat brain. No dose-response was found.

Globally, experimental conditions showing significant increased endogenous albumin leakage remained limited (in 12.5% of experimental conditions). However, it should be noted that the most pronounced effect after exposure to 13 W/kg GSM-1800 was comparable to the highest background level found in cage control rats. Measurements of Hsp-25 and Hsp-70 expression after exposure to 13 W/kg GSM-1800 or UMTS signals are currently in progress, and complementary results will be presented at the meeting.

Conclusions. The overall conclusion is that physio-pathological consequences are unlikely after repeated exposure to GSM-1800 and UMTS, at BASAR levels up to 13 W/kg. Moreover, dosimetric calculations showed that the maximum SAR in the periphery of the rat brain is ca. twice that value i.e. 26 W/kg. Extrapolation to the human situation gives a SAR(10 g) of ca. 50 W/kg, which is much larger than the 2 W/kg SAR(10 g) exposure limit but twice lower than the critical effect as defined by ICNIRP. These findings need to be confirmed and mechanistic hypotheses further investigated.
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Wednesday

PLENARY 5: BENCH TO BEDSIDE II: FIBROMYALGIA, BONE HEALING

P5-1 FIBROMYALGIA; ITS DIAGNOSIS AND PHARMACOLOGICAL TREATMENT

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Summary of Abstract. Fibromyalgia is the most common, diffuse chronic pain with stiffness and fatigue, more common in women than men, with a peak incidence at ages 40-60. According to the American College of Rheumatology 1990 criteria for definition, pain must be widespread in four quadrants of the body, such as in the right and left sides as well as above and below the waist, as well as axial (spine and chest) skeletal pain. Furthermore, digital palpation with about 4 kg pressure must identify at least 11 tender sites among 18 specific points.
Etiology of fibromyalgia is unknown; however, it is strongly associated with a low pain threshold and with poor, light, fragmented sleep. No single diagnostic test exists. Diagnosis is based on clinical findings and by excluding other conditions. Once diagnosed, patient education and reassurance are important, emphasizing that fibromyalgia is neither a psychiatric nor a rare disorder.
Basic treatment is medication. Antidepressants and several other drugs are effective. Narcotics should be avoided and if used, should be tapered off and supported with education. Physical therapy is encouraged, especially aerobic exercises and stretching of shortened muscles.
P5-2 PULSED ELECTROMAGNETIC FIELDS FOR THE TREATMENT OF FIBROMYALGIA

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Summary of Abstract. Specific pulsed magnetic field (CNP) exposure has previously been used to induce antinociception (analgesia) in land snails (Cepeae nemoralis), mice, rats, human volunteers, and patients suffering from rheumatoid arthritis and fibromyalgia. Recently, a FDA clinical trial involving the CNP treatment of fibromyalgia sufferers (40 min twice per day) across the United States and Canada has reached the mid-point and the interim analysis is expected approximately Q3-2008 (www.fralex.com). Here we will also present some results from a recent fMR (BOLD) imaging study (also see presentation 8-1) showing the pathways activated or suppressed by CNP or Sham exposure while volunteer participants underwent acute thermal pain and functional magnetic resonance imaging. Significant changes were seen in the way the brain processes pain, particularly in the insula and anterior cingulate. The 15 min exposure to the CNP led to a reduced activation relative to pre-exposure and to sham in both brain regions. Functional imaging may prove to be a more sensitive tool to investigate the effect of magnetic fields on pain processing than subjective reports.

P5-3 FROM BENCH TO THE PATIENT: ORTHOPEDIC APPLICATIONS OF PULSED ELECTROMAGNETIC FIELDS

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Summary of Abstract. The development of modern EMF orthopedic applications was stimulated by the clinical problems associated with non-union and delayed union bone fractures. It started with the fundamental orthopedic question of how bone adaptively and structurally responds to mechanical input by suggesting that an electrical signal may be involved in the transduction of the mechanical signal to cellular activity. This naturally led to the suggestion that superimposing an exogenous EMF upon the endogenous fields accompanying normal cellular activity could help in the treatment of non unions and difficult fractures where delayed healing is likely. The first animal studies employed microampere level DC currents delivered via implanted electrodes. Remarkably, this resulted in new bone formation particularly around the cathode. As these studies progressed it became clear that the new bone growth resulted from the chemical changes around the electrodes caused by electrolysis. The first therapeutic devices were based on these early animal studies and used implanted and semi-invasive electrodes delivering DC to the fracture site. This was followed by the development of clinically preferable externally applied electromagnetic field modalities. Subsequent studies concentrated on the direct effects of electromagnetic
fields leading to modalities which provided a non-invasive, no-touch means of applying an electrical/mechanical signal to a cell/tissue target. Therapeutic uses of these technologies in orthopaedics have led to clinical applications, approved by regulatory bodies worldwide, for treatment of recalcitrant fractures and spine fusion and recently for osteoarthritis of the knee. Additional clinical indications for EMF have been reported in double blind studies for the treatment of avascular necrosis and tendinitis. This spectrum of applications clearly demonstrates the potential of this biophysical modality to enhance musculoskeletal tissue healing.

**Objectives.** Cellular studies: These have addressed effects of electromagnetic fields on both signal transduction pathways and growth factor synthesis. The important overall result from these studies is that EMF can stimulate the secretion of growth factors (e.g., insulin-like growth factor-II) after a short duration trigger stimulus. The clinical benefit to bone repair is enhanced production of growth factors upregulated as a result of the fracture trauma. The induced electric field thus acts as a triggering mechanism which modulates the normal process of molecular regulation of bone repair mediated by growth factors. Studies underlying this working model have shown effects on calcium ion transport, increase in cell proliferation and IGF-II; increased IGF-II receptor expression in osteoblasts; increases in IGF-I and II respectively have also been demonstrated in rat fracture callus. Stimulation of TGF-β mRNA with PEMF in a bone induction model in the rat has been reported. PEMF stimulated an increase in TGF-β1 in bone non-union cells. Using specific inhibitors suggests EMF acts through a calmodulin-dependent pathway. Acceleration of Ca+2 binding kinetics to CaM has been reported., as has been upregulation of mRNA for BMP2 and BMP4 with PEMF in osteoblast cultures, as well as upregulation of TGF-β in bone and cartilage with PEMF. There is substantial support for ion binding as the transduction pathway for PEMF effects. The latest studies suggest PEMF modulates the NO signaling pathway, which controls all of the stages of repair.

**Methods.** Animal Studies: A PEMF signal was first shown to accelerate bone repair by 150% in a canine tibial osteotomy model. A bilateral cortical hole defect model in the metacarpal bones in horses showed PEMF treated holes produced a statistically significant increase in amount of new bone formation and mineral apposition rate. A capacitively coupled signal was shown to prevent osteopenia due to both sciatic-denervation and castration in rat osteopenia models. PEMF inhibited bone loss in an ovariectomized canine model. Combined magnetic fields reversed osteopenia in ovariectomized rats. An avian ulna disuse model showed a significant increase in bone formation when treated with PEMF. The frequency dependence of EMF effects was also studied in this model. The results showed maximal response was observed with a 15 Hz sinusoidal waveform producing 10 μV/cm peak electric field in tissue. Experimental models of bone repair show enhanced cell proliferation, calcification, and increased mechanical strength with DC currents. Capacitive coupled fields have been reported to improve the mechanical strength of experimental fractures and healing osteotomies. Several studies with PEMF showed increased calcification and enhanced mechanical strength in healing bone. The mechanical strength of late phase osteotomy gap healing in the dog was stronger in PEMF treated limbs. PEMF increased
bone ingrowth into hydroxyapatite implants in cancellous bone. The use of in vivo micro-computed tomography showed PEMF reduced bone loss in a non-union fibular model in the rat by threefold.

**Results.** Clinical Studies: Electromagnetic stimulation modalities have been used clinically to treat fresh fractures, osteotomies, spine fusions, and delayed and nonunion fractures. The efficacy of EMF stimulation on bone repair has been studied in a formal meta-analysis. Twenty randomized control trials were identified. Fifteen trials supported EMF effectiveness and five failed to show effectiveness. Most studies used PEMF. In all cases, the primary outcome measure was bone healing assessed by radiographs and clinical stability test. Results from pooled trials of 765 cases supported the effectiveness of PEMF stimulation of bone repair. However, because of the inability to pool data from all studies, conclusions regarding PEMF efficacy in bone repair were only suggestive. PEMF significantly accelerated union of femoral and tibial osteotomies in randomized, placebo controlled studies by approximately 50%.

PEMF have been used to promote healing of spine fusions for the treatment of chronic back pain from worn or damaged intervertebral discs. This is measured by the increase in successful fusions from 50% to approximately 80% using EMF as adjunctive treatment. This application has also been subjected to meta-analysis. Five randomized, controlled trials and five nonrandomized case controlled studies showed positive results for the enhancement (by 60%) of spine fusion by electrical and electromagnetic stimulation. There are many studies and reviews which show electrical and electromagnetic stimulation is effective in promoting spinal arthrodesis. The effectiveness of EMF in promoting healing of recalcitrant fractures has been reviewed. Twenty-eight studies of ununited tibial fractures treated with PMF were compared with 14 studies of similar fractures treated with bone graft with or without internal fixation. The overall success rate for the surgical treatment of 569 ununited tibial fractures was 82%, while that for PMF treatment of 1718 ununited tibial fractures was 81%, suggesting it is significantly more advantageous for the patient to use PEMF rather than submit to invasive surgery for the first bone graft. There are several observational studies suggesting the efficacy of PEMF techniques in stimulating healing of delayed unions and nonunions. Finally, there are a promising studies on the effects of PEMF on distraction osteogenesis for the correction of bone length discrepancies.

**Conclusions.** PEMF modalities now constitute part of the standard armamentarium of orthopaedic clinical practice. Since the success rate for these modalities has been reported equivalent to that for the first bone graft, a huge advantage to the patient ensues because PEMF therapy is non-invasive and is performed on an out-patient basis. PEMF therapy also provides significant reductions in the cost of health care since no operative procedures or hospital stays are involved. This also applies for the increased success rate of spinal fusions with EMF. Thus, the clinical effects of EMF on hard tissue repair are physiologically significant and often constitute the method of choice when standard of care has failed to produce adequate clinical results. It is interesting to note that EMF may be the best modulator of the release of the growth factors specific to each stage of bone repair, certainly more so than the exogenous application of the same growth factors. PEMF technology is advancing rapidly as its mechanism of action is better understood. As a result, extension
to PEMF treatment of arthritis, osteoporosis and other pathologies such as wound repair, neurodegenerative and cardiac diseases is proceeding at a rapid pace.
Session 07: Dosimetry I

7-1 COMPUTATIONAL COMPARISON OF THE SAM PHANTOM TO ANATOMICALLY CORRECT MODELS OF THE HUMAN HEAD AT 300, 450, 2450, 3500, AND 5800 MHZ

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Summary of Abstract. Present mobile phone compliance testing with respect to human RF exposure limits (IEEE C95.1-1999 and IEEE C95.1-2005 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields from to 3 kHz to 300 GHz and International Commission on Non-Ionizing Radiation Protection (ICNIRP) 1998 Guidelines for Limiting Electrical, Magnetic, and Electromagnetic Fields (Up to 300 GHz)) requires Specific Absorption Rate (SAR) measurements in a human phantom exposed in the near-field of the device under test in predefined positions in the RF frequency range up to 6 GHz. The Specific Anthropomorphic Mannequin (SAM) phantom, as defined in the current standards (IEEE Std 1528-2003 and IEC 62209 Part 1-2005), was developed to provide conservative SAR estimates while enabling practical SAR measurement procedures. Recently, a large-scale computational study (Beard, et al., Comparisons of Computed Mobile Phone Induced SAR in the SAM Phantom to that in Anatomically Correct Models of the Human Head IEEE Trans. EMC., May 2006) has been conducted by 14 international research centers, demonstrating the conservative nature of the SAM phantom for mobile phone exposure compliance assessments at 835 and 1900 MHz by comparing the SAR in the SAM phantom to those computed in anatomically correct adult and child head models. The study was conducted to address concerns regarding the conservativeness of standardized SAR compliance procedures.

Objectives. The goal of this work was to extend the aforementioned computational study to other frequencies of relevance in wireless communications, specifically 300, 450, 2450, 3500, and 5800 MHz. The frequencies were chosen to cover a large variety of RF emitting handheld devices that may be operated next to the head.

Methods. The extension study has been designed with the same protocol to simulate the compliance exposure conditions with the SAM phantom as well as to reproduce similar exposure conditions with the adult and child head models. The computed results described in this work are part of the larger study organized by the IEEE International Committee on Electromagnetic Safety, Technical Committee 34, Working Group 1 with seven different participating labs from different countries that performed similar computational SAR evaluations. Numerical simulations using the FDTD methodology were performed with two different head models. One head model was from the National Library of Medicine’s visible man model which was further modified by the Air Force Research Laboratory (Brooks AFB, TX), another model was provided by Nagoya Institute of Technology (NIT), Nagoya, Japan. The Japanese head model was scaled down with non uniform scaling factors for different
parts of the head to obtain the child head with representative anatomical properties. For each simulated frequency, a generic handset model has been defined with dimensions similar to those used in the previous study but featuring different antennas. The 300 and 450 MHz handsets had helical antennas while patch antennas were used at the higher frequencies. Simulated exposure conditions included two different handset positions (“touch” and “tilt”) reproducing those used in compliance testing. SAR values produced in the SAM phantom were compared to those produced in the head only tissues excluding the pinna. According to the IEEE C95.1b-2004 and IEEE C95.1-2005 standards, the pinna is subject to a higher exposure limit.

**Results.** The results of this study obtained in our laboratory show that the SAM phantom indeed provides conservative SAR estimates in the head at all simulated frequencies. The comparison of SAR in the adult and child head models with the respective values obtained in the SAM phantom is presented in Fig 1 and Fig. 2 which also include the results from the previous study at 835 and 1900 MHz. The simulations of the child and adult head models also allow estimating the 10-g average SAR in the pinna, which is an organ that is subject to the same limit as extremities according to IEEE Std C95.1-2005. The results further show that the pinna SAR would be compliant with the relaxed limit if the SAR in the SAM phantom is compliant with the head limit, with a slight exception (13% at most) at 3500 MHz. As suggested by an analysis of the results presented in the original study, such an exception is well within the expected variation of computed SAR values in anatomical head models relative to SAM phantom.

**Conclusions.** SAR simulations of adult and child head models exposed to a wireless communications handset at 300, 450, 2450, 3500, and 5800 MHz were performed to verify the conservative nature of the SAM phantom specified in SAR compliance standards. The results indicate that the SAM phantom provides a conservative SAR estimate in the anatomically correct child and adult models, while ensuring that pinna SAR is complaint with the IEEE limit when simulation uncertainties are taken into account.

![Figure 1](image-url)  
**Figure 1.** The comparison of peak 1g SAR in the adult and child head models with the respective values obtained in the SAM phantom.
COMPARATIVE EXPOSURE OF THE USER HEAD OF MOBILE PHONE WITH AND WITHOUT HANDS FREE KIT OR BLUETOOTH EARPIECE

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Summary of Abstract. Supélec has carried out many measurements of DAS on mobile phones and hands free kits. The excellent sensitivity of its new dosimetric assessment system made it possible to measure 18 Bluetooth earpieces. These measurements make it possible to compare the exposure of the user head for these 3 use kinds of mobile phones.

Objectives. Since a few years the use of Hands Free Kits (HFK) and Bluetooth earpiece with mobile phones is increasing. The distance between the phone antenna and the user head is larger with these accessories and one can think that the RF power deposited in the user head is significantly reduced. However the wire of HFK is metallic and the RF currents induced on this wire can be the sources of power deposition in the user head [1] [2]. Supélec carries out dosimetry measurements for HFK since a few years and a large data base has been constituted with 124 different mobile phones and HFK measurements [3].

The Bluetooth earpieces are radiating systems in the 2.45GHz frequency bandwidth, and induce a power deposition in the user head. The level of the DAS of such an earpiece is very low, which makes impossible its measurement using a commercial base dosimetric, except by using simplified methods [4]. Recently Supélec has improved the performances of its own dosimetry measurement system [5], allowing the measurement of very low Specific Absorption Rate (SAR), and 18 different Bluetooth earpieces have been tested.

Methods. The 124 different mobile phones and their HFK have been measured following EN50361 protocol for the handset and the following described protocol for HFK, in the GSM900 and DCS1800 frequency bands. The measurements are performed with the SAM
phantom. There are 6 different measurements for each frequency band, corresponding to 2 different HFK wire configurations and 3 different frequencies: lower, central and upper frequencies. The 2 different wire configurations are tensed wire and wire with two three cm diameter loops near the phone antenna, the exact position of which corresponding to an obtained maximum SAR value at the central frequency. The HFK SAR is the maximum obtained value for the 6 measurements.

The Bluetooth earpieces are also tested on the SAM phantom [6]. Two measurements are performed for each earpiece: one for each SAM head side. The Bluetooth earpiece SAR is the maximum obtained value for these two measurements.

Results. The figure 1 shows the distribution function for the different devices SAR 10g values. The SAR values are significantly decreasing with the use of HFK or Bluetooth earpieces compared with direct use of mobile phones. The obtained SAR values are lower with Bluetooth earpieces than with HFK. The mean value, standard deviation, maximum value and minimum value of the different devices SAR 10g are given in figure 2 and table 1. Statically, the SAR values are divided by 5 with HFK and 100 with Bluetooth earpieces in comparison with the direct phone exposure.

Figure 1: Distribution function for the mobile phones, HFK and Bluetooth earpieces SAR 10g values.
Figure 2: Mean value and standard deviation for the mobile phones, HFK and Bluetooth earpieces SAR 10g values.
Table 1: Mean value, standard deviation, maximum and minimum values for the mobile phones, HFK and Bluetooth earpieces SAR 10g values.

Conclusions. The measurements which have been performed at Supélec on HFK and the Bluetooth earpieces characterization allowed by the new high performance dosimetric assessment system enable to compare the mobile phone user head exposure with or without these accessories. The user head exposure is very different for these three cases. The use of HFK reduces the exposure level of about a factor 5 and the use of Bluetooth earpieces of about a factor 100. This exposure reduction has to be relativized due to the body worn mobile phone exposure of an other part of the user body.

References:

Acknowledgements. The author would like to thank Bouygues Telecom for its financial support.

**Figure 1.**

**Figure 2.**
7-3 DEVELOPMENT OF A NEW IN SITU SAR MEASUREMENT SYSTEM AND ITS USE FOR MAKING SAR MEASUREMENTS INSIDE VEHICLES.

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Summary of Abstract. This abstract describes the development and use of a new in situ SAR assessment system. The system was used to measure SAR from 400 MHZ TETRA radios inside and on three vehicles. SAR data were also calculated and the results of measurement and modelling compared with each other, with existing SAR data for the radios used and with SAR measured using standard commercial laboratory systems.

Objectives. The aims of the work were
to develop new whole-body physical and computational phantoms,
to develop and test a portable self-contained system for measuring SAR in real exposure situations (not in the laboratory,
to assess what differences there are between exposure from a single personal radio used outside a car and the situation when several such radios are used inside a car

Methods. A system with a scanning probe capable of measuring SAR at any position in the torso and head of a phantom was. The whole body phantom is also available as a CAD file so it can be used in computational modelling.
A robot is installed in the upper torso. There is a recessed section in the pelvic section which takes the motors and gearing and which is “dry” (see Figure 1). The rest of the phantom is filled with tissue-equivalent liquid. The robot is under computer control and can position the probe almost anywhere on the inner surface of the torso or head. The software that controls the robot and processes the data is based on standard laboratory SAR system control software, and uses the normal measurement procedure of a surface or "D scan to locate the SAR maximum, followed by a 3D volume scan to return the 10 g average value. The SAR calculation, interpolation and surface extrapolation are the same as in a commercial laboratory SAR system.
The in situ SAR system was validated against both computational predictions of SAR (calculated in a computational model of the same phantom using the same radio) (see Figure 2) and against data obtained using a standard commercial SAR measurement system. The agreement was to within 10%; the uncertainty for the in situ system is comparable with the standard commercial SAR measurement system: less than 30%
Measurements were made and calculations were undertaken for real TETRA radios used on and in vehicles (see Figure 3). Motorola MTP 700 1 W (peak power) personal radios and MTM800 3.3 W (peak power) vehicle radios were used; the vehicles were a Ford Mondeo, a Nissan Primera Estate and a BMW R1200RT. All three vehicles were modelled by EMSS using CAD data supplied by manufacturers, and SARs calculated with 1, 2, 3 or 4 "passengers": these were the MCL whole-body phantoms. MCL made corresponding measurements in the real vehicles using 1, 2, 3 or 4 whole body phantoms of which one had the in situ SAR system.
Results. Measured and predicted SAR data agree well, and agree with existing SAR data for MTP700 radios. Exposure levels from vehicle antennas are negligible with respect to exposure guidelines at all driver/passenger locations. In all cases the vehicle radios gave rise to exposures less than 5% of the ICNIRP general public restriction and less than 1% of the ICNIRP occupational basic restriction. Significant exposure inside a vehicle or on a motorcycle comes only from an officer’s own radio, and is essentially the same as the exposure from that device outside the vehicle provided that the radio power remains constant.

The maximum 10 g-average localised SARs from MTP700 personal radios, determined by computation or measurement, were approximately 0.5 W/kg. This can be compared with the relevant ICNIRP basic restriction of 2 W/kg for the public and 10 W/kg for occupational exposures. The maximum whole-body average SARs were below 0.004 W/kg, which can be compared with the relevant basic restriction of 0.08 for the general public and 0.4 W/kg for occupational exposures.

Conclusions. In all cases the vehicle radios gave rise to exposures less than 5% of the general public restriction and less than 1% of the occupational basic restriction.

The in situ SAR measurement system gives results that are consistent with commercial laboratory SAR measurement systems and with the results of computational modelling. On that basis it represents a valuable new approach for the measurement of SAR in real exposure situations. It has been shown that the system can be used for making SAR measurements inside cars and on motorcycles.

Significant exposure inside a vehicle or on a motorcycle comes only from an officer’s own radio, and is essentially the same as the exposure from that device outside the vehicle provided that the radio power remains constant.

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**Figure 1.** - Whole body phantom & SAR robot

**Figure 2.** - validation of in-situ SAR system by comparison with modelling
Figure 3.
7-4 EVALUATION OF THE CORRELATION BETWEEN RF EXPOSIMETER READING AND REAL HUMAN EXPOSURE

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Summary of Abstract. It has been demonstrated by numerical and analytical means that commercial available exposimeters tend to underestimate the exposure of a person.

Objectives. Individual RF exposure assessment is a very challenging task. One approach is to carry small measurement devices, so called exposimeters. Due to multipath propagation it is necessary that such devices have a large dynamic range. Moreover they should be able to measure the signals of the most prominent services being operated in the RF range. One of the major questions is the way the reading of such exposimeters worn on the human body is correlated to the effective exposure of a person. This project is dedicated to assess the correlation of the exposimeter reading to the average exposure (field strength) at the location of the person in the FM, GSM 900, UMTS and WLAN band using two different types of exposimeters, an Antenessa EME SPY 120 and a Maschek ESM 140.

Methods. Numerical simulations to investigate the correlation between the exposimeter reading and the exposure were performed. For this purpose the Visible Human Phantom was positioned at different locations in a virtual urban area and exposed to the signals of antennas located on the roof of one of the buildings. The exposimeter was mimicked by an area corresponding to the volume of the antenna of the device. The field levels were averaged over this volume at different locations close to the human body model. These positions correspond to the location of the exposimeter on the human body, i.e. the hip, the back and the upper arm. The readings of the exposimeter were compared to the field levels at the location of the phantom without the phantom being present. For this purpose the average rms field points within the sensor were computed. In addition, the results of the numerical simulations were verified by measurements in an anechoic chamber. In this case exposimeter readings were also compared to the averaged field levels.

Results. Both the results obtained by simulations and measurements indicate that the exposimeter tend to underestimate exposure. The simulations showed that the normalized average of all exposimeter readings was 0.94 at 100 MHz, 0.76 at 946 MHz, 0.87 at 2,140 MHz and 0.64 at 2.450 MHz. All field levels averaged over the volume of the antenna mimicking the exposimeter reading were normalized to the field averaged over the volume of the human body not being present. The measurements performed in the anechoic chamber confirm these results.
Conclusions. Taken together, exposimeters are a quite promising approach to investigate individual exposure. One has to take into account that the single reading of an exposimeter has little meaning, it can recommended to look at the average of many readings of the device measured during a person is exposed in a typical environment. But also these readings have to be adjusted by correction factors taking into account the impact of the user’s body on the exposimeter reading. The results shown in the frame of this work give information on the correlation of the exposimeter reading and real exposure for whole body exposure and sources being located at larger distances from the human body. Additional research is needed to investigate the correlation of exposimeter readings and the localized exposure arising from sources operated close to the body, e.g. the mobile phone.

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Methods. For TETRA, DVB-T, GSM 900, GSM 1800, UMTS and WiMax the field distribution in a representative urban area is investigated by applying an optical simulation tool. The area consists of 4 buildings made of concrete. The transmitting antenna is located on the edge of the roof of one of the buildings. The information on the incoming electromagnetic waves is obtained by analysing their amplitude, phase and time of propagation and direction of propagation at 21 reference positions. Nine positions are located 1 m above ground on the street, eight at a height of 10 m close to the wall of the buildings and four in 21 m height above ground on the roofs of the buildings. The body of information obtained by the optical tool is used to expose the Visible Human phantom to the superimposed electromagnetic waves using the FDTD tool SEMCAD. The obtained SAR values are then normalized to the incoming averaged electric field levels and compared to the SAR obtained by plane wave exposure.

Results. The results obtained at 946, 1,840 and 2,140 MHz show that the relation between the whole body SAR obtained for heterogeneous exposure condition and the whole body SAR ranges between -3.4 to 1.9 dB, depending on the frequency. For partial body exposure the variation ranges from -11.3 to 4.9 dB. Taking the three frequencies together it has been shown that 12 % of all examined cases show higher whole body SAR compared to the reference plane wave condition. An overview of all results including the results obtained for TETRA, DVB-T, WLAN, Bluetooth and WiMax will be shown at the conference.

Conclusions. The results obtained so far clearly demonstrate that plane wave exposure can not be considered as worst case condition regarding both whole body and partial body SAR. This body of information needs to be extended to other frequencies and exposure conditions. Moreover it is imperative to investigate heterogeneous exposure conditions in combination with different types of phantoms, in particular those of children. It has been demonstrated by several authors that the basic restrictions can be exceeded although the reference levels are met when phantoms of children are exposed. To obtain worst case conditions, phantoms suitable to represent the variability of the anatomy and morphology of the general population need to be investigated both for homogeneous and heterogeneous exposure conditions.

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EXPERIMENTAL EVALUATION OF THE SAR INDUCED IN A HEAD PHANTOM OF A THREE YEAR OLD CHILD

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Summary of Abstract. This study addresses the ongoing controversy over whether the current compliance test procedure based on a large adult head (SAM) is also appropriate for children. We experimentally evaluated the influence of the human head anatomy with respect to compliance testing of mobile phones on the SAM head and on a child’s head. The results confirm those of previous numerical studies comparing the energy absorption in different human heads and the SAM, i.e., the SAM phantom also conservatively estimates the peak spatial specific absorption rate (SAR) exposure in a child’s head.

Objectives. Currently, all mobile phones are evaluated with respect to SAR prior to market authorization using international and national compliance test standards, e.g., IEEE1528, IEC62209-1. Although these techniques are well established and generally accepted, there has been an ongoing controversy questioning their validity for the exposure of children. A summary of this discussion and the corresponding studies is given in [3]. While related numerical studies did not find any evidence of a correlation between the head size and energy absorption, experimental results validating these finding were not available. The aim of this study is to experimentally evaluate the SAR induced in the head of a 3 year old child by mobile handsets.

Methods. A 3-D CAD representation of the shell of a head model based on MRI scans of a 3 year old child head was developed. Based on the 3-D shell data an experimental head phantom was manufactured using a laser-sintering process. The shell has a thickness of 2 mm (6mm at the ear) and is fully compatible with standard head tissue simulating liquids. The evaluations were based on two Generic Mobile Phones [1] operated at 900 and 1800 MHz as well as a Motorola T250 mobile phone operated at the center frequencies of the GSM 900 and GSM1800 bands. Positioning of the phones was based on the procedure suggested in [2]. The dosimetric evaluations were performed using the DASY5 NEO dosimetric assessment system for the experimental SAR evaluation and SEMCAD X for the numerical SAR evaluation. The SAR of the mobile phones were experimentally and numerically assessed at the right hand side in standard touch and tilt positions using the standard tissue simulating liquid properties in accordance with IEC62209-1. The results in the child’s head were compared to results obtained in the standard compliance test phantom (SAM) and to numerical results in heterogeneous head phantoms.

Results. Good agreement between the numerically and experimentally determined SAR distributions in the homogeneous child head was obtained. The obtained SAR compliance test results were in agreement with the SAR results obtained in the SAM phantom within the uncertainty due to the variability of the human head anatomy with respect to SAR as investigated in [2].
Conclusions. The study confirms that the SAM phantom also results in conservative estimates of the peak spatial SAR exposure in the heads of children.

References:
[2] "Dosimetric comparison of the specific anthropomorphic mannequin (SAM) to 14 anatomical head models using a novel definition for the mobile phone positioning", Wolfgang Kainz, Andreas Christ, Tocher Kellom, Seth Seidman, Neviana Nikoloski, Brian Beard and Niels Kuster, in Physics in Medicine and Biology, Volume 50, Number 14, pp. 3423–3445, July 2005

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7-7 INCONSISTENCY OF REFERENCE VALUES AND SPATIAL AVERAGING OF IEEE/ICNIRP GUIDELINES WITH BASIC RESTRICTIONS

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Summary of Abstract. Reference levels for testing compliance of human exposure with radiofrequency (RF) safety limits have been derived from very simplified models of the human. Our findings suggest that the reference levels of current electromagnetic (EM) safety guidelines for demonstrating compliance as well as some of the current measurement standards need to be revised.

Objectives. Currently, the testing of compliance with safety limits for human exposure to electromagnetic fields (EMF) from fixed base station transmitters is widely based on reference levels proposed by ICNIRP and IEEE C95.1. These reference levels were derived from very simplified models of the human anatomy. The spatial averaging of incident fields as proposed in IEEE C95.1 and ICNIRP have never been validated with respect to their consistency with the basic restrictions for localized exposure.
The aims of the study were: 1) Evaluation of the consistency of reference levels of international standards for limiting human exposure to EMF with the basic restrictions by applying the latest MRI-based human models; 2) Development of methods to demonstrate compliance of fixed transmitters with EM safety limits.

**Methods.** This study was based on numerical evaluations of the induced SAR of various human anatomies in homogeneous and inhomogeneous field distributions (SEMCAD X). A variety of human models (male, female, child) were exposed to typical incident field distributions in the vicinity and the far field of fixed transmitters in the frequency range from 50-2500 MHz. For these configurations, the worst-case whole body average and peak spatial SARs were determined in comparison to the basic restrictions of ICNIRP (exposure ratios) when an equivalent field at the ICNIRP reference levels is incident to the models.

**Results.** The results show inconsistencies in International Safety Standards for Human Exposure to EMF. The reference levels were not consistent with the basic restrictions for all human anatomies. In particular, children are likely to be exposed above basic limits when a field at the reference limit is incident. The maximum localized SAR values were found at locations of partial body resonances such as penis, nose, chin, wrist or fingers. It was further found that spatial averaging of the incident field over a body-equivalent area is suited only for demonstrating compliance with whole-body SAR and may result in an underestimation of the peak spatial SAR limits. However, peak incident field values that consider the directivity of the local incident field can be designed to be consistent with the local basic restrictions and do not greatly overestimate the exposure.

**Conclusions.** These findings suggest that the reference levels of current EM safety guidelines for demonstrating compliance as well as some of the current measurement standards must be revised. An extension of this study using a broader range of anatomical models exposed in various postures is necessary to derive a conservative envelope for all people and the entire frequency range as well as sound procedures for demonstrating compliance. Nevertheless, a rigorous method for testing compliance with safety limits in-situ was already derived from the sweeping method:

Step 1: Conduct a peak search of the incident E-field using the sweeping technique (maximum hold).
Step 2: If the E-field peak is compliant then the site is compliant; if the peak is not compliant then Step 3 is required.
Step 3: Perform a volume scan around the peak to determine the maximal whole-body exposure and determine compliance with peak spatial SAR by directive incident field evaluations.

The details of Step 3 must be determined in future projects.

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**7-8 AGE DEPENDENT CHANGES IN SAR AND TEMPERATURE DISTRIBUTION INDUCED IN THE USER’S HEAD BY CELLULAR PHONES**

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**Summary of Abstract.** There has been a long standing controversy over whether the effects of cellular phone radiation exposure are age dependent. Although most recent studies confirmed that the peak spatial average SAR in the head is not a function of age, the age dependent exposure of specific tissues, the impact of age dependent changes of the tissue properties on the exposure and the induced tissue heating have not yet been rigorously assessed. This study discusses age dependent changes in SAR and temperature based on anatomically correct models of adults and children and on recent experimental data on dielectric tissue properties. A correlation of the peak spatial average SAR with age dependent could not be established. Large changes, however, were observed for the exposure of particular brain regions.

**Objectives.** The goal of this study was to conduct a detailed evaluation of the RF energy absorption and tissue temperature changes of mobile phone users of different age groups. This includes:

- Numerical assessment of peak spatial average SAR in different anatomical models of adults and children exposed to mobile phone radiation as a function of thickness of the pinna, anatomy of the head and tissue parameters
- Evaluation of the exposure of different brain regions, e. g., the hippocampus, the hypothalamus, the pineal gland, etc.
- Numerical and experimental assessments of the temperature increase in the auditory canal and on the cheek caused by cellular phone use.

**Methods.** The induced fields inside anatomically correct head models of three children and one adult from different cellular phone models were simulated in the “touch” and “tilted” positions at 900MHz and 1800MHz. Dielectric parameters were modified to consider age dependent changes based on recent measurements in pig tissue [1]. The peak spatial average SAR of the head and the exposure of different brain regions were evaluated. Additionally, thermal simulations were performed for all exposed head models considering worst-case conditions for the thermal tissue parameters. All simulations are carried out using the FDTD method and the integrated simulation platform SEMCAD X. The numerical results were complemented by experimental evaluations of the temperature increase in the auditory canals and on the cheeks of 16 adults and 16 children exposed to the radiation of a commercial and a generic mobile phone using miniaturized temperature probes (Schmid & Partner Engineering AG, Zürich).

**Results.** The evaluation of the peak spatial SAR shows variations of less than ±30% for the different head models and tissue parameters. Large age dependent changes (>300%) were observed for the exposure of particular brain regions.
Conclusions. A correlation of the variations of the peak spatial SAR with age dependent changes of the tissue parameters or the anatomy could not be established. The changes of the exposure of particular brain regions are mainly attributed to the distance of the exposed region to the location of the maximum current on the cellular phone. The measured differences in the thickness of the compressed pinna and temperature due to cell phone exposure will be discussed in detail.

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8-1 FUNCTIONAL IMAGING OF MAGNETIC FIELD THERAPY

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Summary of Abstract. The effect of a specific pulsed magnetic field on pain processing was examined using functional magnetic resonance imaging.

Objectives. Previously, we have described a specific pulsed magnetic field (CNP\textsuperscript{R}) that was able to induce an analgesic effect in snails, mice, normal human volunteers, as well as chronic pain patients including those with fibromyalgia. These studies have included both whole-body exposures as well as head-only exposures. Thus, we know that the central nervous system is involved in the mechanism. The objective of this work is to examine how the neural processing of pain is altered by the application of this pulsed magnetic field therapy.

Methods. Functional magnetic resonance imaging (fMRI) was used to determine the neural activity in the brains of normal volunteers. BOLD (blood oxygenation level dependent) images will be obtained with a Siemens Avanto 1.5 T clinical MRI, and analyzed with Brain Voyager QX software (Brain Innovation B.V.). A Peltier thermode device (1.6x1.6 cm probe, TSA-II, Medoc) was affixed to the hypothenar region of the subject’s dominant hand. This delivered a noxious heat stimulus (48-51°C, depending on the subject’s individual pain threshold) 10 times, each for 21 seconds in a “boxcar” design within the MRI. The subjects were then exposed to the CNP\textsuperscript{R} pulsed magnetic field (peak 200 µT), or a sham condition for 15 minutes, and the fMRI/heat procedure was repeated post-exposure.

Results. 31 subjects (17 sham, 14 exposed) have been analyzed in a General Linear Model multishort, multistudy analysis. Several regions showed significant changes in activation (using False Discovery Rate correction FDR $q<0.05$). In particular, the anterior cingulate showed a decrease in activity following pulsed magnetic field exposure, and an increase in activity following sham exposure. Also, the posterior cingulate had an increase in activity following pulsed magnetic field exposure relative to pre-exposure activity.

Conclusions. These results indicate that there may be an effect of pulsed magnetic field exposure on acute pain processing with fMRI. The effect seen in the posterior cingulate areas is interesting as this is a region not typically associated with the processing of acute pain. To the best of our knowledge, this is the first use of functional magnetic resonance imaging to demonstrate the effect of a weak pulsed magnetic field on neural functioning and/or brain blood flow.
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8-2 MOBILE PHONE-RELATED HUMAN SLEEP EEG CHANGES ARE REPLICABLE IN THE SAME INDIVIDUALS

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Summary of Abstract. This research re-tests participants from a previous mobile phone/sleep EEG study, to determine whether their neural changes during sleep, in response to a mobile phone exposure prior to sleep, are consistent over time. It finds that they are.

Objectives. We previously reported increased alpha power (11.5-12.25 Hz) of the human electroencephalogram (EEG) during the first NREM period of sleep following a 30-minute exposure to a test mobile phone (Loughran et al, Neuroreport 2005(16):1973-6). This supported changes in one but not the two other frequency ranges that had previously been reported in the literature. It was suggested that this discrepancy may be due to the variation that occurs between different individuals’ alpha frequency, and corresponding to this, the different individuals alpha frequencies in different studies. In order to test this possibility and ensure that such results were not merely chance, we re-tested a subset of participants that took part in the original study.

Methods. This was a double-blind, counter-balanced, sham-controlled cross-over design. Twenty participants (7 males, 13 females; mean age = 27.9 years, SD = 6.8; all participants from Loughran et al who consented to be re-tested) slept three consecutive nights in a sleep laboratory. The first was an adaptation night, and the second and third were experimental nights. On the experimental nights a GSM mobile phone (MP), either transmitting (ACTIVE) or turned off (SHAM), was mounted on the right side of the head in a position that simulated normal use for a period of 30 minutes prior to sleep. The MP was a Nokia 6110 (0.25 W, 217 Hz modulated, 895 MHz output), set via laptop and manufacturer software to continuously transmit at a mean power output of 250 mW (peak power of 2 W). MP SAR measurements were conducted using the Specific Anthromorphic Mannequin phantom and a precision robot RF Dosimetric Assessment System (DASY4). Spatial peak 10g averaged SAR of 0.67 W/kg was measured midway between the auricle and temple, while the 10g averaged SAR measured in-line with the phone’s antenna (approximately over the ‘temporal lobe’) was 0.110 W/kg. The experiment was carried out double-blind with regard to
phone status. During sleep, EEG, ECG, EOG, EMG, SaO2 and respiratory measures were monitored. EEG channel data from the first NREM period were analysed to provide power spectral density estimates (FFT routine, Hanning window, averages of 4-second epochs) for the first 30 minutes of each NREM period, from the same montage as was reported in Loughran et al (the mean of C3 and C4). For statistical purposes, participants were divided into two groups based on whether their 11.5-12.25 Hz alpha power increased (Increasers) or decreased (Decreasers) in Loughran et al. Based on the results from Loughran et al, directional t-tests were employed to test for an overall increase in the 11.5-12.25 Hz band, and for more of an increase in the 11.5-12.25Hz band (ACTIVE/SHAM ratio) in the Increasers than Decreasers.

**Results.** Of the twenty participants that returned for the re-testing, 8 wereIncreasers and 12 were Decreasers. In spite of this, the twenty participants as a group exhibited more 11.5-12.25 Hz power in the ACTIVE condition than SHAM ($t[19]=1.78; p=0.045$). Further, the ACTIVE condition resulted in more of an increase in the 11.5-12.25 Hz band in the Increasers than the Decreasers ($t[18]=1.95; p=0.034$; see Figure 1).

**Conclusions.** Employing a strong methodology, the current findings support previous research that has reported an effect of MP exposure on the EEG during NREM sleep. Further, it provides strong evidence that the effect of MP exposure is different for different people. This may explain why results have not been very consistent in the past, and that rather than effect sizes being small, MPs may have large but differential effects on different people. As it cannot be determined from this study whether such effects are positive or negative, it is important to explore the functional significance of these results in detail.

**Acknowledgements.** National Health and Medical Research Council of Australia

![Figure 1](image-url)  
**Figure 1.** Power in the 11.5-12.25 Hz band during the ACTIVE condition is shown as a function SHAM, for those that increased and decreased in Loughran et al, separately. Note that ‘100’ means no change, and that larger numbers correspond to an increase in power during the ACTIVE condition.
COMPARISON OF THE THRESHOLD CURRENTS FOR PERCEPTION DETERMINED BY THREE DIFFERENT THRESHOLD TRACKING METHODS

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Summary of Abstract. Safety guidelines for contact hazard have been based on the threshold currents for perception in humans. Comparing the thresholds obtained by three different methods, the best method for threshold tracking is investigated. The threshold determined by the method of limits was higher than those determined by the other two methods. Consequently, 2AFC method is recommended as the threshold tracking.

Objectives. Some radio frequency protection guidelines for contact hazard have been made based on the subjective perception threshold for contact currents in humans. Therefore, the method for threshold measurement is very important. However, the best method of threshold measurement remains to be determined. The main aim of this investigation is to compare the thresholds obtained by three methods and to conclude the best method for threshold tracking.

Methods. Six normal volunteers participated in the present experiments. The perception threshold was measured with three different methods in all six subjects.
Method of limits: Most of previous studies used this method. The induced currents are increase linearly from the subthreshold level. The threshold is determined at the lowest level when the subject feels some currents.
Method of constant stimuli: Several different intensity currents are given in random order, and the subject is asked whether he/she feels it or not. The threshold is determined as the lowest intensity to give perception in half trials.
Two alternative forced choice method (2AFC): In one trial, one pair of pulse was given. One is a current at certain intensity, and the other sham stimulation with no currents. The subject should reply which is on and which is off even when he/she can feel it or not. The threshold is defined as the level at which the correction rate is 0.76.
The stimulation current was given through the electrodes fixed at the index finger tip with a home-made electric stimulator connected to a Wavetek model 81 function generator. The duration of the current was about 1 second, and its shape was sinusoidal at the frequency of 10 or 20 kHz. The current was measured using a Fluke model 8060A digital multimeter. This procedure was approved by the ethics committee of the University of Tokyo, and no side effects were noted in any individuals.
**Results.** The mean (+ SD) thresholds for the current perception were 2.6 (+0.5) mA in the method of limits, 2.1 (+0.4) mA in the method of the constant stimuli and 1.9 (+0.3) mA in 2AFC method for 10 kHz currents. They were 5.3 (+1.2) mA, 4.2 (+0.6) mA and 3.8 (+0.6) mA for 20 kHz currents, respectively. For both 10 and 20 kHz frequency currents, the threshold determined by the method of limits was higher than those determined by the other two methods. They did not significantly differ between the other two thresholds.

**Conclusions.** As expected, the threshold determined by the method of limits was higher than those determined by the other two methods. 2AFC method must be the best for obtaining the physiological threshold that is the level at which some neurons are activated by the currents. We recommend that we should use 2AFC method in the threshold tracking. The thresholds determined by that method should be used for considering the safety issues or in comparisons of the threshold between non-hypersensitive and hypersensitive subjects.

**Acknowledgements.** The authors thank Prof. M. Nishikawa, Kawamura Gakuen Woman’s Univ., Dr. A. Ushiyama, NIPH, Prof. H. Shirai, Chuo Univ., and Prof. M. Taki, Tokyo Metro. Univ., for their precious advices.

![Figure 1. Threshold currents at 10 kHz](image)
Figure 2. Threshold currents at 20 kHz

8-4 A LITERATURE SEARCH FOR EXPLANATIONS OF “ELECTROMAGNETIC HYPERSENSITIVITY”

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Summary of Abstract. Based on a systematic literature review various possible explanations, including electromagnetic fields, of “electromagnetic hypersensitivity” have been explored. Sham controlled double blind studies have failed to provide evidence for a relation between electromagnetic fields and symptoms. There are indications that nervous system dysfunctions, and in particular regarding the autonomous system, may play a role. Amplification of symptoms and attribution of symptoms to electromagnetic fields may be explained by psychosomatic and psychosocial mechanisms. Individuals may differ regarding the role of various possible causes.

Objectives. Some people report about complaints when using or being near sources of electromagnetic fields, and based on their own experience they have been denoted “electromagnetic hypersensitive” (EHS). The spectre of symptoms reported by this group does not vary from that reported by the general population. An EHS individual may, however, experience a higher number of and more intense symptoms, and in some cases the condition is disabling. The objective of this literature review is to explore a possible relation between exposure to electromagnetic fields and the complaints experienced by EHS individuals, and to search for alternative explanations of this condition.
Methods. Literature has been identified from data bases and other sources like review articles and reports. Primarily four main groups of studies have been reviewed. 1) Sham controlled studies testing a possible relation between exposure to electromagnetic fields (low frequency or high frequency) and symptoms or physiological responses. 2) Studies exploring possible physiological deviation or dysfunction of groups of “electromagnetic hypersensitive” individuals compared to controls. 3) Studies on causes for amplification and attribution of symptoms in general and in conditions exhibiting similarities to electromagnetic hypersensitivity. 4) Studies of EHS individuals which may indicate whether the same causes can be used to explain the electromagnetic hypersensitivity phenomenon.

Results. A high number of sham controlled studies has been performed with EHS individuals exposed to low frequency or high frequency fields. Some of the few positive findings has not been possible to confirm in follow-up studies and some may be due to statistical flaw or other methodological weaknesses. In summary, the results indicate that the symptoms are not provoked by the electromagnetic fields, the EHS subjects are not able to detect the fields more often than would be expected by chance, and no physiological effect of the exposure that may explain the “hypersensitivity” reaction has been identified.

In some cases medical examinations have revealed that EHS individuals have diseases that can account for their symptoms, but in many cases the complaints can not be explained. Some groups of scientists have tested the response and status of the nervous system of EHS subjects. The threshold for perception of 50 Hz electric current is reported to be lower than for controls and EHS individuals appear to have a higher sensitivity than others to flickering light as measured by visually evoked potentials. Moreover, EHS subjects have demonstrated deviating base line values and/or stimuli responses of e.g. heart rate, heart rate variability, electrodermal activity and left-right difference in facial skin temperature suggesting autonomous nervous system dysfunction.

Such dysfunction may possibly account for increased sensitivity to external and internal stimuli, thereby resulting in a higher level of complaints. Furthermore, psychogenic causes are important for symptom amplification and attribution. When an individual suspects that he/she suffers from a disease, the bodily awareness will increase, thereby affecting the perception of symptoms that normally occur. This causes distress. Sensations assumed to have a pathological origin are selected for conscious attention and are amplified. In turn, the belief of being sick is reinforced and a vicious circle is established, which may result in a disabling condition. When people assume a hypothesis that explains their symptoms, they will seek for information that confirms their belief, and their belief will affect their perception of the symptoms and the way they selectively monitor them. Expectation that some exposure may harm, may cause acute or chronic effects (i.e. the nocebo effect). Furthermore, the belief of a disease may bias the recall of passed symptoms. Various social factors influence the establishment of schemas and the development of the condition. Among these are media publicity, sympathetic physicians, disability compensation, and patient advocacy groups.

Several aspects related to the causes for symptoms mentioned above have been substantiated in studies with EHS subject. Among observations are the nocebo effect (symptoms are provoked to the same extent by sham and electromagnetic fields exposures in double blind studies); a correlation between sleep problems and fear for mobile phone base station
radiation; a difference between EHS subjects and controls regarding assumption about to
the exposure status in provocation studies (e.g. EHS subjects most often believed that they
had been exposed to magnetic fields while controls most frequently believed that they had
not been exposed, while both groups were equally wrong); a possible relation between the
occurrence of electromagnetic hypersensitivity and mass media coverage; physicians often
considering an association between electromagnetic fields and symptoms to be plausible.

Conclusions. Scientifically based evidence fails to support the assumption that electro-
magnetic fields may play a role in complaints associated with electromagnetic hypersen-
sitivity. There are indications that at least some EHS individuals suffer from nervous system
dysfunctions, which might explain the experience of more symptoms, whereas there may
be other reasons for the complaints of other individuals. Psychosomatic and psychosocial
mechanisms may be a reason for symptom amplification and attribution of symptoms to
electromagnetic fields. Future studies should be designed to explore the role of explanations
other than electromagnetic fields.

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8-5 EXPOSURE AT UMTS ELECTROMAGNETIC FIELDS: STUDY ON
POTENTIAL ADVERSE EFFECTS ON HEARING. THE EUROPEAN
PROJECT EMFnEAR

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Summary of Abstract. The multicentre project funded by the European Commission
named EMFnEAR involved eight centres and aimed to assess potential changes in audi-
tory function as a consequence of exposure to low-intensity electromagnetic fields (EMF)
produced by UMTS cellular phones both on laboratory animals and on humans.

Objectives. The purpose of this paper is to present the final outcomes of the project.
**Methods.** The animal studies involved both a longitudinal assessment of acute effect of short and long-term exposure, cross-sectional comparison of groups of exposed animals and combined exposure with ototoxic drugs. Four different groups of Sprague-Dawley rats were included, i.e. a group exposed to UMTS field, a group sham exposed to UMTS, a control group treated with kanamycin (KM) and UMTS exposed (KM + UMTS) and a control group treated only with KM, which is a well-known ototoxic drug. The KM treatment was a dose of 250 mg/kg body weight (Kanacill Fortius - kanamycin sulphate sol 20%, corresponding to 15% KM), given by a daily intra-muscular injection in the hind limb, for 22 days. The animals were locally exposed or sham exposed to a controlled UMTS field, frequency of 1946 MHz, at SAR level of 10 W/kg, 2 hours a day, 5 days a week, for 4 weeks in a blind mode. Auditory function of rats was assessed before, during and after exposure, by recording Distortion Product Otoacoustic Emissions (DPOAEs) which reflect the functional status of the Outer Hair Cells (OHC) of the cochlea.

The human studies involved longitudinal assessment of acute effects of short-term exposure. The human experimentation was divided into two phases: i) ”Base experiments”, which corresponds to the study of the potential adverse effects of UMTS cellular phones on hearing in case of exposure for 20 minutes to the maximum power level at 1947 MHz. A UMTS commercial phone (NOKIA 6650) connected by serial cable to a PC was used (maximum SAR, at a distance of 30 mm from the surface of the phantom which corresponds approximately to that of the cochlea, of 0.069 W/kg); ii) ”Additional test”, which corresponds to the studies on the effects of UMTS exposure on hearing using an exposure system based on patch antennas. The patch antenna provides more localized exposure to the inner ear region at a SAR equal to 1.75 W/kg, (averaged over 10 g of tissue).

For both studies, the assessment of auditory function was based on a conventional battery of tests for audiological assessment in clinics: pure tone audiometry (PTA), distortion product otoacoustic emissions (DPOAE), effects of contralateral acoustic stimulation (CAS) on TEOAE and late cognitive potentials (P300). They were performed immediately before and after real or sham exposure to EMF and only the exposed ear was tested. All testing was carried out in blind mode.

**Results.** In summary, as to the animal studies, the analysis of the data suggest no effects of UMTS electromagnetic fields exposure on the peripheral auditory system of rats, both in normal ears as well as in ears exposed to a well recognized ototoxic agent (KM), even when the hearing system is exposed to a high SAR level of 10 W/Kg. As to human experiments, results suggest no effects of UMTS electromagnetic fields exposure on the inner ear of humans, both in the case of cellular phone exposure and patch antenna exposure.

**Acknowledgements.** This work was supported by the European Project EMFnEAR ”Exposure at UMTS Electromagnetic Fields: Study on Potential Adverse Effects on Hearing” (DG Health & Consumer Protection”, Agreement Number: 2004127, 2004–2007).
EFFECTS OF EXPOSURE TO ELECTROMAGNETIC FIELDS EMITTED BY MOBILE PHONES ON BRAIN ACTIVITY AND COGNITIVE FUNCTION IN YOUNG MALE SUBJECTS.

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Summary of Abstract. Brain activity and cognitive function were not affected by electromagnetic fields emitted by mobile phones (GSM900 and UMTS, i.e. mobile phones of the 3rd generation) in most of the tests in 30 healthy young males. The small number of statistically significant results (five out of 39 for GSM900; two out of 39 for UMTS) was below the number expected just by chance, and predominantly reflected a reduced reaction time under RF exposure. In none of the tests accuracy of performance was affected. More pronounced effects on CNS (central nervous system) and performance were found by time of day.

Objectives. Since results of studies on possible effects of electromagnetic fields emitted by mobile phones on brain activity during daytime and on cognitive functions are contradictory, possible effects of continuous RF exposure on the CNS and various aspects of daytime function were studied.

Methods. The sample comprised 30 healthy male subjects within the age range 18-30 years (mean ± SD: 25.3 ± 2.6 years). Subjects were tested on nine study days (separated by a two weeks interval) in which they were exposed to three exposure conditions (Sham, GSM900 and UMTS) in a randomly assigned and balanced order during the test procedures. A cell phone use at maximum RF output power was simulated, the transmitted power was adjusted in order to approach, but not to exceed the SAR limits of the law (localised SAR = 2.0 W/kg – averaged over 10g). All tests were presented twice on each study day in the same order in an identical timeframe. Tests on CNS and cognitive function included analysis of the wake EEG, event related potentials and slow potentials, evoked potentials, tests of vigilance and attention and a working memory task.

Results. Most of the daytime test parameters (Contingent Negative Variation, Visual Monitoring Task, Auditory Evoked Potentials, Continuous Performance Test, Divided Attention Test, Vigilance Test, n-back Task) were neither affected by GSM900 exposure nor by UMTS exposure. The small number of statistically significant results (five out of 39 for GSM900; two out of 39 for UMTS) was below the number expected just by chance. The significant performance parameters predominantly reflected a reduced reaction time under RF exposure. In none of the tests accuracy of performance was affected. Effects of time of the day were much more pronounced than effects of RF exposure. Performance was better during the afternoon testing session. Results of pupillography were indicative of a higher activation level of the CNS in the afternoon, which might explain the better performance at this time of the day in this sample. The necessity to control time of the day was particularly evident in the results for the waking EEG. Alpha power showed a statistically significant time of the day effect with higher levels in the afternoon, which is in good agreement with the observations mentioned above. Neither for GSM900 nor for UMTS exposure the number of significant results exceeded the one expected just by chance.
Conclusions. The results of the present study underline the necessity to control for time of the day and to standardise not only the test situation but also the daily routine including meals in studies of RF effects. The absence of standardisation may have contributed to the lack of consistence in previous studies. A limitation of the study is that only healthy young males were investigated.

Acknowledgements. This study was funded by the Federal Agency of Radiation Protection, Germany, Project Nr. M8808.

8-7 INVESTIGATION OF SLEEP QUALITY IN PERSONS LIVING CLOSE TO A MOBILE PHONE BASE STATION – RESULTS FROM AN EXPERIMENTAL STUDY

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Summary of Abstract. For residents living close to mobile phone base stations, the subjective perception of a disturbed sleep is among the most often mentioned complaints attributed to the EMF exposure. The promising approach used in this study is to study a possible relationship between the EMF exposure and sleep in an experimental setting in the home environment of subjects living close to a mobile phone base station. Both, exposure and outcome are objectively measured.

Objectives. There is some evidence that sleep parameters, brain activity during wake (EEG) and the processing of intellectual information are influenced by exposures to mobile phone fields, i.e. at field intensities below accepted limit values. For residents living close to mobile phone base stations, the subjective perception of a disturbed sleep is among the most often mentioned complaints attributed to the EMF exposure. Epidemiological studies have shown contradictory results. The aim of the present study is to analyse the impact of electromagnetic fields of mobile phone base stations on sleep of residents in an experimental setting using a double-blind, sham-controlled, balanced randomized cross-over design.

Methods. Study participants were recruited from sites, where 1) no mobile phone service was available, 2) only weak fields from other RF-sources (TV etc) were present, and 3) there was no emotional EMF-discussion in the run-up to the study. Data acquisition comprised individual measurement of EMF-exposure (performed by IMST GmbH, Kamp Lintfort, Germany), questionnaires to characterize the sample (with regard to clinically relevant sleep disorders (LISST), overall sleep quality (PSQI), excessive daytime sleepiness (ESS), Zung scales to assess anxiety and depression (SAS and SDS), attitude towards mobile communication and personality traits (NEO-FFI)), and subjective (morning and evening protocols) and objective (derived from frontal EEG and EOG recordings performed in an ambulant setting at home) sleep data. For each participant subjective and objective
Sleep data were recorded for twelve nights. Exposure was realized by an experimental base station working constantly with a well defined emission. The base station was manipulated to ensure blinding.

Results. Altogether 397 subjects (> 17 years) from 10 villages in various parts of Germany participated in the study. The number of inhabitants of the villages varied from 125 to 652, the total number was 2856 (> 17 years: 2329), which reflects 17.1% of the eligible inhabitants participated in the study (50.9% females in the sample out of 48.5% eligible females). The mean age of participants was 45.0 ± 14.2 years, the range was 18 to 81 years. Males were slightly, but not significantly older than females (46.3 ± 14.2 years vs 43.8 ± 14.2 years). 21 subjects (5.3%) had to drop out of the study before the end due to illness (own or of relatives) or job-related reasons.

Analysis of the questionnaires to characterize the sample showed that study participants are representative of general population based samples. There was no indication of an increased prevalence of depression, anxiety, special personality traits, morning-evening types. Furthermore the attitude towards mobile communication in the sample was equivalent to results from representative population surveys. The analysis of the subjective and objective sleep data in relation to exposure is under way and will be finalized by the end of March 2008. So it will be possible to present the data at the meeting.

Conclusions. One conclusion to be drawn so far is that the participants are a representative sample of the general population. There is no selection bias with regard to factors that might influence the relationship between EMF exposure and sleep.

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**8-8 THE ACUTE EFFECTS OF WHOLE BODY EXPOSURE TO A 1800 MICRO-TESLA, POWER-LINE FREQUENCY MAGNETIC FIELD ON THE HUMAN CARDIOVASCULAR SYSTEM**

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Summary of Abstract. The physiological effects of magnetic field (MF) exposure on the human cardiovascular system have been questioned and debated in the literature for many years now. Several research teams have focused their efforts on power-line frequency field exposure, investigating macrocirculation parameters such as blood pressure, heart rate, and heart rate variability. The results of these studies have proved inconclusive and often contradictory. This is likely due to heterogeneous field characteristics employed in the various
studies as well as confounding variables that have been identified in the literature. Interestingly, there has been very little research conducted on the effect of power-line frequency fields on the microcirculation. As the macrocirculation and microcirculation are continuous, we believe that by investigating how both respond to exposure in the same experiment, we might gain a better picture of the cardiovascular response. Previous unpublished work conducted in our laboratory on rats has suggested a decrease in microcirculation as a result of exposure to power line frequency MFs. The results of this study would then be of value in determining risk assessment models for populations subject to this type of exposure, addressing previous inconsistencies in macrocirculatory literature and as a possible therapeutic approach for microcirculatory pathologies.

**Objectives.** Our objective was to determine if changes in peripheral microcirculation, blood pressure (BP), heart rate (HR), heart rate variability (HRV) and skin surface temperature (SST) occur during and/or after an acute, 60 Hz MF exposure session at 1800 µT. It is hypothesized that MF exposure will decrease peripheral microcirculation and heart rate variability and have no effect on heart rate frequency, systolic blood pressure, or skin surface temperature.

**Methods.** This project is part of a current study protocol (University of Western Ontario Health Sciences Research Ethics Board # 11956E) investigating various physiological responses to power line frequency MF exposure. Ethics has been obtained to recruit 120 healthy adult volunteers between the ages of 18 and 55 years of age. The experiment uses a double blinded computer program (National Instrument Inc., USA) to assign subjects to 2 counterbalanced exposure sessions administered on 2 separate days. The exposure sessions are either real (active) or control (sham). Each session is composed of 4 blocks of testing interspaced with 15 minutes of rest. Testing occurs 15 minutes before the beginning of exposure, after 15 and 45 minutes of exposure and 15 minutes following exposure.

During each block of testing, the subject’s peripheral microcirculation is measured with a laser Doppler flowmetry probe (PF 5010 Laser Doppler Perfusion Unit, Perimed, Sweden) attached to the ventral tip of the middle finger of the non dominant hand. After each perfusion recording has been taken in each block of testing, a systolic blood pressure measurement is taken with a digitally controlled pressure cuff (PF 5050 Pressure Unit, Perimed, Sweden). Additionally heart rate and skin temperature are continuously recorded throughout the testing block with an ambulatory electrocardiogram (Siesta, Compumedics Inc., USA) and skin surface thermistor (Series 400, Yellowstone Scientific Instruments, USA) respectively.

The exposure chamber consists of two Helmholtz like orthogonal coils, 1.6 m wide (80 turns of AWG10 wire) spaced with 1.2 m apart. The subject is seated in the middle of the coils for whole body exposure.

**Results.** We are presently concluding this study and are in the process of analyzing data from 94 subjects. The results will be presented at the conference in June.

**Conclusions.** The results from this study will be the first investigation into the effects of power line frequency magnetic fields on the human microcirculatory system. Additionally
the data will provide a “big picture” perspective of how the cardiovascular system responds to fields of this nature.

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![Relative Microcirculation Changes in Two Conditions Over Time](image)

**Figure 1.**
9-1 A PROPOSED ELECTROCHEMICAL MECHANISM FOR EMF MODULATION OF TISSUE REPAIR

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Summary of Abstract. This study proposes PEMF accelerates tissue repair by directly affecting the kinetics of Ca\(^{2+}\) binding to calmodulin (CaM), via which further molecular signaling is modulated. This work shows how effective EMF signals may be configured a priori to be first messengers by evaluation of signal to thermal noise ratio (SNR) in a two step pathway involving Ca\(^{2+}\) binding to CaM, followed by Ca\(^{2+}\)/CaM binding to epithelial or neuronal nitric oxide synthase (eNOS and nNOS, respectively), which modulates nitric oxide (NO) release. A scheme for PEMF acceleration of tissue healing is proposed.

Objectives. The activation of calmodulin (CaM) by Ca\(^{2+}\) has been found to be the initial stimulus for many biochemical cascades involved in tissue repair, starting with the inflammatory phase. The initial steps of the Ca/CaM-dependent cascades often start with activation of eNOS which causes an immediate release of NO. This causes an immediate vasodilation which is subsequently followed by increased, e.g., cGMP formation which can enhance growth factor release. It is shown here how PEMF signals may be configured to modulate Ca/CaM binding leading to increased tissue repair.

Methods. The EMF target is considered to be Ca\(^{2+}\) binding to CaM followed by CaM binding to eNOS or nNOS, both of which control the CaM-dependent release of the signaling molecule nitric oxide (NO). Analysis of the kinetic equations describing this two step process yields a two time constant electrical equivalent circuit analog, as shown in figure 1. Here \(R_A C_A\) and \(R_B C_B\) are the time constants for Ca\(^{2+}\) binding to CaM, and CaM binding to, e.g., NOS, respectively; and \(C_d\) and \(R_M\) are the membrane capacitance and leak resistance, respectively. Knowledge of the actual time constants, allows any EMF signal to be assessed in the frequency domain with respect to its ability to produce a detectable (i.e. \(\text{SNR} \approx 1\)) voltage in the target. This has been reported for pulsed radio frequency (PRF) signals which confirmed the correct pulse modulation of a 27.12 MHz sinusoidal RF signal to modulate the Ca/CaM pathway significantly accelerated tendon repair in a rat model. A PEMF bone repair signal was predicted ineffective in the same study.

Results. A PRF signal configured a priori for the Ca/CaM pathway was tested clinically in a randomized double-blind study for its effect on pain reduction immediately post breast augmentation. Active patients received the PRF signal every 4 hours, days 1-3, every 8 hours, days 4-6, and every 12 hours thereafter. Pain was assessed twice daily using a validated VAS. The results are shown in figure 2. Bars represent the mean VAS pain score at Day 1 for all breasts and at Day 7 for both the active and sham groups. Mean (± SD) VAS score was 54 ± 9 mm for all groups on Day 1. Mean VAS decreased to 17 ± 4.4 mm in the treated group (218%, \(P<0.001\) vs Day 1) and to 31 ± 5.6 mm in the sham group (74%, \(P<0.001\) vs Day 1). The difference in mean pain between the active and sham cohorts was
also statistically significant \( (P<0.001) \), suggesting post surgical use of PRF therapy could produce a clinically meaningful reduction in pain by nearly a factor of 3. Active patients also exhibited a concomitant decrease in pain medication by a factor of 2.5.

**Conclusions.** It is proposed EMF signals configured via SNR analysis to match the band-pass of a second messenger target can act as a first messenger to modulate biochemical cascades related to tissue growth and repair. The likely second messenger is \( \text{Ca}^{2+} \) binding to CaM which activates eNOS or nNOS. The result is PEMF acts to reduce the inflammatory phase of tissue repair and then acts to accelerate the remaining phases of repair by directly modulating the appropriate growth factor release at the appropriate time and with the correct kinetics. A scheme for PEMF acceleration of tissue healing based upon the model presented here is proposed in figure 3.

![Figure 1.](image-url)
FIGURE 2.

**PEMF Mechanism**

PEMF

\[ \text{Ca}^{2+} + \text{CaM} \rightarrow \text{Ca}^{2+}\text{CaM} \]

PEMF increases \( \text{Ca}^{2+} \) binding to CaM (milliseconds)

\[ \text{Ca}^{2+}\text{CaM} + \text{eNOS} \rightarrow \text{NO} \]

\( \text{Ca}^{2+}\text{CaM} \) binds to eNOS, catalyzes NO release (seconds)

Anti-inflammatory: increased Blood & Lymph Flow
Pain/Edema Decrease (seconds)

\[ \text{NO} \rightarrow \text{cGMP} \rightarrow \text{Growth Factors (hours/days)} \]

- VEGF Angiogenesis (hours/days)
- FGF Collagen/Granulation (days)
- TGF-β Remodeling (days/weeks)

FIGURE 3.
9-2 COOPERATIVE EFFECTS OF DIFFERENT EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS ON MINERALIZATION OF OSTEOBLASTS

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Summary of Abstract. The extremely low-frequency electromagnetic fields (EMFs) can promote the healing of bone fractures, but their effects are dependent on the wave forms of EMFs. We have found that rectangular electromagnetic field (REMF) or pulsed electromagnetic field (PEMF), sinusoidal electromagnetic field (SEMF), triangular electromagnetic field (TEMF) can respectively make the proliferation, differentiation and mineralization of osteoblasts changed. All processes of proliferation, differentiation and mineralization are concerned in during the healing period of bone fractures and the cooperative stimulation of different EMFs may be more valuable to the treatment of bone fracture. The purpose of the study was to examine the response of neonatal rat calvarial bone cells to the cooperation of different EMFs. The stimulatory effects of EMFs were evaluated by the mineralization (area ratio of mineralized nodules of the cells). 6 groups (control and group 1-5) were included in the experiments and the protocol of stimulation with EMFs were listed in tab1. The results showed that the mineralized area of group 1 was significantly increased than other group and the mineralized areas of group 1-5 were significantly increased, compared with control (Tab 2). More over, it seems that the intracellular calcium responses of osteoblasts stimulated with PEMF and SEMF were very different (Fig 1).

Objectives. To find the cooperative effects of different EMFs on the mineralization of osteoblasts and the biological mechanism of osteoblast response on the stimulation of EMFs.

Methods. Osteoblasts were stimulated for 20d with different EMFs and there is 30min stimulation everyday. Control and group 1-5 were included in the experiment and their experimental protocol were listed in tab 1. Mineralized level was evaluated at last. Single osteoblast was labeled with the fluorescent indicator Fura-2AM and the intracellular calcium levels were represented as the ratio of fluorescence at 510 nm during illumination with 340 and 380 nm light.

Results. Compared with the Control, the mineralized levels of group 1-5 were significantly increased and group 1 has significantly increased mineralized level than other group (Tab 2). The intracellular calcium response stimulated with SEMF and PEMF were very different (Fig 1).

Conclusions. It is valuable for the treatment of bone fracture that different EMF stimulation would be used in different period of bone recovery.
9-3 PULSING ELECTRIC FIELD (PEF) ENHANCES CHONDROCYTE PROLIFERATION VIA AN ENDOGENOUS NITRIC OXIDE NO PATHWAY WITHIN NORMAL PHYSIOLOGIC PARAMETERS.

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Summary of Abstract. Use of weak, non-invasive electromagnetic fields (EMFs), such as those produced by bone growth stimulators, has demonstrated beneficial clinical outcomes. Although not completely understood, these benefits occur with no known side effects.

Objectives. Recently a PEF signal designed for pain relief has been shown to increase chondrocyte growth, in vitro, possibly through a mechanism that involves an increase in calcium mobilization, an increase in cGMP, activation of nitric oxide synthase, and release of nitric oxide (Fitzsimmons et al., J.Orthop. Res., 2008, in press). That study, as well as several others, indicate that NO is a key modulator in the biologic pathway acted upon by EMF signals. This study compares PEF-stimulated cell growth with cell growth stimulated by an NO donor to investigate comparable physiologic ranges.

Methods. Normal human chondrocytes (Clonetics) were plated in rectangular cell chambers in monolayer with media (DMEM) containing 0.1% calf-serum. The time varying PEF is composed of biphasic quasirectangular pulses with alternating, nominally 30- and 200-microsecond phases, grouped in 10-millisecond bursts repeated at 15 Hz. The PEF signal is delivered through anodized niobium wires (capacitive coupling) with 2.7 uA peak current and induced peak electric fields of 0.2 mV/cm. Culture media was collected and measured for NO using the Griess method. Cell growth was measured by DNA content of cell layer using a kit from Invitrogen Inc. The NO donor SNP was utilized as a positive control. EDTA was added to culture media to reduce extracellular calcium.
Results. The PEF signal increased NO in a time dependent manner as shown in figure 1, with a rapid return to non-significant levels after termination of PEF treatment. If the extracellular calcium is reduced by a factor of 2-fold using EDTA the PEF no longer increased NO at 30 minutes or DNA content at 72 hours as shown in figure 2. As expected, when SNP was added at a concentration that increased NO levels within the range of that from PEF treatment, there was a rapid increase in NO as shown in figure 3. Of interest is when SNP was present for only 30 minutes there was an increase in DNA content 72 hours later whereas prolonged exposure to SNP (20 hours) decreased DNA content.

Conclusions. PEF-stimulated cell growth can be mimicked with SNP applied to increase NO to the same magnitude as PEF and for only 30 minutes. These data suggest the low-energy PEF signal is acting on the biologic system to increase a mediator (NO) to the appropriate level and within the appropriate time frame. Loss of PEF-stimulated NO release and DNA content with EDTA supports a connection with calcium/calmodulin. Although not conclusive, this data support the original proposal that weak EMF signals act as a trigger, with the cell/tissue supplying the necessary physiologic mediators.

![Figure 1](image.png)

**Figure 1.** Normal human chondrocytes were plated in DMEM containing 0.1% calf-serum. The next day the cultures were treated to a PEF signal delivered through niobium wires. The PEF signal was applied for only 30 minutes. Culture media was collected from control and PEF treated cultures at various time points as indicated and measured for nitric oxide content. The data is expressed as percent of PEF treated group compared to its matching control group (n=6, *p<0.05).
Figure 2. Normal human chondrocytes were plated in DMEM containing 0.1\% calf-serum. The next day EDTA was added to one group of cultures to 0.6 mM. Two hours later the cultures were treated to a PEF signal delivered through niobium wires for 30 minutes. An aliquot of culture media was collected and measured for nitric oxide content. The cultures were allowed to grow for an additional 72 hours at which time cell number was assessed by DNA content of the cell layer. The data is expressed as percent of PEF treated group compared to its matching control group (n=6, *p<0.05).
Figure 3. Normal human chondrocytes were plated in DMEM containing 0.1% calf-serum. The next day SNP was added to all groups. In one group the culture media was changed after 30 minutes. The collected culture media was measured for nitric oxide and compared to a corresponding control. In a second group the culture media was changed after 20 hours and measured for nitric oxide. The cultures were then allowed to incubate for a total duration of 72 hours since addition of SNP at which time cell number was assessed by DNA content of the cell layer. The data is expressed as percent of SNP treated group compared to its matching control group (n=6, *p<0.05).
9-4 PEMF INDUCES NITRIC OXIDE AND HAS DUAL EFFECTS ON CYCLIC GMP IN THE DOPAMINERGIC MN9D NEURONAL CELL LINE

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Summary of Abstract. PEMF signals were applied to MN9D cells in culture for 30 minutes. Conditioned media and cell lysates were collected at specified intervals and NO and cGMP levels were assessed. PEMF treatment increased the production of NO that was blocked by inhibitors of both calmodulin and neuronal nitric oxide synthase. Increases in cGMP were associated with PEMF treatments when cells possessed characteristics of differentiated neurons and conversely, PEMF treatment decreased cGMP levels when cells were in a proliferative state. Taken together this suggests that the actions of PEMF on neuronal levels of NO and cGMP are mediated by Ca/CaM.

Objectives. In Parkinson’s disease, dopaminergic neurons of the substantia nigra in the midbrain are selectively vulnerable and there is currently no neuroprotective treatment. Experimental evidence provides several mechanisms by which neuronal survival might be increased. These include; increasing growth factor levels, modulating calcium ion/protein interactions, and inducing signal cascades initiated or regulated by nitric oxide. Because these mechanisms of neuroprotection overlap with known actions of pulsed electromagnetic fields (PEMF), we are currently testing the potential of these signals to influence neuroprotective pathways. Using a cell line of rodent dopaminergic neurons, we tested the ability of specific PEMF signal configurations that enhance Ca²⁺ binding to calmodulin (Ca/CaM) to activate the synthesis of NO by the neuronal isoform of the enzyme nitric oxide synthase (nNOS). We predicted that in turn this would activate NO-sensitive guanylate cyclase (GC) to increase levels of cyclic GMP (cGMP).

Methods. MN9D cells, a hybrid cell line made from the fusion of rodent primary dopaminergic neurons and N18TG2 cells, a mouse neuroblastoma cell line, were provided by Dr. Alfred Heller at the University of Chicago. Cells were maintained in DMEM/10% fetal bovine serum in a humidified incubator. Cells were dissociated by trypsinization, plated in 35 mm culture dishes, and allowed to attach for at least 2 days before treatment. For differentiation studies, cultures were incubated with 1 mM cAMP, which was removed before PEMF and null treatments. A PEMF signal configured a priori to induce Ca/CaM-dependent myosin phosphorylation consisting of 5 msec bursts of 27.12 MHz sinusoidal waves repeating at 5 bursts/sec, at 0.05 Gauss peak amplitude was administered as a 30 min exposure. Control cultures were subjected to “null” signals under identical conditions. To initiate experiments, culture medium was changed to either DMEM with serum or DMEM alone. At various times, conditioned medium was changed to either DMEM with serum or DMEM alone. At various times, conditioned medium was removed from cultures and cell lysates were harvested in 0.1 N HCl. NO, the product of nNOS, was quantified in conditioned medium indirectly by measuring NO2 in Griess assays. Cyclic GMP, the product of NO-sensitive
Results. Medium change effectively removed all extracellular NO from culture dishes, and levels of NO2 represented de novo NO synthesis. NO2 concentrations in conditioned media increased from 0 to 1 micromolar over 5 hours. Cultures exposed to PEMF exhibited an accelerated increase in NO2 concentrations within the first 2 hours after treatment and both control and PEMF groups attained similar levels of NO2 between 2 and 5 hours. Inhibitors of Ca/CaM and nNOS blocked NO2 accumulation, demonstrating that the mechanism of NO induction was similar to that found in neurons. Cyclic GMP levels could be either up- or down-regulated over this 5-hour period and was associated with the state of neuronal differentiation, demonstrating decreases when cells were actively dividing and increases when cells exhibited more neuronal morphology.

Conclusions. Our results demonstrate effects of PEMF signals on NO synthesis in a neuronal cell line that can be attributed to the direct actions of PEMF on Ca/CaM, which in turn induces a burst of nNOS activity. When cells demonstrated a more differentiated neuronal phenotype, cGMP levels rose. Conversely, when cells were in a proliferative state, PEMF signals decreased cGMP levels. It is possible that in undifferentiated cells PEMF may also up-regulate the activity of PDE1, a Ca/CaM-dependent phosphodiesterase that metabolizes cyclic nucleotides, producing a decrease in cGMP levels. Because alterations in both NO and cGMP levels can influence neuronal survival, future experiments will address more downstream events in the PEMF signal transduction cascade.

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reduce inflammation and modulate pain in a number of wound healing and pain modulation studies. A study of PEMF treatment with a blinded, randomized design is described in this report, using a validated rat model of acute inflammation induced by paw injection of microgram amounts of carrageenan. The results indicate the efficacy of a pulse modulated sinusoidal PEMF signal in reducing edema and preventing a decrease in pain tolerance, both indicators of acute inflammation in this animal model.

**Objectives.** This study tests the hypothesis that a PEMF signal, configured a priori to modulate Ca2+/CaM-dependent anti-inflammatory cascades, possibly involving the signaling molecule nitric oxide, can inhibit both pain and edema resulting from tissue trauma or injury.

**Methods.** Inflammation was induced in the left hind paw of male Harlan Sprague-Dawley rats (200-340g) by injection of 100µL of a 3.5mg/mL sterile phosphate buffered saline-based carrageenan solution into the footpad using a 30 gauge tuberculin syringe. The carrageenan dose was carefully calibrated to produce a mild, controllable form of inflammation that could be evaluated for rate of onset. All study procedures were approved after consideration of the Institutional Animal Care and Use Committee and conform to guidelines from the International Association for the Study of Pain. Edema was determined using a plethysmometer volume displacement transducer system and pain tolerance was evaluated using a Randall-Selitto paw pressure analgesia instrument (both devices from Stoelting Company, Wood Dale, IL). Edema and pain tolerance were measured pre-injection and at 1, 4 and 8 hours after carrageenan injection. Rats were exposed to either the PEMF signal or a control, untreated experimental coil configuration for 15 min. An experimental 8” coil system was used to provide PEMF exposures at 0.25, 2, 4 and 8 hours post-injection (SofPulse, Ivivi Technologies, Inc., Montvale, NJ). The system delivers a 2 msec burst of 2 MHz sinusoidal waves repeating at 2 bursts/sec, and inducing 1 V/m electric field at a target diameter of 2 cm. This PEMF signal was configured a priori to modulate Ca2+ binding in a calmodulin (CaM) transduction pathway. Data were analyzed with SigmaStat 3.0 software (SPSS, Chicago, IL) using Student’s unpaired t-test and one way ANOVA, as appropriate. Differences were also compared using the Mann-Whitney test for two independent groups. Significance was accepted at P ≤ 0.05.

**Results.** The results showed a pre-injection pain threshold for both groups that was not significantly different (P = 0.568), nor was hind limb volume (P = 0.433). There was no significant difference between active or control groups in mean pain tolerance before the injections (P = 0.880), or at 1 hour (P = 0.688). In contrast, mean pain tolerance decreased by 51 ± 8 % at 4 hours and 52 ± 10% at 8 hours in the control cohort (P < 0.009), compared with no significant difference in pain tolerance at 1 hour (P = 0.797), at 4 hours (P = 0.878), or at 8 hours (P = 0.566) in the active treatment cohort. Mean edema volume in the control group animals was 33 ± 7% greater at 1 hour post-injection (P = 0.037), 41 ± 8 % greater at 4 hours (P = 0.005), and 47 ± 9% greater at 8 hours (P = 0.009) than edema volume in the PEMF treated animals at these time points.

**Conclusions.** Data from these experiments confirmed the hypothesis that specifically configured PEMF signals can effectively inhibit pain and edema resulting from inflammation.
Previous reports have indicated a reduction in Visual Analog Scale for human post-surgical pain with similarly configured PEMF signals. Injected carrageenan produces localized irritation and inflammation of short duration in a rat paw model. By downregulating these in vivo indicators of inflammation, we have demonstrated the analgesic potential of SofPulse PEMF therapy using objective corollary determinations in a randomized, blinded animal study.

**Acknowledgements.** This work was supported by Ivivi Technologies, Inc., Montvale, NJ.

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**9-6 PULSED ELECTROMAGNETIC FIELDS ACCELERATE NORMAL AND DIABETIC WOUND HEALING BY INCREASING FGF-2 SECRETION**

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**Summary of Abstract.** PEMF accelerates normal and diabetic wound healing

**Objectives.** While the use of pulsed electromagnetic fields (PEMF) for complex fracture healing is well established, its effect on soft tissue healing is less well understood. We have previously demonstrated that PEMF is able to augment angiogenesis in vitro and in vivo through increased fibroblast growth factor (FGF) secretion. We hypothesized that the pro-angiogenic effects of PEMF could be utilized to facilitate healing of normal and diabetic wounds.

**Methods.** Both db/db and streptozotocin (STZ) induced diabetic mice (n=10 per group) were wounded and exposed to PEMF and compared to control non-diabetic mice. Wounds were followed until closure and analyzed for cell proliferation and angiogenesis through immunohistochemistry. In addition conditioned media harvested from human umbilical vein endothelial cells (HUVEC) exposed to PEMF were also applied to diabetic wounds and compared with untreated and control media treated mice (n=10 per group). Finally, ischemic flaps elevated on the dorsum of STZ mice were exposed to PEMF and compared to normal and diabetic controls (n=10 per group). Flaps were analyzed for survival, tissue oxygenation, and histology.

**Results.** We demonstrate the PEMF significantly accelerated wound healing in both diabetic and normal mice. Media harvested from HUVEC cultures exposed to PEMF demonstrated a 3-fold increase in FGF which similarly enhanced wound healing when applied topically to diabetic wounds. Wounds exposed to PEMF of PEMF conditioned media demonstrated increased angiogenesis and cell proliferation through CD31 and BrdU staining respectively when compared to controls. Finally, PEMF improved flap survival and improved tissue oxygenation in diabetic mice.
Conclusions. Thus, we conclude that PEMF is able to augment normal and diabetic wound healing through increased FGF mediated angiogenesis. In addition, we demonstrate that PEMF can prevent tissue ischemia and improve tissue oxygenation through increased angiogenesis. This may represent a novel, non-invasive modality for stimulating angiogenesis and a potential therapy for treating and preventing chronic wounds in diabetic patients.

Acknowledgements. Oak Foundatio

9-7 PEMF ACCELERATES POST SURGICAL PAIN REDUCTION AND ENHANCES HEALING IN COSMETIC AND RECONSTRUCTIVE SURGERY

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Summary of Abstract. PEMF therapy decreases post surgical pain through a NO mediated pathway.

Objectives. The resurgence in breast implants, body contouring and facial rejuvenation procedures in recent years has been staggering. Clearly surgical procedures are associated with some degree of pain. It has been shown that pain can adversely affect physiological and psychological functions and prolong a hospital stay and most importantly prolong post surgical recovery. Surgeons and anesthesiologist alike try to minimize discomfort by providing pre-operative and appropriate post operative medications.

Methods. The recent literature with regrads to PEMF therapy and NO metabolism was reviewed.

Results. The potential physiological steps of pain and edema reduction will be described in full detail based on the recent literature and correlated clinically.

Conclusions. Although the appeal of pain free surgeries may have once been a dream, this technology has brought forth the possible positive implications of a noninvasive pain control device. This is a miniaturized very portable device that can be worn over clothing, dressing, and garments. Its user friendly as there is no need for care except for wearing the device and can be easily camouflaged under clothing. This device can be used for any surgical procedure and current research is very promising.

Acknowledgements. Arthur Pilla, Patrick Maxwell
PEMF RAPIDLY MODULATES INTRACELLULAR SIGNALING EVENTS IN CULTURED OSTEOBLASTS.

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Summary of Abstract. Pulsed electromagnetic field (PEMF) treatment has been employed for augmentation of bone healing. However, a major limitation that decreases enthusiasm for the treatment of orthopaedic infirmities using PEMF is the scarcity of information regarding its molecular mechanisms of action. Specifically, there are only a few published reports suggesting that PEMF exposure induces immediate and rapid changes in cellular metabolism or tissue behavior. A recent study reported that PEMF treatment of MC3T3-E1 osteoblastic cells stimulated the rapid phosphorylation of the mammalian target of rapamycin (mTOR) and its downstream mediators, p70-S6 kinase and the S6 ribosomal subunit.

Objectives. The purpose of the current study was to build upon this theme and measure the rapid, time-dependent changes in the phosphorylation state of several key-signaling molecules by PEMF exposure of osteoblastic cells in culture. Further, this study sought to compare the kinetics and amplitude of these phosphorylation events with those induced by two anabolic agents for bone tissue, intermittent parathyroid hormone (PTH) and insulin.

Methods. Orthofix Inc. (McKinney, Texas) provided a PhysioStim® PEMF waveform generator connected to a Helmholtz coil-box housed within a cell culture incubator that was used for PEMF treatments. UMR106-01 BSP osteoblastic cells were plated at 1000 cells/mm² into individual 35 mm dishes. Our experimental design utilized a short kinetic protocol (2.5−30 minutes duration) using 5 µg/ml insulin, 100 nM PTH1-34 peptide, or PhysioStim® PEMF treatments to determine the activation of specific signaling proteins using phospho-specific antibodies. After various treatments, total cell lysates were obtained and centrifuged for 10 minutes at 10,000g to generate cytosolic fractions. Supernatant proteins were separated by SDS-PAGE and transferred to polyvinylidene difluoride (PVDF) membranes for Western blot analysis using phospho-antibodies (phospho-IRS-1, phospho-eNOS, phospho-CREB, phospho-Erk, and phospho-S6) and α-tubulin. Other cultures were immunostained with pS6 antibody and Alexa594-secondary antibody to permit laser-confocal microscopy detection of intracellular localization.

Results. PEMF treatment induced rapid phosphorylation reactions of select intracellular signaling molecules in cultured osteoblasts. Some signaling molecules like the extracellular response kinases 1/2 (Erk1/2) and the cAMP response element binding protein (CREB) were activated by insulin and PTH, respectively, but not by PEMF treatment. Other signaling molecules like the insulin receptor substrate-1 (IRS-1), the S6 ribosomal subunit kinase, and the endothelial nitric oxide synthase (eNOS) were phosphorylated by PTH, insulin and PEMF to the same relative extent and within the same time frame. Select pharmacological inhibitors of specific signaling kinases effectively blocked PEMF’s effects on intracellular signal transduction. Phosphorylation of the S6 ribosomal subunit enhances its translocation from the nucleus to the cytoplasm, and this event has been correlated with an enhancement in protein translation. Ten-minutes of PEMF treatment induced a
detectable elevation in phosphorylated S6 staining and its translocation to the cytoplasm in some of the cells.

**Conclusions.** Our study demonstrates that PEMF can induce intracellular signaling responses of comparable kinetic time frame and approximate intensity level to those induced by short-term insulin or PTH exposure. These observations suggest that PEMF may be able to induce canonical intracellular signaling responses in bone cells of sufficient speed and amplitude leading to sustained metabolic and physiological changes. In addition, both insulin (signaling through a receptor tyrosine kinase) and PTH (signaling through a G-protein coupled receptor) induce phosphorylation of IRS-1, eNOS and S6, and these proteins have been implicated in bone anabolism. Our results suggest that the anabolic effects of PEMF may be mediated, in part, through the activation of these proteins. Therefore, as PEMF phosphorylates some of these same molecules, it leaves open the possibility that PEMF may operate through a transient activation of both types of cell surface receptor families. Future investigations need to better define the receptors that are actually activated by PEMF.
10-1 RISK ASSESSMENTS USING NUMERICAL DOSIMETRY FOR RF WORKERS WITH METALLIC IMPLANTS

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Summary of Abstract. Risk assessments were performed for RF workers with metallic implants. Local peak SAR was calculated with the metallic implant inside a human phantom. The peak SAR was compared to the basic restrictions. Results obtained for various types of implants show that the basic restrictions are not exceeded at field exposures equal to the reference levels.

Objectives. According to international RF safety guidelines and standards RF workers can be exposed to higher levels of electromagnetic fields than the general public. It has also been established that the presence of metallic implants in a human body could increase the 10g averaged local peak SAR [1]. We have performed a series of risk assessments on RF workers with metallic implants working in an RF environment.

Methods. The first step was to assess the implant in accordance with the general guidelines proposed in [1]. If the specific implant was not covered by the guidelines in [1], a full wave numerical analysis was performed using the Method of Moments (MoM) and Finite Difference Time Domain (FDTD). For RF workers working on a mobile network the assessments were performed over a frequency range of 50MHz to 3GHz, taking into account exposure to share partner technologies. The visible human man was used for the simulations but the implant was positioned inside this phantom at a similar position and orientation as it occurred in the RF worker.

Results. Local 10g averaged peak SAR was calculated in all cases, with and without the implant in the human body. Field exposure was an incident plane wave with different polarization and different incident angles. Plane wave exposure was at the ICNIRP occupational reference levels for the different frequencies under investigations. The local peak SAR was then compared to the ICNIRP occupational basic restrictions. The difference between the ICNIRP basic restriction for limbs and the rest of the body was also taken into consideration. Finally, a risk assessment report was written for each individual case. The report details the methodology employed and concludes with the increased risk of over-exposure (if any) for the RF worker.

Conclusions. Results obtained for all the cases investigated thus far show that although the local peak SAR might be higher due to the implant, it is still well below the basic restrictions when exposed to reference level RF fields.

10-2 SAR CALCULATIONS IN A HUMAN VOXEL PHANTOM UNDER EXPOSURE CONDITIONS WHERE THE INCIDENT ELECTROMAGNETIC FIELD IS REFLECTED FROM A GROUND PLANE


Summary of Abstract. Whole-body averaged SAR, localised SAR and ankle currents have been calculated for the exposure of a human voxel phantom to electromagnetic fields from above and at 45° to the vertical under grounded conditions. In all exposure configurations studied, the ICNIRP reference levels and IEEE MPEs were found to provide a conservative estimate of the basic restrictions.

Objectives. If an electromagnetic field is incident onto a perfectly conducting ground plane from, say, above or at an incidence angle of 45° to the vertical, the incident field is reflected back into the domain above the ground plane. The result is a standing wave within this domain. Objectives of this work include the determination of whether these irradiation conditions cause compliance issues with electromagnetic guidelines, if a person is present, in terms of either whole-body averaged or localised SAR values.

Methods. Whole-body averaged SAR, localised SAR and ankle currents have been calculated for the exposure of a human voxel phantom to electromagnetic fields from above and at 45° to the vertical under grounded conditions. The finite-difference time-domain (FDTD) method was employed to do this, with the voxel phantom NORMAN (NORmalised MAN). NORMAN is a detailed, anatomically correct model of an adult male, derived from the partial-body MRI scans of a single human subject. Amongst the irradiation configurations studied were a vertically polarised electric field to the front (AP$_{V}$), a horizontally polarised exposure with the electric field orientated front to back from above (TOP$_{HFB}$) and exposure from an electric field aligned front to back at an angle of 45° to the vertical (ANG$_{FB}$). In all situations, time-harmonic plane waves were used.

Results. Whole-body averaged SAR values calculated for the phantom are presented in Fig. 1. For exposure from above, TOP$_{HFB}$, the SAR values are always lower than the AP$_{V}$ scenario and the location of the absorption in the body is determined by the positions of the peaks and troughs of the standing wave, set up by the reflection in the ground plane. This is shown in Fig. 2. Regarding calculated localised SAR, despite the reflection back into the computational domain for the TOP$_{HFB}$ and ANG$_{FB}$ exposures, these do not produce the highest localised SAR values when the phantom is grounded. Typically, for the frequencies studied in this work, the highest values occur for the AP$_{V}$ orientation. External field values required to produce basic restrictions on whole-body averaged SAR were calculated, and compared with guidelines. In all exposure conditions studied, the reference levels were found to provide a conservative estimate of the basic restrictions. Comparisons of occupational exposure reference levels with calculated field values required to produce restrictions on
localised SAR have also been considered. In a similar way, both ICNIRP reference levels and IEEE MPEs provide conservative estimates of the basic restrictions.

**Conclusions.** Calculations of SAR in a human voxel model have been performed for a variety of exposure conditions. Field reflections from the ground plane for exposure from above or at 45° caused the field amplitude to vary in the vertical direction. However, in the frequency range studied, this failed to produce SAR values higher than those calculated when reflection did not occur. The calculated external field values required to produce basic restrictions on the body for the whole-body averaged and localised SAR have been compared with IEEE and ICNIRP reference levels. These calculations show that the whole-body averaged SAR was more restrictive than localised SAR, and the reference levels provide a conservative estimate for both occupational and public exposure.

**Acknowledgements.** This work was carried out by the HPA with funding from EPRI.

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**Figure 1.** The whole-body averaged SAR for the various orientations under grounded conditions. The spatially averaged applied incident electric field was 1 V m\(^{-1}\) (rms).
Figure 2. SAR intensity plots for exposure from above at 300, 800 and 2000 MHz under grounded conditions. The spatially averaged applied incident electric field was $1 \text{ V m}^{-1}$ (rms).

10-3 PERSONAL RF ELECTROMAGNETIC FIELD EXPOSURE AND RELATION WITH ACTUAL ABSORPTION FOR GENERAL PUBLIC


Summary of Abstract. Personal electromagnetic-field exposure of the general public is characterized for 28 realistic exposure scenarios by a statistically relevant number of measurements. The E-field exposure is related to the actual whole-body absorption in the human body for a GSM downlink signal. 95th and 99th percentiles of the whole-body SAR of $3.97 \mu \text{W/kg}$ and $9.58 \mu \text{W/kg}$ are obtained for a 95th percentile of $0.36 \text{ V/m}$ of the E-field values for outdoor walking in an urban environment during the daytime.

Objectives. The objective of this paper is to characterize personal electromagnetic-field exposure of the general public. 28 realistic exposure scenarios are defined and a relevant number of measurements are executed with a personal exposure meter (PEM). A method to relate the exposure to the actual whole-body absorption in the human body is proposed.
Methods. People are exposed during their daily activities. Scenarios are defined and based upon four conditions: time, environment, activity, and location. The electromagnetic fields for these conditions will result in a different exposure: e.g., exposure of a person depends upon time (different exposure is expected during day time while people are working and e.g., making phone calls in comparison to at night when people sleep), etc. A selective isotropic personal exposure meter of type DSP120 EME SPY from Antenessa is used to assess the electric fields. The PEM can measure 12 frequency bands and identify the contribution of each emitter. Also a GPS device is used together with the PEM. In this way, the routes and activities of the persons wearing the PEM can be traced and checked. The PEM is worn by different persons in a backpack or shoulder bag when the person changes places (by walking, in the train, etc.), while for standstill, sleeping, etc., the PEM stands alone next to person. Measurement samples are acquired each 10 s for the different scenarios during at least 5 hours.

First, the cumulative distribution of the E-field PEM data of an RF source is determined and a known distribution function is fitted to this data. The parameters of this distribution can be used as input to the statistical tool described in [1]. Then, a human body phantom model is selected and 5000 simulations with this tool of [1] are performed. Next, the simulated fields and whole-body SAR (\(\text{SAR}_{wb}\)) distribution are rescaled to the value of each measured E-field PEM sample of the considered scenario. In this way each measured E-field sample is related with a distribution of 5000 \(\text{SAR}_{wb}\) values. Finally, the 95th and 99th percentiles \(p_{95}\) and \(p_{99}\) of the whole-body averaged SAR are determined as a function of the measured PEM E-field samples.

Results. Fig. 1 shows the 95\(^{th}\)- and 99\(^{th}\)-percentiles of the E-field values of the different RF-sources for scenario ”outdoor-walking-urban-day”. The RF source with the highest contribution for this scenario is GSM downlink (DL) with values of 0.36 V/m and 0.57 V/m \(p_{95}\) and \(p_{99}\), respectively. These values are below the ICNIRP reference level of 42.38 V/m at 950 MHz. Also FM, TV, DCS DL, and UMTS DL are present in the outdoor urban environment (Fig. 1). During daytime, phone calls of people using their mobile phones are also registered but these values occur more occasionally (GSM uplink (UL), DCS UL). UMTS UL is not registered (below sensitivity) because only a limited number of people in Ghent have UMTS enabled mobile phones or laptops.

Fig. 2 shows the \(p_{95}\) and \(p_{99}\) values of the SAR (\(p_X (\text{SAR}_{wb})\), with \(X = 95, 99\)) in a homogeneous spheroid model of an average man (half-axis \(2a = 1.75\) m and \(b = 0.138\) m, relative permittivity \(\epsilon_r = 41.4\) and conductivity \(\sigma = 0.99\) S/m of IEC 62209) as a function of the measured fields \(E\) [V/m]. The 95\(^{th}\)- and 99\(^{th}\)-percentiles of \(\text{SAR}_{wb}\) increase almost quadratic with increasing E-fields in an environment (Fig. 2). For e.g., \(E = 0.36\) V/m (95th percentile), SAR-values \(p_{95}(\text{SAR}_{wb}) = 3.97\) \(\mu\)W/kg and \(p_{99}(\text{SAR}_{wb}) = 9.58\) \(\mu\)W/kg are obtained. These values are much lower than the basic restriction of 0.08 W/kg for the whole-body SAR.

Conclusions. Personal electromagnetic-field exposure of the general public to 12 different radio-frequency sources is characterized for realistic exposure scenarios. For each scenario the exposure is determined by performing a statistically relevant number of measurements with a personal exposure meter.
The E-field exposure is related to the actual whole-body averaged absorption in the human body for scenario outdoor-walking-urban-day for a GSM downlink signal at 950 MHz. 95th and 99th percentiles of the whole-body SAR of 3.97 µW/kg and 9.58 µW/kg are obtained for a 95th percentile of 0.36 V/m of the measured E-field values.

REFERENCES

![Figure 1](image_url)

**Figure 1.** Electric field (E) of 12 different RF sources measured with PEM (95th- and 99th-percentile) for scenario day-urban-outdoor-walking (horizontal black line indicates the sensitivity of the PEM).
Figure 2. 95<sup>th</sup>- and 99<sup>th</sup>-percentiles of SAR<sub>wb</sub> and fit as a function of the electric field measured with the PEM (scenario: day-urban-outdoor-walking).

10-4 NUMERICAL ELECTROMAGNETIC DOSIMETRY FOR IN VITRO STUDIES AT MILLIMETER WAVES: IMPORTANCE OF NATURAL PHYSIOLOGICAL VARIATIONS IN CELLS

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Summary of Abstract. This paper provides numerical data on the local SAR distribution and average SAR for keratinocyte cell monolayers located inside a standard tissue culture plate exposed to low-power millimeter waves (MMWs). The influence of the physiological variations in cell monolayer thickness and water content is quantified and discussed.

Objectives. The main objective of this contribution is to estimate the effect of the physiological variations in the keratinocyte cells used in in vitro bioelectromagnetic experiments on the local and average SAR values within the cell monolayer exposed to MMWs.

Methods. We considered a standard 24-well tissue culture plate with a keratinocyte cell monolayer attached to the bottom of the well and covered by culture medium as a typical model commonly used in in vitro bioelectromagnetic studies at MMW frequencies. Different
numerical approaches were used and compared to find the SAR distribution inside the cell monolayer.
Tissue culture plates were exposed from the bottom by a normally-incident linearly-polarized plane wave at a superficial power density of 1mW/cm$^2$. Two particular frequency ranges have been considered: (1) the 57-64GHz frequency range dedicated to near-future applications in high speed wireless communication systems (e.g. wireless personal area networks) and (2) the discrete frequencies commonly used in MMW therapy, namely 42.25GHz, 53.57GHz, and 61.22GHz. The electromagnetic (EM) problem was solved numerically using the frequency-domain finite element method (FEM). This method in combination with a non-uniform adaptive tetrahedral mesh has an excellent capability to model objects with complex shapes and small sub-structures at MMW frequencies. In order to confirm the accuracy of the numerical results obtained using the FEM, the same problem was solved using the finite integration technique (FIT). The dielectric properties of keratinocyte cells and culture media were determined using permittivity data of free water and Maxwell’s mixture equation.

**Results.** The local SAR distribution and average SAR were calculated numerically within the cell monolayer and compared at different frequencies. The cell monolayer was approximated by a homogeneous uniform layer with a thickness of 30µm. It was found that at 60GHz the maximal deviation of local SAR within the cell monolayer was equal to ±35%. The power transmission coefficient as defined as the ratio of the average intensity of the internal EM field within the cell layer and the intensity of incident plane wave was equal to 0.55. The average SAR was found by averaging the local SAR values over the cell layer volume. It was shown that for the considered frequencies the typical average SAR within a cell monolayer is in the range of 13-16W/kg. The results provided above were obtained for a cell monolayer with average water content (65%) and constant thickness (30µm).

However, it is important to consider physiological variability of these parameters in the keratinocyte cells in order to estimate their contribution to the resulting SAR. Since the typical size of keratinocytes varies from 10µm to 30µm and their water content is in the range from 57% to 73% (F. A. Duck, Physical properties of tissue. Bath, England: Academic Press, 1990), we computed the average SAR resulting from MMW exposure as a function of these two characteristics. Variations of the average SAR corresponding to the above variations of the water content were equal to ±1.3W/kg. The maximal variation of the average SAR obtained for the different thickness of the cell monolayer was equal to ±0.2W/kg. The results obtained by the FEM were in excellent agreement with the calculations performed using the FIT.

**Conclusions.** In this study we analyzed the SAR distributions within a cell monolayer in a tissue culture plate exposed to MMWs. The typical average SAR within a cell monolayer for the considered frequencies was in the range of 13-16W/kg. The maximal variations of the local SAR within the cell layer at 60GHz were found to be ±35%. The contribution of the physiological variations of the water content in the keratinocyte cells as well as variability of the cell monolayer thickness to the resulting average SAR was determined. It was shown that average SAR varies significantly as a function of cell water content, whereas the thickness of cell monolayer has little impact on the results.
**Acknowledgements.** This study was supported by National Institute of Health, NIH NCCAM, USA under Grant No. P01-AT002025; National Research Agency, France, under Grant No. 2006 SEST 19 02 (HIMWR project); and Health and Radiofrequency Foundation, France, under project “StressOM”.

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10-5 PERMITTIVITY AND PENETRATION DEPTH OF MILLIMETER WAVES IN HUMAN AND MURINE SKIN

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**Summary of Abstract.** Millimeter wave reflection measurements were used for determination of human and murine skin permittivity. In modeling mm wave reflection, unilayer and several multilayer skin models were tested. It was accepted that the permittivity of skin in the mm wave frequency range is adequately described by the Debye equation. Using Fresnel equations for reflection we determined the skin parameters best fitting to the reflection data and derived the permittivity of skin layers. The permittivity data of skin was further used for calculations of the penetration depth, power density and SAR profiles within the skin and for determination of water content in different skin layers.

**Objectives.** The aims of the present study were: (1) to measure mm-wave reflection from human and murine skin; (2) to develop skin models which fit best to the experimental data; (3) to apply the successful models to find permittivity of skin layers; (4) to use the obtained permittivity values to calculate (a) the power density and SAR profiles; (b) the penetration depth of mm waves in skin; (c) the free water content in healthy skin treated with different hydrating substances (lotion, pure water, glycerol, and petroleum jelly).

**Methods.** Seven male and five female volunteers ranging between 45 and 60 years of age participated in this study with the approval of the Temple University Institutional Review Board. They were informed about exposure relevant to human health and they freely gave their consent to participate in this study. In animal studies we used two strains of mice: male Swiss Webster hairy mice and female SKH1-hairless mice. The Institutional Animal Care and Use Committee of Temple University approved the experimental protocols. We used ten animals of both strains in each experiment. Reflection was measured at the open ended waveguide applied to the skin in the 37-74 GHz frequency range.

In modeling mm wave interaction with skin, we applied homogeneous unilayer and multilayer skin models. The four layer model contained (1) the stratum corneum (SC), (2) the viable epidermis plus dermis, (3) fat layer and (4) muscle which had infinite thickness. The permittivity of each skin layer was described by the Debye equation with a single relaxation time equal to that of pure water at skin temperature. The permittivity increments found
from fitting the skin models to the reflection data were used for determination of the volume fractions of free water in the skin layers. To calculate the power reflection coefficient and power density profiles as a function of skin depth we applied the Fresnel equations.

**Results.** Our approach first tested in pure water and gelatin gels with different water contents gave a good agreement with literature data.

Reflection from both human and murine skin decreased with increasing the frequency. At each frequency tested, reflection from the palm was lower than reflection from the forearm. Permittivity of the forearm skin obtained with the homogeneous model was close to the skin permittivity reported by others. The thin SC in the forearm and murine skin had little influence on the interaction of mm waves with skin. The thick viable epidermis plus dermis in humans, containing a large amount of free water, greatly attenuated mm wave energy. However, millimeter waves penetrate into the human skin deep enough ($\delta = 0.65$ mm at 42 GHz) to affect most skin structures located in the epidermis and dermis. The deeper fat and muscle layers had little effect on the power density and SAR profiles. We observed the appearance of a moderate SAR peak in the therapeutic frequency range (42-62 GHz) within the skin at a depth of 0.3-0.4 mm. In murine skin, due to the thinner epidermis, dermis, and fat layers, 42 and 32% of mm wave energy entering the skin at 42.25 and 61.22 GHz, respectively, reach the muscle layer.

Millimeter wave reflectometry was used for determination of the free water content in human skin treated with different moisturizers (skin lotion, pure water, glycerol, and petroleum jelly). Treatment of the forearm and palm skin with different hydrating substances did not produce notable changes in the free water content of the viable epidermis and dermis. The only layer affected by moisturizers was the SC. The greatest hydration was produced by pure water and skin lotion and the lowest by Petroleum jelly. Petroleum jelly may be used for prolonged retention of water in the SC following its hydration by other moisturizers.

**Conclusions.** It was shown that mm wave reflectometry was an adequate method for the determination of skin permittivity in the mm wave frequency range. Besides, this method could be applied for the determination of the water content in the different skin layers in vivo. Calculations made with multilayer skin models revealed that mm waves penetrated deeper in murine skin than in human skin. In human skin most energy of mm waves was absorbed within the epidermis and dermis while in murine skin mm waves reached the muscle layer. Therefore, when extrapolating the effects of mm waves found in animals to humans, it is important to take into account the possible involvement of the muscle structures in animal effects.

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Summary of Abstract. This paper deals with variability of body models used in numerical dosimetry studies. Six adult anthropomorphic voxel models have been collected and used to build 5-, 8- and 12-year-old children using a morphing method respecting anatomical parameters. Finite-difference-time-domain (FDTD) calculations of specific absorption rate (SAR) have been performed for a range of frequencies from 20MHz to 2.4GHz for isolated models illuminated by frontal plane waves. Variability of input data i.e. numerical models and of output data i.e. SAR has been assessed.

Objectives. Several studies have been performed to analyze adults and also children behaviour towards electromagnetic exposure. The main limitation of lot of these studies is linked to the variability. Human population is highly diverse and it is impossible to generalize any result obtained on one model. The objective of this paper is to push back this limitation using several adult models.

Methods. For this study, five male adult models and one female adult model have been gathering: Visible Human, Norman, the Japanese models male and female, the Korean model and Zubal The six adult models represent different types of morphology. To enlarge the models sample, child models have been constructed from adult models. 5-, 8- and 12-year old children have been built by a piecewise reduction of adult models. This study is focused on exposure assessment to an incident frontal vertical polarized plane wave for isolated conditions. Exposure is quantified by specific absorption rate (SAR). SAR is calculated by using an in-house code based on Finite Difference Time Domain (FDTD) method.

Results. First results concern variability of adult models. Main external parameters as heights, masses and ensuing Body Mass Index (BMI) have high standard deviations. Concerning internal morphology, skin, bones, muscles and fat constitute about 85% of the total mass for all phantoms and are very different from one model to another. Concerning children, they have been constructed in order to respect mean parameters of 5-, 8- and 12-year old child found in the literature. Concerning adults’ exposure, numerical calculations have shown for all phantoms a resonance around 70MHz of the whole-body (wb) SAR. Figure 1 shows the mean evolution of wb SAR induced in adult models and the bounds of interval $\pm \sigma$ the standard deviation. ICNIRP has recommended limits to protect general public against overexposure to electromagnetic fields. Basic restrictions define among others a limit value for the whole body averaged SAR. Reference levels have been also defined in order to ensure respect of these basic restrictions. Figure 2 displays wb SAR for the six adult models for an incident power density equal to ICNIRP public exposure reference levels. Around 2GHz, the Japan female is very closed to the basic restriction.
Finally, concerning children, they represent mean children. So, their variability is by construction low. The wb SAR has the same evolution as for adult but the frequency’s and amplitude’s resonance are higher. Figure 3 displays wb SAR for the mean children models for an incident power density equal to ICNIRP public exposure reference levels. Fast all children have a wb SAR exceeding the basic restriction around 2GHz.

**Conclusions.** Before any calculation, morphology variability of adult models used in this study has been pointed out.

The morphology variability affect induced SAR in models. FDTD calculations have pointed out an important variability of whole body averaged SAR implying a standard deviation from 10% to 30% depending on frequency.

By subjecting adult models to ICNIRP reference levels of public exposure, we point out that all the adult models used in this study respect basic restrictions but are not so far from them. Moreover the variability of models leads to envisage models that might exceed basic restrictions.

Concerning children, morphing’s method enables to obtain more realistic models than by a simple homothetic transformation. Children have behaviour similar to adults. A whole body resonance appears at a frequency and with amplitude increasing with decreased age.

By subjecting children models to ICNIRP reference levels of public exposure, we point out that a number of the children models used in this study exceed basic restrictions around the gigahertz region.

As the 6 adult models are of course not representative of the entire human population, analysis of uncertainly linked to human variability should be examined in more detail in further work.

**Acknowledgements.** Dr Watanabe, Dr Lee, Dr Dimbylow, Dr Mason, Dr Ziriax and Pr Zubal to have provided models.

![Figure 1](image)

**Figure 1.** Mean evolution and standard deviation of wb SAR induced in adult models. Incident power density=1W/m^2
Figure 2. Whole body averaged SAR for the six adult models depending on frequency for an incident power density fixed by ICNIRP reference levels.

Figure 3. Whole body averaged SAR for the mean model (for adult and children) depending on frequency for an incident power density fixed by ICNIRP reference levels.
10-7 MEASUREMENTS OF CONTACT CURRENTS INDUCED BY ELECTRICAL FIELD IN HIGH VOLTAGE SUBSTATIONS

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Summary of Abstract. We have measured contact currents occurring when workers in high voltage substations touch grounded objects.

Objectives. The ICNIRP 1998 guidelines have a reference value for electric field of 10 kV/m and a reference value for magnetic field of 500 µT, at 50 Hz. Our measurements have shown that the electric field strength quite commonly exceed this reference value in 400 kV substations, while the magnetic field usually is within the reference value. The ICNIRP’s guidelines give the opportunity to increase the reference value to 20 kV/m, if adverse indirect effects from contact with charged conductors can be excluded. The reference value for a 50 Hz contact current is set to maximum of 1 mA.

Methods. In this study the contact current have been measured for different work tasks, to see for which situations the reference value is fulfilled. The work in a substation involves touching of control units of circuit breakers and disconnecting switches as well as other grounded metallic objects exposed to high electrical fields. For stationary body to ground contact current, i.e. when contact has been established, the current was measured using a sensitive ampere meter. Pre contact spark discharge currents were measured with a current probe connected to a digital oscilloscope.

Results. An example of measured stationary contact current, when touching breaker units is shown in Figure 1. Much higher peak currents were registered when spark discharges were measured at pre contact with a grounded object, see Figure 2. The spark discharges was found to cause the most annoyance by their stimulation of muscle nerves, but such discharges are not limited in the guidelines. Levels of up to 1.75 A during a fraction of a second where obtained.

The contact currents were measured for most ordinary work tasks in 3 different 400 kV substations. The highest stationary current value (RMS) when a person touches a single grounded object was 0.18 mA. A worse case is when a person simultaneously touches an ungrounded object exposed to the electric field and a grounded object at the same time. A contact current of 1.17 mA was measured when a person simultaneously touched a van and a grounded pole.

By using clothing with a grounded metal strip and semi-conducting boots the contact current could be reduced by 20 %. If a conducting grounded helmet was added, the reduction increased to 45 %.

Conclusions. The conclusion is that the stationary contact currents are below the reference value if simultaneous touching of grounded and ungrounded objects in the field is avoided. Thus, for most work situations, the reference value for electric field can be raised to 20 kV/m, a field strength that usually is not exceeded in 400 kV substations.
Figure 1. Stationary contact current, when a person, of the length 1.80 m, touches a grounded breaker unit, note the tendency to sparks.

Figure 2. Spark discharge current measured before contact is reached, when a person, of the length 1.80 m, touches a grounded breaker unit.

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10-8 THE IMPORTANCE OF DOSIMETRY IN IDENTIFYING ARTIFACTS IN RF BIOLOGICAL EFFECT STUDIES

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**Summary of Abstract.** There are more than 50 years of research on the question of safe human exposure to radio frequency energy resulting in the development of today’s internationally accepted maximum permissible exposure levels. There is a strong consensus of scientific support for these standards that are based on reviews of the peer-reviewed literature including both high and low RF exposure levels and established RF-induced effects. However, public controversy still exists today since both positive and negative effects continue to be reported on many different biological endpoints at low exposure levels. Because there is no known mechanism to explain any observed effect at low levels, the changes have been called “non-thermal effects” by some researchers. The problem in confirming that the effect is indeed ”non-thermal,” and not a weak thermal effect or an artifact, contributes greatly to the controversy about bioeffects of RF exposure. Simply labeling a change as a “non-thermal effect” lacks scientific merit.

**Objectives.** The objective of this presentation is to show the importance of dosimetry in identifying a weak thermal effect or artifact in low level RF biological effect studies. This requires proper exposure and dosimetric techniques, as well as a good understanding of electromagnetics and thermodynamics.

**Results.** As a graduate student in 1971, Chou’s first project in bioelectromagnetics was to replicate a Soviet study reported in the 1960’s showing a non-thermal effect of microwaves on action potentials of isolated nerves. The research showed that when the nerve was kept in a temperature-controlled waveguide filled with physiological solution, no effect on action potentials other than thermal in origin was observed, even if the nerve was exposed to very high pulsed power levels with peak SAR up to 220 kW/kg. US investigators in 1965 reported behavioral effects in rats at a low power density level (1 mW/cm\textsuperscript{2}); however, a more thorough dosimetry evaluation showed the effect to be due to a high SAR. Because of a poorly designed exposure system, the SAR was found to be as much as 185 W/kg (a hyperthermia level) in the hind legs when the rat’s tongue touched the water bottle and the legs and tail were in contact with the metal ground plane [1]. Without these detailed dosimetry data, the behavioral effect was misinterpreted as evidence of a non-thermal RF effect. In the late 70’s, we were on the verge of reporting a non-thermal RF effect on tumor cells, until we realized there was a significant temperature gradient at the monolayer at the bottom of the cell culture container. More recently in 2006, de Pomerai et al. [2] reported that their earlier published paper claiming that SARs of 4–40 mW/kg induced an apparently non-thermal heat-shock response in nematodes was incorrect. Careful dosimetry showed that a small temperature rise explained the effect. In 2007, Tattersall [3] reported...
that the effects of low intensity RF fields on electrical activity in rat hippocampal slices published in 2001 were due to heating at the metal electrodes. In 1972, Johnson and Guy [4] had shown that metal electrodes in the cat brain can induce intense heating at the electrode tip. Although it is well known that one should not heat a drink or food in containers with a metallic rim inside a microwave oven, exposing human subjects to RF fields while with metallic electrode leads attached to their heads is a common practice nowadays in EEG, sleep, and headache studies. Whether any observed effect is due to the RF field or the induced current through the leads is difficult to determine. Chemists in Austria found no evidence of differences between four chemical reactions occurring under microwave and conventionally heated conditions when stirring was efficient (Herrero et al. 2007) [5], earlier studies had reported “non-thermal” effects on these reactions. RF heating is volumetric (heating from inside) and conventional heating is by conduction (heating from outside where the source is). The RF heating rate and heating distribution are difficult or impossible to match identically. The results of Herrero et al. are important in evaluating claims of “non-thermal” effects in biological systems exposed in vitro. These examples show the importance of persistent dosimetry research to help identify reasons to explain positive RF bioeffects.

**Conclusions.** Because of the complex interaction between RF fields and biological systems, researchers must include detailed and accurate dosimetry as an integral part of their biological studies to make their efforts useful for the understanding of RF bioeffects.

**References:**
P6-1 MECHANISMS FOR RF EFFECTS ON BIOCHEMICAL REACTIONS

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Summary of Abstract. This is a review paper of mechanisms by which radio frequency fields, RF, can modify biological systems. It will trace these effects from the physics through the chemistry and biology to the potential for health effects. The objective of this review is to help develop a chain of logic that shows the steps that will be required in order to develop models that lead to biological changes and in turn have the potential to lead to health effects. These models need to include the effects of variations in frequency, amplitude, length of exposure and the initial state of the biology.

We begin by briefly looking at an example of short high power pulses on membranes. This is followed with a discussion of heating and calculations for the heating of tissues and its effects on chemical reaction rates. It is shown that both the peak temperature and rate of change of temperature can be important.

The gradient of the RF fields can both lead to drift currents of molecules with induced dipole moments and provide forces that change their orientation. The induced drift currents can become important when they are on the order of the natural diffusion or drift currents and have a potential for providing a way signaling cells. Additionally temperature gradients and lead to convection currents. These signals can be amplified to change the firing rate of pacemaker cell, growth rates and possibly the direction of migration of neutrophils.

In closing we will look at the possible effects of the Stark and Zeeman effects on excited state energy levels and their possible effects on chemical reaction rates.
11-1 A SOLID SAM HEAD FOR TRP AND TIS TESTING

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Summary of Abstract. We have developed a solid SAM (SS) head to replace the liquid-filled SAM phantom in OTA testing where a liquid phantom is not functionally required. We have obtained TRP and TIS data for GSM 900, DCS 1800 and UMTS handsets using both SS and liquid-filled head phantoms. The results will be presented and discussed.

Objectives. The aim is to present the manufacturers and operators of RF telecommunication equipment and networks with a practical alternative to the liquid-filled head phantom for performance testing of cellular handset transceivers. The objectives are as follows:

To develop a mouldable, solid material having dielectric properties similar to those of tissue equivalent liquids.

To use the material to produce a head phantom for use in over-the-air (OTA) performance tests of cellular telecommunication handsets.

To carry out total radiated power (TRP) and total isotropic sensitivity (TIS) for different handsets using the newly developed SS and the traditionally used liquid-filled SAM head phantoms.

To obtain sufficient technical data to support a proposal to technical standards committees to consider solid tissue equivalent phantoms where it proves advantageous.

Methods. The material for SS heads should have dielectric properties similar to those of the liquid tissue equivalent material currently used; it should be mouldable, and sufficiently stiff to retain its shape under test conditions; sturdiness and durability are also desirable properties. We have developed such a material, it is a carbon-silicone mixture, its dielectric properties are given in Figure 1 where they are compared to those of the liquid used for SAR testing (see, for example, IEEE Std 1528T-2003) and those of the liquid in the 2003 CTIA document (Method of Measurement for Radiated RF Power and Receiver Performance March 2003 Revision 2.0).

Results. A SS has been made from the new developed material (Figure 3), the carbon/silicone mixture replaces the liquid part that fills the inner SAM head, a section of the shell covers the ear region to enable correct positioning with respect to the ear and the lossy material.

TRP and TIS tests were carried out on handsets using SS (Figure 2) and a liquid filled SAM shell. The results for 3 handsets operating GSM 900, DCS 1800 and UMTS are given in Figure 3. TRP and TIS are expressed in dBm, the agreement is good and no systematic differences are observed.
Conclusions. The use of a liquid-filled SAM head for TRP and TIS is potentially problematic (air bubbles, leakage, spillage and deterioration of the liquid). For this reason, we propose the use of a SS head phantom instead. Our results show good agreement between TRP and TIS data obtained using the liquid-filled and the a solid SAM model developed.

Acknowledgements. I am grateful to Dr. Andrea Schiavoni and his team for carrying out the TRP and TIS measurements.

Figure 1. Permittivity and conductivity of the solid tissue equivalent material compared to those of the liquid used for SAR testing (solid line) and those of the liquid in the CTIA procedure (square symbol).
**Figure 2.** Inner SAM-shaped-solid head with an outer SAM shell earpiece with all the markings.
Figure 3.
11-2 MAGNETICALLY INDUCED CURRENTS FOR SELECTIVELY DESTROYING PINE BEETLES IN SITU

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Summary of Abstract. A system for magnetically inducing currents which could treat trees infested with pine beetles is described and dosimetrically modelled.

Objectives. To utilize magnetically induced currents to heat (and/or shock) pine beetles and their larvae which have infected the sap layer (xylem) of coniferous trees so that maximal inactivation of the insects is achieved with minimal damage to the tree.

Methods. BACKGROUND AND METHODS: In recent years the mountain pine beetle (dendroetonus Ponderosae) has been infesting and destroying millions of trees in the western USA. In recent years the infestation has reached the western slope of Colorado and now is poised to cross the continental divide and “swoop” down the eastern slope of the Rockies into the western suburbs of the Denver-Boulder area. So far, the only effective counter measure has been “slash and burn” —i.e. to cut down and remove enough of the infected trees to allow “natural” forest defenses (such as cold winters or very hot summers) to keep the infestation in check. Spraying with pesticide has been less effective and carries with it a substantial risk of damage to the environment and human health. It seems to us, however, that less draconian approaches may be effective. One of these would be the use of in situ hyperthermia on pine trees which are in a relatively early stage of larval infestation. Ideally, we would like to heat the larvae to a point of inactivation (or death) and do only minimal damage to the tree. We believe that magnetically induced currents might be an optimum means of achieving this goal. There have been a number of past studies utilizing microwaves or RF energy to thermally treat insect infested lumber. For example, Fleming et. al. (2005) used commercial 2.45 GHz microwave equipment to kill cevambyed larvae and pinewood nematodes that were infesting freshly cut lumber. They found that wood temperature elevation to 620 C produced 100% insect and larval mortality for 4”x4” x 20” logs and lower temperatures sufficed to achieve the same effect in 1” thick boards. Such temperature elevations if restricted to the subbark layer for short periods (a minute or less) should not damage living pine trees unduly. Attempts to annihilate larva in living trees using low level microwaves (producing little or no temperature rise) have been less successful—as for example reported by Whitney and Charadly (1984). On the other hand, other methods that are hyperthermically based have been shown to be effective in laboratory situations—as, for example using concentrated solar energy [Negron et. al. 2001]—which would not be practical in an actual forest.

Our approach to magnetically inducing currents in the sap layer (xylem) is essentially to use that cylindrical conductor as the secondary of transformer. A single loop of conductor, (such as a sheet of copper or aluminum foil) driven by a low voltage, high current, generator would comprise the “primary” of an equivalent transformer while the “secondary” would be
the high conductance xylem loop within the tree. A thermally insulating blanket around the primary conductor will increase the efficiency of the design by minimizing heat loss to the atmosphere—and would also add a measure of electrical safety since it could prevent contact shocks to the operator. For this initial study, we have explored the efficacy of the design by calculating the source power required and the energy deposition pattern that it would achieve and have used that to get a sense of its practicality. Another approach, which we are also considering, would use a much lower frequency (perhaps 60 Hz) induced current that could destroy the beetles by virtue of electric shock rather than hyperthermia. In principle, this could be accomplished with very little temperature elevation so that the deleterious impact on the tree would likely be less than with hyperthermia.

**Results.** Our calculations indicate that induced currents could be expected to be highest in the larvae and thus achieve lethal hyperthermia there with only minimal thermal impact on the rest of the tree. The exposure of the larvae would be relatively uniform around the circumference of the inner bark surface and along the length of the exposure cylinder. Thus it could be effective even in infested areas of the tree which have not yet outwardly manifested the presence of beetles or their larvae. Source power output would need to be in the range of several thousand watts if effective hyperthermia levels were to be reached within a few minutes. Such sources may be practical even in a remote forest setting as they could be of manageable weight and driven by fairly compact portable electric generators.

**Conclusions.** A particularly cost effective and environmentally sound application of this induced current approach would be to save “high value” coniferous trees from sacrifice—as, for example, large pine or spruce trees in parks or residential landscapes where sufficient power could probably be drawn from domestic sources (e.g. an electric outlet designed for powering clothes dryers or other high wattage loads). This approach should be far less costly than spraying with pesticides – both from a monetary and an environmental standpoint.
**11-3 CHILDHOOD LEUKEMIA IN RELATION TO RADIOFREQUENCY ELECTROMAGNETIC FIELDS EMITTED FROM TELEVISION AND RADIO BROADCAST TRANSMITTERS: A CASE-CONTROL STUDY IN GERMANY**

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**Summary of Abstract.** Almost 2000 cases of childhood leukemia living in the vicinity of high power TV and/or radio broadcast transmitters in Germany between 1984 and 2003 were enrolled in a case-control study to study radiofrequency electromagnetic fields (RF-EMF) as a possible risk factor. We observed no association with overall RF-EMF and no associations with amplitude-modulated fields or frequency-modulated fields separately.

**Objectives.** Leukemia is the most common type of cancer in children accounting for about one third of all cancers in children under the age of 15 years. Little is known about the causes of this disease. For several decades, electromagnetic fields have been investigated as a possible risk factor, however, few studies are available on radiofrequency fields. This study examines the possible association between childhood leukemia risk and exposure to radiofrequency electromagnetic fields emitted from TV or radio broadcast transmitters in Germany.

**Methods.** The study has started in March 2005 with a pilot investigation in order to specify the study design. For the main study, 25 regions with high power TV or radio broadcasting transmitters have been selected in West-Germany. Cases are children aged 0 to 14 years with a primary leukemia diagnosed between 1984 and 2003 who lived in the vicinity of these TV- and/or radio towers. The study area was defined as all communities at least partially within 120 dB(µV/m)-circle centered around AM radio towers or a 90 dB(µV/m)-circle centered around FM/TV towers, including all related municipalities. Cases have been identified by the national German Childhood Cancer Registry. Three controls per case have been individually matched by age at diagnosis, sex, time of diagnosis and study area. The retrospective exposure assessment is based on data from transmitter network operators. Reliable reconstruction of the technical operation and radiation characteristics of all transmitter sites contributing significantly to the radiofrequency electromagnetic exposure in the area were available. The exposure level for each place of residence of cases and controls one year before diagnosis was calculated. Furthermore, the distance between residence and the nearest transmitter station was considered in the analysis. Conditional logistic regression analyses was used to estimate odds ratios. In a validation study, the exposure metric of calculated radiofrequency fields was compared to actual field measurements.

**Results.** A total of 1959 cases and 5848 controls have been included in the analysis. The odds ratio for all types of leukemia did not show an increased risk (highest 10% percentile compared to the 90% lowest percentile): OR 0.8 (95% confidence limits 0.7-1.0). Stratification for transmitter types or subtypes of leukemia yielded similar risk estimates. Further
results will be presented at the meeting. The validation study showed a satisfactory agreement between measured and calculated fields and revealed that using distance is not a good exposure proxy in studies combining exposure from various transmitters.

**Conclusions.** This population-based epidemiological study with individual exposure assessment involving almost 2000 cases showed no association between childhood leukemia risk and exposure to radiofrequency electromagnetic fields.

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**11-4 INTERPHONE STUDIES TO DATE, AN EXAMINATION OF POOR STUDY DESIGN RESULTING IN AN UNDER ESTIMATION OF THE RISK OF BRAIN TUMORS.**

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**Summary of Abstract.** INTERPHONE is a 13-country case-control study on the risk of brain tumors and parotid gland tumors from cellphone use. This is an investigation into 6 INTERPHONE Protocol design flaws. Eleven brain tumor studies have been published. Two of the 11 Interphone studies partially overlap other studies. Thus, 9 studies were evaluated. The data was reviewed, asking what if there is no risk? If there is no risk of brain tumors, then about half would have an odds ratio (OR) <1.0, and about half would have OR>1.0 (not counting OR=1.0). Additionally, about 5% of the all ORs would be significant.

**Objectives.** To identify the 7 flaws and report the evidence and/or missing information that generates these flaws.

**Methods.** All non-redundant ORs, confidence intervals (CI), date range of eligibility, percentage participation of cases & controls, and subscribers by year were entered into an Excel spreadsheet. This data was arranged into 4 categories: significant results for 10+ years, non-significant results for 10+ years, significant results for <10 years, and non-significant results for <10 years. These 4 categories were then arranged into 4 sub-groups: all brain tumors, acoustic neuromas, gliomas, and meningiomas. Weighted average calculations were made for eligibility time, eligibility date, and percentage participation of controls and cases. Percentage of subscribers by latency time was calculated as well as the weighted average number of cases & controls Results were analyzed in the context of the 7 flaws.
Results. All but 2 of the 9 studies reported use of a cellphone provided a total of 47 significant “protective” results (OR<1.0). The 2 studies without significant “protective” results had 0 cases for cellphone use of 10+ years. This incredulous result is prima facie evidence of design flaws. Seven flaws were investigated, 6 of them underestimate the risk of tumors. For an examination of the number of ORs <1.0 and >1.0, and the OR ratios (OR<1.0/OR>1.0), see Table 1. For the percentage of observed vs expected ORs, see Table 2. Flaw 1, Selection Bias: The weighted average participation rate of controls was 59%. If participating controls use cellphones more than non-participating controls, then selection bias will exist. This will result in an underestimation of risk. Flaw 2: Tumors outside the cellphone’s radiation plume, even when ipsilateral use is reported (acoustic neuromas excepted), are unexposed tumors. A cellphone’s radiation plume penetrates a small proportion of the brain’s volume. Nearly all of it is absorbed by the temporal lobe, the acoustic nerve, or the parotid gland. Inclusion of tumors unexposed to the plume results in an underestimation of risk. Flaw 3: Latency time and definition of “regular” cellphone use includes a large percentage of users, given the rapid increase of subscribers, who have been exposed for less than any reasonable assumption of brain tumor latency time. This results in an underestimation of risk. Flaw 4: Children and young adults are not included. The Interphone Protocol states that cases be between 30 and 59 years of age. While a few studies have included cases as young as 20, the non-inclusion of <20 year olds results in an underestimation of risk because children, with their high rate of cell division, are at higher risk of tumors than adults. Flaw 5: The cellphone’s radiated power is not generally considered. In urban areas digital cellphones, radiate far less power, than in rural areas. When rural and urban cellphones are not reported separately, the result is an underestimation of risk. Flaw 6: Cordless phone users treated as unexposed, the result is an underestimation of risk. Flaw 7: The number of cases and controls who have used a cellphone for 10+ years is too small to determine if there is, or is not, a risk. Table 3 presents both the numbers and percent of such users.

Conclusions. With 6 flaws, each independently underestimating the risk of tumors, suggests why the Interphone studies report such a large number of significant “protective” results. Because the cellphone industry provides a substantial proportion of the funding there is an inherent conflict-of-interest issue. The cellphone industry states, when addressing potential conflict-of-interest issues, that there is a “firewall” between their funds and the research teams who do the studies. While it is true that the cellphone industry provides the funds to another organization (UICC), which then decides on the teams for each study, the researchers are aware that a substantial proportion of their funds are coming from the cellphone industry. There is no reason to doubt the integrity of the researchers. Yet, an inherent conflict-of-interest still exists, best described by the saying, ”Don’t bite the hand that feeds you.” This could result in downplaying actual results. However, the fundamental problem is not conflict-of-interest. The fundamental problem is the Interphone Protocol, and independently, the available funds. To resolve these flaws would require additional funding. The Interphone Study has substantial, yet insufficient funding, from the cellphone industry. In addition if the participating countries had calculated the potential cost of a pandemic of brain tumors, the cost effectiveness of contributing additional funds, would have been obvious. Tragically, the opportunity to do a large, well-designed case-control
study is closed. Case-control studies require exposed and unexposed subjects. It is no longer possible to find unexposed subjects.

11-5 UPDATED META-ANALYSIS OF MOBILE PHONE USE AND BRAIN TUMORS

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Summary of Abstract. None

Objectives. Two recent meta-analyses of studies published through early 2007 have evaluated the use of mobile phones and risk of brain tumors. However, these meta-analyses used different exposure classifications: one of latency, the other of “regular use” and duration of use and arrived at different conclusions (Hardell L, et al. Occup Environ Med 2007; 64:626-632 and Kan P, et al. J Neurooncol 2008; 86:71-78, respectively). Also, these two meta-analyses did not include the same set of studies. Four additional case-control studies not included in either meta-analysis were published in 2007 and 2008 and three case-control studies of acoustic neuroma published between 2002 and 2006 were not included in the meta-analysis of regular use (Kan et al). We have included these studies in an updated meta-analysis of mobile phone use and brain tumor risk, considering exposure assessments defined as regular use, and duration of use, latency, and other categories.

Methods. Using MEDLINE we exploded the search terms of brain tumor, acoustic neuroma, meningioma, glioma, and cellular telephone to locate any additional studies through 2008 that reported information on mobile phone and brain cancer risks. Meta relative risks (RRs) and 95% confidence intervals (CI) were calculated using a random-effects model (stratified by specific tumor types) for regular phone use, duration of use, and latency. Sensitivity and influence analyses were also conducted.

Results. Of 35 initially identified publications, 17 case-control studies containing 8,272 cases of brain tumors and 17,398 controls were included. Studies excluded overlapped with included studies or did not report data for regular or duration of use. Eight studies reported results for regular mobile phone use and risk of acoustic neuroma, ten for risk of glioma, and eight for risk of meningioma. The meta RR for regular use and risk of acoustic neuroma was 0.86 (95% CI: 0.74-1.01). For glioma the meta RR was 0.87 (95% CI: 0.77-0.99) and for meningioma was 0.78 (95% CI: 0.68-0.91). Four studies reported information on duration of use greater than 10 years by tumor type. The meta RR for all types brain tumors combined was 1.07 (95% CI: 0.83-1.37). Our meta RR value regular use remains similar to Kan et al values despite the addition of new studies. For duration of use, our meta RR was lower than
the value reported by Kan et al, which could be explained by differences in the estimates used in analysis.

**Conclusions.** We observed no increased risk by specific type of brain tumor with regular use of mobile phones. We also did not observe a risk with duration of use greater than 10 years. Our results are counter to results obtained by the Hardell et al meta-analysis, which analyzed latency and not duration of use, and did not calculate summary relative risks for “regular use”. Future IARC publications that will pool all of the data across INTERPHONE studies and assess a variety of exposure metrics should help to resolve these discrepancies.

**11-6 COMPARISON OF SAR VALUES FOR CHILD AND ADULT HEAD MODELS DUE TO DIFFERENT USAGE CONDITIONS IN 835 MHZ AND 900 MHZ CELLULAR PHONES**

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**Summary of Abstract.** SAR (dose rate) values caused by Cellular Phone (CP) exposures were determined by SEMCAD-X software. The effect of frequencies (835 MHz and 900 MHz), metallic accessories like eyeglasses, usage conditions of CP (cheek and tilt), different head dimensions and dielectric properties (adult and child) on SAR were evaluated. SAR phantom and generic CP model were used to find out peak 10 g SAR values. The obtained SAR values from the cheek positions were more than the tilt positions. For the metal rectangle eyeglasses, the higher SAR values were determined both at the cheek and tilt positions and also at both frequencies. When the SAM phantom modeled by the child’s dielectric characteristics and head size, an increase in the SAR values was determined when compared to the adults.

**Objectives.** The effects of cellular phone (CP) usage to Specific Absorption Rate (SAR) in different conditions without dependence on human’s anatomic structure and CP’s models and brands were researched in this study. It was aimed to determine how SAR values, caused by CP exposure, were effected according to

- frequencies of CP (835 MHz and 900 MHz)
- different usage circumstances of CP (cheek and tilt)
- head dimensions and dielectric properties of the user (child and adult)
- metallic accessories usage (eyeglasses)
Methods. In these simulation studies done by SEMCAD-X software, the effect of metallic accessories like eyeglasses, usage conditions of CP, different head dimensions and dielectric properties on SAR (dose rate) caused by CP exposure was studied in 835 and 900 MHz frequencies. Those were selected as 835 and 900 MHz to compare the dose rates which have been used in United States and Europe, respectively.

SAR phantom and generic CP model was used to find out SAR and peak 10 g SAR values was calculated. SAR values were obtained by normalizing antenna input power to 1 Watt. In this study, generic cell phone model which represents a plastic monopole antenna chassis and printed circuit board into this chassis consisting of a smooth metallic layer and also be approved by Mobile Manufacturers Forum was selected. It was assumed that phone model sizes had 102 mm height, 42 mm width, 21 mm thickness and consisting of a hard plastic chassis. Printed circuit board had been made a material that has Perfect Electric Conducting. It has been modeled as a 1 mm thick smooth layer and had been settled in the phone body in a form that body edges has 1 mm gaps.

In this study, antenna had settled on top part of chassis on the center. Antenna height had modeled as %20 shorter than quarter wave (\(\lambda/4\)) height to obtain reasonable input impedance near different head models. Cheek and tilt positions had used for CPs which was defined at IEEE 1528-2003 standards and commonly preferred by public.

Dielectric features and sizes in the IEEE 1528–2003 had been used for adult SAM phantom. Child SAM phantom had been obtained with scaling 0.9 factor means ratio of 7 years old child’s head contour to adult person’s head contour. Dielectric features of liquid in child SAM phantom had been obtained with applying of Peyman and Gabriel’s study.

In the study, eyeglasses frame was modeled presuming that it had 37 mm width and 63 mm height and made from metal material having Perfect Electric Conducting. The length of eyeglasses’ arm is 140 mm and Perspex lens was selected. On the nose area, it had taken care of eyeglasses, not to enter and not to touch into texture.

Results. The CPs are important among the Radio Frequency field sources because of the closer positioning to a sensitive organ such as brain and the mobile’s common usage.

- It was determined that the most effective parameter of the SAR value was the CP usage position. The obtained 10 gram SAR values from the cheek positions were more than that of tilt positions.
- When the SAR values were investigated depending to the frequency, higher SAR values were determined on cheek position at 900 MHz frequency and on tilt position at 835 MHz frequency.
- In the condition of the usage of metal rectangle eyeglasses, the higher SAR values were determined both at the cheek and tilt positions and also at 835 MHz and 900 MHz frequencies compared to having no eyeglasses conditions. In addition, it was observed that local SAR values were higher at the head model near to the eyeglass position. It has been thought that this situation has been resulted from the induced current at the metal frame of the eyeglass.
- When the SAM phantom modeled by the child’s dielectric characteristics and the child’s head size, an increase in the SAR values was determined when compared to the adults. As a result of the consistence of this increase, beside the head size’s becoming smaller, the contribution of the increase in the dielectric characteristics has been thought.
Conclusions. The frequent increase in the frequencies of the wireless communication and pursuit systems is observed depending on the development of the technology. While the working frequency of the cellular phone increases, the value of the SAR increases. The eyeglass, which is one of the most widely used accessories in daily life may affect the SAR values. The level of this effect may change under different positions and conditions. Furthermore, such sensitive organ like eye can be exposed to high SAR because of the induced current at the eyeglasses. As a conclusion to the SAR calculations which has been done, the positioning usage of the CP is the most effective parameter. It has been thought that this is related with the distance. Since children are on the growing up period and they are more sensitive to the environmental factors, their RF radiation dose rate caused by the CP usage are higher than adults because of the size of their head and dielectric properties. Under these conditions, it should be considered that the children will be affected more than adults and they should have precautions in using the technology.

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12-1 LIGHT ALTERS NOCICEPTIVE EFFECTS OF MAGNETIC FIELD SHIELDING IN MICE: INTENSITY AND WAVELENGTH CONSIDERATIONS

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Summary of Abstract. Previous experiments (Koziak et al Bioelectromagnetic 27, 10-15) with mice have shown that repeated one hour daily exposure to an ambient magnetic field shielded environment induces analgesia (antinociception). The exposures were carried out in the dark (< 0.05 W/m²) during the mid-light phase of the diurnal cycle. However, if the mice were exposed in the presence of visible light (0.6 W/m², 400-750 nm) see Figure 1, then the analgesic effects of shielding were eliminated. Here, we show that this effect of light is intensity and wavelength dependent. Introduction of red light (peak 635 nm) had little or no effect, even though it was in the animal housing “white light”, presumably because mice do not have photoreceptors sensitive to red light. In contrast, introduction of ultra-violet light (peak 405 nm) abolished the effect even though it was not in the animal housing “white light”, presumably because mice do have UVA receptors. Blue light exposures (peak 465 nm) of different intensities demonstrate that the effect has an intensity threshold of approximately 12% of the blue light in the housing facility, corresponding to 5 x 10¹⁶ photons/s/m². This intensity is similar to that associated with photoreceptor-based magnetoreception in birds. Could the detection mechanism for the induction of analgesia in mice be similar to that in bird navigation?

Objectives. To determine the wave lengths of light and related intensity thresholds that modulate the analgesic effects of repeated magnetic field shielding.

Methods. A series of six experiments have been conducted in London, Ontario, Canada (43° 02’N, 81° 09’W), that were performed on a total of 838 CD-1 mice (Charles River, Canada). Experiments involved five or ten consecutive days in which each mouse was exposed and tested. In each experiment, exposure order between experiments was randomized. One of us (DDH), naïve of any anticipated outcome, conducted all the measurements, but did not analyze the data. One of us (AWT) analyzed all the data. Animals were used in only one experiment and exposed to only one condition and then were euthanized.

Results. As reported in Koziak et al. (2006), 100 % white light abolished the induction of analgesia, while a reduction to 66% and 33% gave mixed results. That is, at 66% and 33% the effect could have returned, but because the experiment did not have a positive control, the effect could have been attenuated. 100% was arbitrarily set to the average intensity of light in the animal facility and this corresponded to 1.87 x 10¹⁸ integral photons/s/m² between 420 nm and 740 nm. Experiment 2 again demonstrated that 100% white light eliminated the effect, while yellow light at 103% of ambient and green light at 158% of
ambient had mixed results. Experiment 3 demonstrated again that 100% white light abolished the effect, that 106% of blue light also abolished the effect, while an intense red light at 170% of ambient had little or no effect on induced analgesia. Results of experiment 4 demonstrated that UVA light of 103% abolished the effect, as did blue light at 50, 100, and 250%. In experiment 5, blue light of 25% intensity eliminated the effect, while the effect may be attenuated by 12.5%, but may not be affected at 6%. Experiment 6a further titrates the effect to between 9.3 and 12.5%. In experiment 6b, the exposure intensities used in experiment 6a are re-examined using a ten day experiment, and shows that when blue intensity exposures are compared to the positive control that the intensity threshold of blue light needed to attenuate/eliminate the induced attenuation effect lies between 9.3 and 12.5%, that is between approximately 3.9 and 5.2 x 10^{16} photons/s/m^2.

**Conclusions.** These experiments provide strong evidence that, in mice, the effects of light in modulating magnetic field influenced behaviours are mediated by the visual system rather than another system, such as the pineal gland through non-visual stimulation or skin absorbance. Also, this result does not seem to be directly affected by ambient light conditions to which the animals are exposed in their housing. It has been established that mouse vision is conferred by two classes of cones having peak sensitivities at 360 and 509-512 nm and that spectral detection is approximately 350 to 630 nm (Jacobs et al. 2004 Vision Res. 44, 1615-1622). Hence, mice cannot “see” the red light introduced into the boxes which had little or no effect and this is consistent with a visual input. Further, mice “see” the UVA light introduced into the boxes which abolished the increased latencies and this is also consistent with a visual input. Note that red light penetrates tissue further than UV, so if the light effect on magnetic behaviours was modulated by the pineal gland, the red exposure would preferentially reach the pineal. This is further evidence that these light effects are input through the eyes of the mice as in birds (Wiltschko & Wiltschko 2006 Bioessays 28, 157-168), rather than the pineal as in newts (Phillips et al. 2001 Exp. Biol. 204, 2543-2552.).

It is also clear from the experiments that blue light abolishes the induced analgesia for intensities ranging from 251 %, 106 %, 51 %, 25 %, and probably 12.5 % of the amount of ambient blue light in the animal housing facility. This strongly suggests that the effect is not dependent on prior or habitat light exposure conditions.

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Figure 1. Light intensity in photons/m$^2$/s/nm as a function of wavelength. This is a composite of all the different spectra introduced in the mu and sham boxes along with the spectra in the animal housing facility shown in black. The introduced white spectrum is shown in white, the UVA in mauve, and the spectra from the other LEDs shown in representative colours.

12-2 CALCULATING THE MECHANICAL FORCE PRODUCED ON AN HYALURONAN CHAIN IN CARTILAGE BY AN APPLIED ELECTRIC FIELD

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Summary of Abstract. The force on a single hyaluronan chain in cartilage exposed to a 10V/m, 10 Hz applied electric field is on the order of 2 pN. The forces on all the chains, transmitted to the chondrocyte, may provide the transduction mechanism for the field.

Objectives. The mechanical torque exerted on negatively-charged glycoproteins has been shown [1,2] to be a plausible transduction mechanism for physiological strength electric fields. If exerted on integrins or glycocalyx molecules, this mechanical signal is transmitted directly to the cytoskeleton and thus to the nucleus. If exerted on the extracellular matrix of cartilage, the signal is transmitted along hyaluronan chains to the chondrocyte. Although the primary transduction mechanism is the generation of a mechanical torque, the actual signal is a force exerted on the actin cortex of the cytoskeleton or the hyaluronan chain. In this paper I describe the calculation of this force for the hyaluronan chain in cartilage.

Methods. The diagram below illustrates the forces exerted on an aggrecan complex that is connected to the hyaluronan chain. The Glycosaminoglycan (GAG) molecules in the aggrecan are negatively charged and will be deflected by an applied electric field. The
The net horizontal force on the aggrecan is $F_{net} = Ma = F_{elec} + F_{base} - F_{drag} - F_{lp}$, where $F_{elec}$ is the total electric force exerted on the GAGs in the aggrecan, $F_{drag}$ is the viscous drag exerted on the aggrecan by the surrounding medium, $F_{lp}$ is the restoring (spring-type) force exerted on the aggrecan by the link proteins. $F_{base}$ (the force of interest) is the force exerted on the aggrecan by the hyaluronan at the base support and is equal in magnitude and opposite in direction to the force exerted on the hyaluronan chain by the aggrecan. $F_{lp}$ is necessary to prevent the divergence of the angular displacement $\theta$ at very low frequencies in the torque calculation. $M$ is the total mass of the aggrecan, and $a$ is the horizontal acceleration of its center of mass.

Then $F_{base} = M(L/2)d^2\theta/dt^2 + C*d\theta/dt + kh\theta - Q_{tot}E\cos(\omega t)$

where $\theta = A\cos(\omega t - \phi)$. $Q_{tot}$ is the total aggrecan charge and $E$ is the applied electric field strength. $F_{lp}$ is assumed to be a harmonic restoring force and is given by $kh$, where $k$ is the force constant and $h$ is the distance of the link protein center above the hyaluronan. $A$ and $\phi$ are obtained by the solution of the torque equation as described in Reference [2]. Thus, $F_{base}$ can be obtained for any set of aggrecan and applied field parameters. The result assumes that the angular displacements, $\theta$, are small. For the calculations shown in the graph the maximum angular displacement is 4.2° for an applied electric field of 10 V/m.

**Results.** The graph illustrates for 1 cycle of a 10 Hz applied electric field the variation of the forces noted above on the aggrecan. The maximum force transmitted to the hyaluronan chain by the single aggrecan is 0.017 pN. However, there are on the order of 100 aggrecans on an hyaluronan chain and their contributions to the force add in phase. Hence, the total amplitude of the oscillatory force exerted on the chain and transmitted to the chondrocyte is on the order of 2 pN.

**Conclusions.** Such mechanical forces have been shown to produce significant biological effects. Moreover, there are numerous such hyaluronan chains attached to the cell so that the overall effect should be quite significant. [1] Hart FX. 2006. Integrins may serve as mechanical transducers for low-frequency electric fields. Bioelectromagnetics 27:505-508. [2] Hart FX. The mechanical transduction of physiological strength electric fields. Bioelectromagnetics (In Press).
Figure 1.

Forces on a single Aggrecan

\[ f = 10 \text{ Hz}; k = 2 \times 10^{-5} \text{ N/m}; \]
\[ h = 10 \text{ nm} \]

Figure 2.
Summary of Abstract. We have investigated the effects of rf-magnetic fields from mobile phones on biochemical reactions.

Objectives. The aim of the present work is to determine to what degree magnetic fields and especially rf-fields can influence biochemical and biological reactions and whether such effects can conceivable be hazardous to human health.

Methods. Our investigation is based on numerical and analytic solutions of the relevant model equations for the radical pair mechanism (RPM). The RPM is a well established mechanism for magnetic field effects on chemical reactions and it has been used to obtain detailed information on the intermediate radical pair step in such reactions. The good agreement between experimental results and accurate solutions of the model equations proves that model calculations can be used to provide reliable estimates of the effects; in most cases even more accurate than experimental measurements that may be extremely difficult to carry out. This procedure allows us to consider a large range of systems and types of reactions.

Results. Our results for the influence of rf-fields, radiated from mobile phones, on biochemical reactions are divided into four different types of reactions.
1. Reactions in liquids, where the radicals are free to diffuse apart. Such reactions show no measurable effect of the weak rf-field radiated by mobile phones.
2. Reactions on membranes can have very large effect of magnetic fields. However, there are several conditions that must be satisfied in order to have an effect of a rf-field. The frequency of the field, i.e. 900 MHz or 1800 MHz, must be in resonance with an electron spin transition. This requires that the radicals have very large hyperfine constant, much larger than the most common values. Another condition is that the lifetime of the radical pair must be long, i.e. scavenging must be slow; reactions satisfying both conditions are rare.
3. Reactions of types 1 or 2 may show an enlarged effect if the reaction scheme includes chain reactions. An example is the lipid peroxidation which is described by a complicated set of reaction steps that include chain reactions. This leads to bifurcations and under some conditions the reaction explodes. We have determined the trigger point and is investigating its dependence on magnetic fields.
4. Enzyme reactions or electron transfer reactions often involve metal radical ions with large hyperfine constants. Such reactions have the potential to be strongly affected by magnetic fields, both static and rf. The phosphorylation by ATP synthase has been observed to have a very large isotope effect. Our calculations confirm the new reaction scheme and show that a strong dependence on a static magnetic field may be expected. The effect of rf-fields from mobile phones, with and without a small static magnetic field, will be discussed.

Conclusions. In general there will be no effect of rf-magnetic fields from mobile phones on biochemical reactions. However, in combination with a static magnetic field, enzyme systems such as ATP synthase can be affected.

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12-4 ION VELOCITY RESONANCES AT CELL MEMBRANES

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Summary of Abstract. We show that the ionic drift velocity in a damped medium under a Lorentz force can be expressed as a Bessel series that includes resonant terms.

Objectives. This work was undertaken to find a physically acceptable explanation for the striking physiological effects observed for systems exposed to weak ELF magnetic fields tuned to ion cyclotron resonance conditions.

Methods. Series solutions to the differential equations describing the drift velocity of a damped ion with arbitrary $q/m$ under the influence of the Lorentz force reveals both transient and resonant terms. For the resonant terms the argument of the 2nd order Bessel functions, $J_n(\epsilon \delta) \times J_m(\epsilon \delta)$, includes the product of two dimensionless terms, $\epsilon$, the ratio of AC to DC magnetic intensities, and $\delta$, the ratio of AC magnetic frequency to cyclotronic frequency.

Results. This approach yields results in sharp contrast to earlier parametric models in that (1) transition probabilities at ion-protein binding sites are not involved, (2) solutions are available for frequencies other than that at resonance, and (3) a damping term is included. Interesting predictions stemming from this new approach are that ICR-like effects are likely to be found at ultralow AC magnetic intensities, and that these effects are more likely to occur in high electric field ($>106 \text{ V/m}$) regions such as found in the vicinity of the cell membrane.

Conclusions. This work suggests a new hypothesis to explain the many ICR-like phenomena that have been experimentally observed, namely that these may be due to the increased probability for ion channel gating interactions stemming from locally enhanced drift velocities. It is also worth noting that this model lends credence to reports claiming weak ELF magnetic field interactions for off resonance frequencies.
12-5 BORDEAUX-MOSCOW PROJECT: CONFIRMATION STUDIES OF RUSSIAN DATA ON IMMUNOLOGICAL EFFECTS OF MICROWAVES


Summary of Abstract. In a series of Russian and Ukrainian papers published in 1975-1986, dealing with immune-system effects on rats exposed to CW RF at 2375 MHz (incident power: 0.1 to 10 W/m$^2$), it was reported that exposure disrupted the antigenic structure of rat brain tissue. Semi-chronic exposure at 5 W/m$^2$ evoked an autoimmune response. Moreover, in a teratology approach, with serum of exposed rats injected into pregnant rats, significantly higher offspring mortality was noticed at the end of the first month of life. Both immunology and teratology experiments were negative in our confirmation study in Bordeaux. We may conclude that, under our exposure conditions (2.45 GHz, CW, 7 hours/day, 30 days, 0.16 W/kg whole-body SAR), there is no influence of RF exposure on several immune and degenerative parameters, or on teratology.

Objectives. Results of soviet studies had shown some effects on the immune system of rats exposed to microwaves. As these data served in part as the basis for the setting of exposure limits in the USSR, it was deemed necessary to perform confirmation studies in two independent laboratories using modern dosimetric and biological methods. Under the coordination of WHO, the two laboratories (i) IMS at Bordeaux University, France, and (ii) the State Research Centre - Institute of Biophysics, Moscow, Russia engaged into a one-year confirmation project.

Methods. Exposure system: The exposure source at 2.45 GHz was provided by the Russian group and installed in Bordeaux in an anechoic chamber (an identical anechoic chamber was used for the sham-exposed group). Measurements of the fields were done under the supervision of P. Lévêque (XLIM, Limoges). The incident power level was 5 W/m$^2$ and the whole-body SAR was calculated by FDTD to be 0.16 W/kg ±25%. There were three groups (exposed, sham, and control) with 16 animals per group.

ELISA: The ELISA approach is based on previous experience with investigations of autoimmune and degenerative processes. Circulating antibodies directed against specific antigens were detected in rat sera using ELISA with custom-made plates. Circulating antibodies directed against 16 antigens, listed in Table 1 below, were evaluated in the coded sera. Immunoglobulins of the A, M and G isotypes were evaluated. Blood samples (ca. 9 ml) were collected by cutting off the heads of the rats after anaesthesia. Sera (1 ml from each animal) were coded and kept in cryotubes at $-80^\circ$C until ELISA testing. The 48 coded sera were diluted at 1/500 in the appropriate buffer. To validate the quality of the plates, positive controls were obtained using antibodies from hyper-immunised animals directed against major tested antigens for the G isotype (1/1000 and 1/500 dilutions).
**Teratology:** Fourteen days after the last exposure session, rats were killed and preparation of the blood sera was done as described above. All teratological experiments were performed at the facilities of the EVIC company near Bordeaux. Coded sera from exposed and sham rats were administered by intraperitoneal route to two female Wistar rat groups (20 rats/group) at the dose of 1 ml/rat on the 10th day of pregnancy. A third group of pregnant females received no treatment at all (control group).

During the experimental period, all the females were daily observed for possible signs of toxicity. One day before the expected date of delivery, five mothers from each experimental group were sacrificed, the uterus removed, and the contents examined for embryonic or foetal deaths and live foetuses and possible foetal abnormalities. For the other females, after delivery, the pups were regularly observed until weaning (body weight, clinical signs, physical and functional development). One week after weaning (28 days after birth), the dams and pups were sacrificed.

**Results. Immunology (ELISA):** All sera were tested in a blind manner for all antigens and isotypes. The statistical analysis based on the non-parametric Mann-Whitney test showed no statistically significant differences between exposed and sham samples. Results were considered useable if the signal was above noise, i.e., \( \text{OD}_{\text{exposed}} > 0.1 \).

**Teratology: Maternal observations** No mortality or toxicity signs were noted in the implanted animals treated with the two tested sera (sham and exposed). The body weight and the food consumption of the “injected” animals were similar to those of control group. The sera from sham and exposed animals did not induce any undesired effects on pregnancy, delivery, and behaviour over the nursing period. Compared to control group, no significant differences were found in the number of implantation sites, resorptions and live foetuses. No foetal mortality was observed; no macroscopic abnormalities were noted after external examination of foetuses.

**Pup examination (natural delivery)** No significant differences were noted between pups from group of females receiving the two tested sera and those from the control group. The chosen parameters (pup number, sex ratio, mean body weight of litter, viability index, external abnormalities, clinical signs, physical and functional development, post mortem examination at necropsy) were similar among the three groups.

**Conclusions.** This conclusion is based on the data obtained in Bordeaux. However the data from both laboratories were confronted in July 2007 with that obtained in Moscow. Our data obtained via careful implementation of the protocol are negative for both immunology and teratology approaches. All experiments were done blindly and no problems occurred in terms of exposure or biological testing. Based on our investigations, we may conclude that, under our exposure conditions (2.45 GHz, CW, 7 hours/day, 30 days, 0.16 W/kg), there is no influence of RF exposure on several immune and degenerative parameters, or on teratology.

**Acknowledgements.** This project received support from the MMF, the GSM Association, and the French CNRS. Coordination of the project was done by an Oversight Committee of the WHO International EMF project.
CHEMO- AND RADIO-PROTECTIVE EFFECTS OF ROTARY CONSTANT-STRENGTH MAGNETIC FIELD EXPOSURE ON ANIMAL SURVIVAL AND HEMATOPOIESIS

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Summary of Abstract. The interaction of magnetic field with living organism is a rapidly growing field in magnetobiology. In the present study, the author investigated the therapeutic potential influence of rotary constant-strength magnetic field (MF) on the survival and hematopoietic recovery of mice receiving 5-FU or irradiation. Groups of mice were injected intraperitoneally with 5-fluorouracil (180mg/kg), then exposed to the MF for 90 minutes one time, twice a day, lasted for thirty days. The results showed that MF treatment induced a significant protective effect with all of the mice survived, while in the control group, 30% of the mice died. When the 5-fluorouracil dose was increased to 210mg/kg, a statistically significant protective effect by MF exposure (100% versus 40%, p<0.001) was again observed. The effect of rotary constant MF on irradiation induced mortality was evaluated in mice after receiving an irradiation at a dose of 7 Gy. The 30 days survival percentage of MF treatment group was obviously increased compared to that of the control group (68.75% vs 12.5%, p<0.005). Moreover, MF ameliorated chemotherapy or whole-body irradiation-induced bone marrow failure after sublethally irradiation or chemotherapy. A significant effect was observed on red blood cells, platelets and hemoglobin in irradiated mice for rotary constant-strength MF exposure when compared to the control group. The white blood cell counts also increased but did not reach a significant level. Similar phenomena were also observed in the mice those received 5-FU(150mg/kg). In both cases, the number of CFU-Mix of MF treat group was markedly increased compared to that of control (p<0.01). These results demonstrate that rotary constant MF has a protective effect on animal survival and hematopoietic recovery after chemotherapy and radiotherapy.

Objectives. Investigating the therapeutic potential influence of rotary constant-strength magnetic field (MF) on the survival and hematopoietic recovery of mice receiving 5-FU or irradiation.

Methods. Survival experiments:
5-FU was injected IP at doses of 180mg/kg and 210mg/kg body weight (BW). TBI was given as a single exposure at a dose of 7 Gy. After irradiation and chemotherapy, the mice were divided into two groups, one group was put with cage into the MF, the other group was in the room far from the magnet as control. In all experiments, mortality was recorded daily.
Peripheral blood analysis:
5-FU was injected IP at doses of 150mg/kg body weight (BW). TBI was given as a single exposure at a dose of 6.5 Gy. After irradiation and chemotherapy, the mice were divided into two groups, one group was put with cage into the MF, the other group was in the same
room far from the magnet as control. Twenty microlitres of blood was collected by tail vein puncture in a vial containing 100 µl of 3.8% trisodium citrate solution every seven days. Blood cell counts were performed automatically on a MS-9 Vett hematology analyzer.

Bone marrow analysis:
Femurs were obtained from mice killed by cervical dislocation after anesthesia with isofluurane on day 9 and 14 after exposure and chemotherapy. Single cell suspensions of flushed bone marrow cells were plated at 5×10⁴ in 1.0 ml methylcellulose medium containing recombinant cytokines for colony assay of murine cells (MethoCult M3434, Stem Cell technologies, Canada). CFU-Mix was counted at day 9 to 12.

**Results.** The Results showed that in the mice those received a dose of 180 mg/kg 5-FU, the MF exposure induced a significant protective effect with all of the mice survived, while in the control group, 30% of the mice died, the repetitive experiments confer the same result. When we increased the dose of 5-fluorouracil to 210mg/kg, a statistically significant protective effect by MF exposure (100% versus 40%) (p<0.001) was again observed. The MF treatment significantly reduced the percentage of mortality in irradiated mice on day 30, the survival percentage of the MF-treated group is 68.75%, while in the control group, it is only 12.5% (P<0.005). Moreover, MF ameliorated chemotherapy or whole-body irradiation-induced bone marrow failure after sublethally irradiation or chemotherapy. A significant effect was observed on red blood cells, platelets and hemoglobin in irradiated mice for rotary constant-strength MF exposure when compared to the control group. The white blood cell counts also increased but did not reach a significant level. Similar phenomena were also observed in the mice those received 5-FU(150mg/kg). The rotary constant-strength MF exposure significantly increased hematopoietic recovery. From day 7 to day 28, the blood cell numbers were always higher in mice treated with MF, on day 14, the difference of white blood cells and platelets between two groups is most significant. The numbers of CFU-Mix per femur in the mice receiving 5-FU or irradiation with or without rotary constant-strength MF are illustrated. In both cases, MF significantly alleviates the impact by the increase in the number of CFU-Mix, compared to that of control (p<0.01).

**Conclusions.** Rotary constant MF has a protective effect on animal survival and hematopoietic recovery after chemotherapy and radiotherapy, as hematopoietic recovery is a predominant factor in the survival of patient in anticancer chemotherapy or radiotherapy, the MF may be of clinical potential during cancer management.
P-1 LACK OF ADVERSE EFFECTS OF WHOLE-BODY EXPOSURE TO A 2.14 GHZ W-CDMA ELECTROMAGNETIC FIELD USED IN CELLULAR PHONES DURING THE GESTATIONAL AND LACTATIONAL PERIOD ON PHYSICAL AND FUNCTIONAL DEVELOPMENT OF THE RAT FETUS

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Summary of Abstract. The present study was designed to evaluate potential adverse effects of long-term whole-body exposure (2.14-GHz (Downlink) W-CDMA signals, 20 hours per day), equivalent to that from a base station for cellular phone communication, during the gestational and lactational period of rats. For low level exposure, the specific absorption rate (SAR) averaged over the fetus and F1 was set within 0.08 W/kg, and at the high level, this SAR was within 0.08 W/kg over the mothers. Parameters evaluated included growth, gestational condition and organ weights for mother rats and survival rates, development, growth, physical and functional development, hormonal status, memory function, and fertility ability of F1 offspring (at 10 weeks of age) and embryotoxicity and teratogenicity in F2 rats. No abnormal data were observed in mothers, or the F1 or F2 generations. Thus, under the experimental conditions applied, gestational and lactational whole body exposure to 2.14-GHz W-CDMA signals for 20 hours per day did not cause any adverse effects on pregnancy and fetal development of rats.

Objectives. Recent rapid increase of uses of cellular telephone and other wireless devices are associating with greatly increased exposure to electromagnetic fields (EMFs) in human population. Such EMF circumstance results in a great concern on our health, particularly, on children, who have been demonstrated to have greater susceptibility to environmental exposures to a number of toxicants and physical agents. The present study was designed to evaluate adverse effects of long-term whole-body exposure to an EMF signal to that from the base station for cellular phone communication during gestational and lactational period of rats. The adverse effects evaluated were included growth, gestational condition and organ weights for mother rats and survival rates, development, growth, physical and functional development, memory function, and fertility ability of F1 offspring and embryotoxicity and teratogenicity in F2 rats.
Methods. A total of 36 pregnant CD(SD) IGS (specific pathogen free animals) rats at 10 weeks old with certification of the gestational day (2nd gestational day) were purchased at 3 time points from Charles River Japan. The experiment was performed in triplicate in exactly the same manner. For each, the pregnant rats were divided into 3 groups, 4 rats each group. Group 1 received sham exposure, and Groups 2 and 3 were exposed to EMF at the low and high levels, respectively. All pregnant rats were individually set in four translucent acrylic cages in each of three exposure boxes. Thus, in total, the number of pregnant rats used for each group was 12. The whole-body exposure setup for rats had been developed at 2.14 GHz (Wang et al., 2006). Inside of the exposure boxes (90 x 90 x 60 cm), except ceiling were covered with 6-cm-thick planar RF absorber. Four translucent acrylic cages with a 90 degree fan-shape were set on a floor of the box, giving a Baumkuchen (Doughnut) appearance. Each cage had a translucent acryl removal cover and punctured square or slit-like holes were set on the cover and side of the each for air ventilation. The ceiling of the exposure box was made of metal mesh to prevent leakage of the radiowaves to the outside. Each cage had a 210 mm depth x 200 mm height with 82.5 p outer circumference and 538.5 cm2 floor space. There was a ventilation hole at the center of the exposure box through which electric fan-forced ventilation air was introduced. A plastic made water bottle was set at the center side of each cage. For whole-body exposure to EMF, a crossing 3/2-wavelength dipole antenna (180 mm long) covered with a ABS resin cap for 2.14 GHz was set from the ceiling of the exposure box for location in the center of the 4 cages. Circularly polarization was realized approximately by using this antenna that intersect at the right angles and have a phase difference of 90 degree. The distance between the antenna and each cage ceiling was set at 40 mm. A 2.14-GHz (Downlink) W-CDMA signal was applied. Intermittent exposure to the 10 week old pregnant rats was started at gestational day 7 and continued until weaning of F1 rats for 20 hours per day. All exposures were controlled with the assistance of a computer system. During the 20 hr-exposure, a 12-hr light/dark cycle at 22 ± 3°C and 55 ± 15% humidity was maintained. The antenna input power was kept at a constant level with an error of within ±5%. Four days after the delivery, 8 F1 rats, 4 males and 4 females as a general rule, were selected for continuous exposure. EMF exposure was conducted at two levels. At the lower level, the specific absorption rate (SAR) averaged over the fetus and F1 was set within 0.08 W/kg, and at the higher level, this SAR was within 0.08 W/kg over the mothers. All cages included wood-chip bedding and animals were allowed free access to pelleted diet and drinking water. After weaning, F1 rats were removed from the exposure boxes and kept in cages on wood-chip bedding in an air-conditioned animal room. At 10 weeks of age, randomly selected male and female of F1 rats were mated over night and then females were separated individually. At gestational day 20, all F1 dams were killed and fetuses were taken out by cesarean section. Reproductive and embryotoxic parameters were carefully examined.

Results. No growth retardation was observed in either mothers or the F1 generation. Reproductive abnormalities of F1 and F2 were not noted. There were no developmental defects (embryotoxicity or teratogenicity) in either F1 or F2 rats. There was no retardation in features of physical development such as pinna unfolding, emergence of hair, eruption of incisors, eyelid opening, opening of vagina and descent of testes. There were also no effects on functional development of F1 rats such as response to pain, pinna, preyer’s, corneal or
pupillary mid-air righting reflexes, or negative geotaxis. No significant differences in open field tests (ambulation, latency, rearing, grooming, defecation and urination) were evident between the exposure and sham exposure groups of F1 rats at 5 and 8 weeks of age. There were no abnormalities in the water maze, hidden platform or prove tests. No effects were observed on fertility of F1 males and females. No growth retardation in pregnant F1 females was noted and no abnormalities were found in F2 fetuses (No. of dead and live fetuses, sex ratio, body weights of live fetuses, placental weights and pregnancy processes).

Conclusions. Thus, under the experimental conditions applied, gestational and lactational whole body exposure to 2.14-GHz W-CDMA signals for 20 hours per day did not cause any adverse effects on pregnancy and fetal physical and functional development.

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**P-2 EFFECTS OF 915 MHZ ELECTROMAGNETIC FIELD IRRADIATED IN TEM-CELL ON BLOOD-BRAIN BARRIER AND NEURONS IN THE RAT BRAIN**

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**Summary of Abstract.** This study was carried out to evaluate whether or not albumin leakage and “dark neurons” were indeed present in rat brains 14 and 50 days after a single 2 hour-exposure to 915MHz EMF as reported earlier by Salford et al. (2003). Eighty male F344 rats (12 weeks old) were used in the present study. They were exposed to 915 MHz EMF at 0, 0.02, 0.2 and 2.0 W/Kg of whole body averaged SAR in a TEM-cell for two hours as protocols described by Salford et al. The rats were killed later by a trans-cardiac perfusion technique with 4% PFA fixative solution under a deep anesthetic condition. The brains were examined histologically and immunohistochemically. No albumin immunoreactivity was observed in all exposed groups. In addition, dark neurons, which were studied by Cresyl violet and hematoxylin-eosin staining were only rarely present in small numbers with no statistically significant difference between exposed and sham exposed animals. We thus must conclude that the data reported by Salford et al can not be confirmed by the present study.
Objectives. There is some concern that exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by cellular phones could cause adverse health effects on the brain. One of the most disputed findings in recent years was the BBB disruption reported by Salford et al. They reported that albumin leakage sites were found in rat brains after 915 MHz EMF exposure. Furthermore, they recently found not only albumin leakage but also increased number of “dark neurons”, that they recognized as an indicator of neuronal damage, in the brains of rats 50 days after a single 2-hour exposure to 915 MHz EMF. Although many research groups have tried to confirm Salford’s results, there were few confirmation studies performed using the same exposure system, endpoints, and experimental schedule. Therefore, the aim of the present study was to confirm the reported findings using a similar experimental design as used by the Salford’s group.

This study was performed as a collaborative project with two other laboratories, IMS, Univ. Bordeaux 1 in France and the Air Force Research laboratory in the U.S.A.

Methods. Eighty-two male F344 rats (12 weeks old) were used in the present study. The rats were placed in an acrylic box on the upper side of a TEM-cell (Fig. 1) and were exposed to 915 MHz EMF at 0, 0.02, 0.2, and 2.0 W/kg whole-body averaged SAR for two hours as in the protocol described by Salford et al. To determine the whole-body averaged SAR level, we measured the input, output, and reflected power using a power-meter. The rats were killed 14 or 50 days later by a trans-cardiac perfusion technique with 4% PFA fixative solution under a deep anaesthetic condition. In three selected sections of the brain, albumin leakage sites were examined using immuno-histochemistry of albumin. Furthermore, the appearance of dark stained neurons was evaluated using Cresyl violet and hematoxylin-eosine staining. To confirm that our staining methods worked, we prepared two brain injury models: cold injury and chemical injury models, as positive controls using additional rats (n=2, 12 weeks old). Cold injury was elicited by a piece of dry ice which was put on the skull of deeply anaesthetized rats for 5 min. Chemical injury was induced by subcutaneous injection of kainic acid (10 mg/kg, s.c.).

Results. The change in BBB permeability was scored as extravasation of serum albumin from cerebral vessels. In the positive control brain, the injured area of brain section was immunostained with anti-albumin antibody. On the other hand, in all of the brain sections at any exposure intensities, either 14 days or 50 days after RF-EMF exposure, no immunostained sites were found anywhere except in circumventricular organs which have no BBB function. The rate of occurrence of dark neurons in the brain sections was examined in the brain sections stained with cresyl violet or hematoxylin-eosine. In the positive control brain, the expression of dark neurons was observed in several regions of the section. However, in the sections of the exposed brain, either of Day 14 or Day 50, the dark stained neurons were only rarely present in small numbers without any relations to RF-EMF exposure.

Conclusions. We must conclude thus that the data reported by Salford et al. were not confirmed in the present study.

Acknowledgements. ARIB in Japan for funding this project. The Air force research lab. for lending us the TEM-cell.
Figure 1. Exposure system (A) A TEM-cell was used in the present experiment. Input, output, and reflected powers were measured using a power-meter. Whole-body averaged SAR values were calculated based on these measured levels and rat body weights. (B) Rats were placed in an acrylic box only in the upper side of the TEM-cell.

**Summary of Abstract.** The circumventricular organs (CVOs) are structures of the central nervous system (CNS) located at the midline, in close association to the cerebral ventricles. Differently from most of the parenchymal areas in the CNS, the CVOs do not disclose a blood-brain barrier (BBB), being permeable to a variety of blood circulating substances. Brain vascular permeability can be altered under certain physiological and pathological conditions including inflammatory, traumatic, degenerative and neoplastic lesions, as well as in exposure conditions to X-rays.

The electromagnetic fields (EMF) are a combination of electrical and magnetic waves running along simultaneously, propagating to the light speed and having certain frequency and wave length.

There are no reports dealing with the effects of extremely low frequency electromagnetic fields (ELEMF) on the blood vascular permeability in the adult rat CVOs.

**Objectives.** The aim of this work was to investigate the effects of ELEMF on the blood capillary permeability to non liposoluble substances of some CVOs in the brain of adult male rats.
**Methods.** Sixty adult male rats (250g body weight) were divided into 3 groups: CTRL (free into their cages); SHAM (2h daily for habituation in the EMF chamber with no energy connected, for 3 days); EXPTL (2h daily exposed to 0.66 microT EMF, for 7 days). Colloidal carbon (CC) (0.5 ml) was intravenously injected to all animals which were sacrificed by decapitation at 0, 1, 5, and 10 min after injection. Brain was obtained through craniotomy and fixed by immersion in 4% paraformaldehyde. Brain tissue fragments were embedded in paraplast and 10 micrometer-thick sections were lightly stained with cresyl violet. The tissue fragments studied were from the subfornical organ, subcommissurual organ, pineal gland, median eminence, area postrema, frontal cerebral cortex and hippocampus. Morphological evaluation and capillary permeability to CC was done under a light microscope equipped with a Pro-Q-Win Leica Image Analyzer

**Results.** Significant increased vascular permeability to CC was seen in the CVOs studied, especially in subfornical organ, the pineal gland and the area postrema in the EXPTL. Similarly, increased vascular permeability was seen in cerebral cortex and hippocampus, of the EXPTL group, but to a lesser extent.

**Conclusions.** 1. ELEMF increase capillary permeability in the CVOs of the adult male rats, and to a lesser extent in other brain areas with BBB.
2. This increased vascular permeability is at least to non-liposoluble substances such as CC.
3. Further investigations correlating these effects on the capillary permeability of the CVOs with the basic functions in which each organ is implicated, are needed.

**P-4 DOSE-DEPENDENT EFFECTS OF 60 HZ MAGNETIC FIELD BELOW 100 MICROTESLA ON THE TESTIS OF MOUSE EXPOSED CONTINUOUSLY FOR 8 WEEKS**

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**Summary of Abstract.** Previously, we reported that continuous exposure to vertically polarized 60 Hz 0.1 mT or 0.5 mT for 8 weeks effectively activates apoptotic death of testicular germ cells, which was detected by TdT-mediated dUTP nick-end labelling (TUNEL)
and hematoxylin and eosin (HE) staining in mice [Lee et al., 2004]. The magnetic field (MF) exposure did not significantly affect the body weight and the testicular weight. In the present study, we aimed to further characterize the effect of continuous exposure to 60 Hz MF of 12.5, 25, 50 uT or 100 uT on testicular germ cell apoptosis and sperm of mice for 8 weeks.

**Objectives.** We would like to suggest the tentative safety dose level of 60 Hz MF on the testis in mouse exposed continuously for 8 weeks.

**Methods.** Male BALB/c mice (7 weeks of age) were exposed to a 60 Hz MF of 12.5, 25, 50 uT and 100 uT continuously, 24 hr/day, for 8 weeks. The mice were housed in specially designed non-metallic polycarbonate cages fitted with non-metallic nozzle water bottles and placed on the tray of the MF generating device. The body weight was recorded every week. After the end of the exposure the weight of mouse testis was recorded. Apoptosis of germ cell in the testis was analyzed by HE and TUNEL. And, the motility, morphology and number of sperm were evaluated microscopically taken from testis and epididymis.

**Results.** There were not significant effects on the body weight and testis weight of mice exposed to 60 Hz MF. In HE and TUNEL staining, germ cells showed a significantly higher apoptotic rate in the mice exposed to 50 uT (p<0.01) or 100 uT (p<0.001). TUNEL-positive cells were mainly spermatogonia. There were not significant effects on the motility and morphology of sperm from the exposed mice. However, the number of sperm decreased in testis and epididymis of mice exposed to 100 uT compared to sham control (P<0.01).

**Conclusions.** Our experimental results suggest that tentative safe dose of 60 Hz MF on the testicular germ cell apoptosis may be less than 50 uT, and the safe dose on the number of sperm may be less than 100 uT in mice exposed continuously for 8 weeks.

**Acknowledgements.** This research was supported by Electric power Technology Evaluation & Planning Center
Figure 1. Effects of 60 Hz MF exposure on the apoptosis of testicular germ cells. Most of TUNEL-positive cells (arrow) were spermatogonia. Frequency of apoptosis increased dose-dependently in exposed mice groups. The data are means ± SE. **P < 0.01, ***P < 0.001 vs sham control. x400.

Figure 2. Effect of 60 Hz MF exposure on the number of sperm from testis (a) and from epididymis (b) in mice. ** P < 0.01 vs sham control.

P-5 METABOLIC EFFECTS OF EXPOSURE OF DJUNGARIAN HAMSTERS TO GSM MODULATED ELECTROMAGNETIC FIELDS AT 900 MHZ

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Summary of Abstract. The effects of electromagnetic fields (900 MHz, GSM modulation, up to 4 W/kg SAR) on metabolism are tested in hamsters

Objectives. While the vast majority of animal studies performed so far did not indicate a health risk of exposure to non-ionizing radiofrequency electromagnetic fields (RF-EMF)
at non-thermal SAR values, some studies found effects on body weight or food consumption. This is in accordance with the hypothesis (Lerchl et al., J. Pineal Res. 2008; doi:10.1111/j.1600-079X.2007.00522.x) that the energy of RF-EMF does not necessarily increase the body temperature of homeothermic mammals whereas it may cause metabolic effects, such that less energy from food is needed for heat production. The present experiment is designed to address this possibility in detail.

**Methods.** Adult male Djungarian hamsters (Phodopus sungorus) from the colony at Jacobs University were put into specially designed, air-tight boxes inside rectangular exposure units (for details see poster by El Ouardi). At the beginning it was planned to place up to three hamster inside one unit, but due to condensation of water from exhaled air this number was found to be too high. Even with two hamsters, this problem persisted so that eventually one hamster was placed inside one box. This had the advantage that we were able to observe even very small individual changes of the parameters investigated.

For one week, the animals (4 per each subset) were allowed to acclimatize, followed by alternating 7-day periods of sham exposure / exposure. While the order of sham exposure and exposure has been retained, the level of exposure during the exposure periods was either 0.08, 0.4 or 4 W/kg. The level was not known to the persons performing the experiment (blind design). Each subset lasts 8 weeks and is repeated 4 times with different animals.

The following parameters were recorded in the air being pumped out of the cages at constant flow: concentration of oxygen and carbon dioxide, temperature, and humidity. These parameters were also registered in the fresh, surrounding air, and thus the consumption / production / change for each parameter was recorded. The respiratory quotient (RQ) was calculated from the carbon dioxide and oxygen values. Every day at a fixed time, thermograph images from all animals were taken, and the temperatures of the back skin and the eyes were measured at a precision of 0.1 °C.

**Results.** At the time of preparation of this abstract, 2 of the 4 experimental subsets are completed, and the code of exposure has not been broken yet. So far, no changes of oxygen, carbon dioxide, or RQ were found. Compared to sham, significantly elevated temperatures were found during exposure (eyes: ∆T approximately 0.5°C; p<0.01; back skin: ∆T approximately 0.8°C; p<0.001). The parameters were found to be quite stable so that even 4 animals per experimental subset allowed sensitive measurements.

**Conclusions.** The data obtained so far are not in accordance with the experimental hypothesis, i.e. differences in production rates of carbon dioxide and consumption rates of oxygen were unchanged under exposure even at thermal SAR values. The thermograph images show, however, very nicely and without touching the animals that thermal effects can be observed under the experimental conditions. The final data will be presented at the BEMS meeting.

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P-6 EXTREMELY LOW FREQUENCY MAGNETIC FIELDS: EFFECTS ON BLOOD FLOW AND BLOOD PRESSURE

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Summary of Abstract. Previous experiments by our lab have shown that a specific pulsed magnetic field of extremely low frequency (Cnp – complex neuroelectromagnetic pulse) is effective in providing analgesia in a variety of species. Indications from our previous experiments that the Cnp can induce pronounced effects on endogenous opioids, led us to investigate whether this specific pulseform may also induce changes, even if only subtle, in blood flow and/or blood pressure. In this experiment, potential effects of the Cnp on blood flow and blood pressure were investigated using laser Doppler flowmetry and arterial insertion of a pressure catheter in a rat model. Several Cnp field strengths were tested, as was a 60 Hz sinusoidal field of varying strengths. No main effect of the 200 \( \mu \)T Cnp exposure on blood flow was observed; analysis of blood pressure and other data is pending.

Objectives. The circulatory and microcirculatory systems are important for the maintenance of proper health and conversely they are often implicated in various disease states. The ability to locally or systemically manipulate blood flow and blood pressure would be advantageous in controlling a variety of medical problems, including wound healing, re-perfusion-ischemia, hypertension, and others. The effects of magnetic fields of various intensities and forms on blood flow and blood pressure have been investigated by several labs, although results are mixed. The main objective of this research is to determine how exposure to a particular pulsed electromagnetic field alters blood flow and blood pressure, and ultimately determine whether these potential effects can be used therapeutically.

Methods. The extensor digitorum longus (EDL) hind-limb muscle of 103 male Sprague-Dawley rats was surgically exposed. Individual rats were placed within a set of Helmholtz-like coils (1.2 m diameter for the coil that generates the vertical low frequency magnetic field), and laser Doppler flowmetry was used to assess blood flow directly from the EDL surface. The Cnp is characterized by a 200 \( \mu \)T peak (400 mT/s), and 5 pulse segments (each 853 ms) with an average frequency of 72 Hz that are each separated by an increasingly long refractory period (110-1200 ms).

Blood perfusion measurements were made at three time-points: ‘Time 0’ (prior to MF/Sham exposure), and 30 and 60 min after the start of exposure (‘Time 30’ and ‘Time 60’ respectively). Acetylcholine (Ach), in one of three concentrations (0.1, 1, or 10 mM), was used to create a deviation from normal blood flow, and was dropped on the EDL at the start of each blood flow recording. At the end of the experiment, rats were euthanized and the Time 30 and 60 peak blood flow values were normalized to the Time 0 peak values.

To elucidate the above data, blood pressure was measured simultaneously to blood flow in a set of animals via insertion of a pressure transducer (mounted in a catheter) in the right carotid artery and advanced to the aorta. Cnp intensities of 100 \( \mu \)T and 500 \( \mu \)T will be tested using this model, as will a 60 Hz sinusoidal field of 100 \( \mu \)T, 200 \( \mu \)T, and 500 \( \mu \)T.
Results. A mixed design ANOVA was performed to test the effects of 200 $\mu$T Cnp exposure on blood flow, using time as a repeated measure. There was a significant difference in peak blood flow response across the 3 tested time points ($F(2, 194) = 22.29, p < 0.001$), where the Time 60 values were lower than the Time 30 values. Also, as expected, there was a significant interaction between Ach concentration (positive control) and length of exposure ($F(4, 97) = 4.4, p < 0.05$). Of main interest, there was no significant interaction between time, Ach concentration, and exposure type, nor was there any main effect of exposure type. Analysis of the blood pressure and other data is pending at the time of abstract submission.

Conclusions. After both 30 and 60 min of 200 $\mu$T Cnp exposure, no effect on peak blood perfusion response was found. A very small effect size was observed (0.2 %), thus we can confidently report that even by increasing the power of the study, no meaningful effect would be reported. In light of this null finding, additional experiments, including the ones mentioned above, are on-going to rule out potential confounds; analysis of the blood pressure data will strengthen this finding. Overall, these results are important in that one potential ‘side-effect’ of magnetic field exposure to this particular sequence seems unlikely. Furthermore, these findings help clarify the specific effects of the Cnp and contribute to the larger pool of data, which is inconsistent, involving the effects of magnetic fields on circulation and microcirculation.

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Figure 1. Change in microvascular blood flow after 30 and 60 min of exposure to the 200 $\mu$T Cnp relative to pre-exposure blood flow baseline. The line of reference at point 0 represents ‘no change’ from the Time 0 blood flow values. Within each of the sham and Cnp cells, the left hand points and error bars refer to the Time 30 measurements and the right hand points and error bars refer to the Time 60 measurements. There is no difference in peak blood flow response between the sham- and Cnp-exposed animals at any of the Ach concentration or any time-point.

P-7 PROTEOMIC ANALYSIS OF PLASMA FROM RATS EXPOSED TO 94 GHZ MILLIMETER WAVES

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Summary of Abstract. Increased development and use of high power millimeter wave (MMW) generating sources suggest a greater risk of overexposure of maintenance technicians and operators. Currently, no known markers exist for assessing MMW exposure, particularly in cases with no overt thermal skin injury.

Objectives. The objective of this study was to screen plasma for the presence of potential biomarkers of MMW overexposure.

Methods. Male Sprague-Dawley rats were either sham-exposed or exposed to 94 GHz MMWs at a total dose of 16 J/cm². Animals were allowed to recover, and skin and plasma samples were collected at 6 or 24 h post-exposure. Proteomic screening of plasma using 2-dimensional gel electrophoresis, image analysis of stained gels, and mass spectrometry was performed to detect and identify proteins that were up- or down-regulated following MMW exposure.

Results. Microscopic analysis of skin indicated changes in histology consistent with thermal insult in the MMW-exposed groups at both time points. In plasma, alterations were detected in several acute phase proteins and IgG2a, an immunoglobulin usually associated with the adaptive immune response. Changes were also detected in beta-globin and apolipoprotein E, which are plasma proteins that previously correlated with thermal insult of skin and inflammation, respectively.

Conclusions. Overall, the results of this study suggest that systemic responses, including components of the innate and adaptive immune reactions, may be elicited by overexposure to 94 GHz MMWs. The longer-term biological significance of these observed responses is currently under study, however, to date, no lasting effects have been found regarding exposure of humans to high power MMWs.

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P-8 ELECTROMAGNETIC FIELDS PROMOTE REGENERATION FOLLOWING INJURY: INDUCTION OF INCREASED HSP70 LEVELS AND BINDING OF INJURY-SPECIFIC FACTORS IN THE MAPK CASCADE

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Summary of Abstract. Regeneration in flatworms has been studied for more than 200 years but the molecular mechanisms that govern the regeneration process are just beginning to be identified. Planaria maintain and utilize a reservoir of embryonic stem cells that comprise up to 30% of the total number of cells in the adult worm. These totipotent cells are scattered throughout the worm’s body and are capable of giving rise to any other cell type.

Objectives. We used the regenerative ability of Planaria as a model to determine whether following injury EM field exposures accelerate regeneration, elevate levels of the cytoprotective stress protein hsp70 and activate ERKMAPK and phosphorylation of Elk1 and increase serum response element binding (SRE). Activation of these MAPK-inase factors has been reported in Aplysia and mouse following peripheral nerve transection.

Methods. Experimental protocol. Planaria Dugesia dorotocethala (Carolina Biological Supply Company) were bisected transversely. The length of each head and tail portion from a single worm was photographed with a high-resolution digital camera and measured using Image J. Individual head and tail samples (n=30) were sham exposed or exposed for 15 days to a 60 Hz sinusoidal signal at a field strength of 80 milligauss (8\(\mu\)T) for one hour twice a day with a four hour interval between the two exposures. Measurements of head and tails growth were made at time zero and days 3, 6, 9, 12 and 15. Protein, isolated from the head and tail samples at days 0, 3, 6, 9, 12 and 15 days, exposed and sham exposed, were analyzed for hsp70 levels, activation of ERKMAPK, phosphorylation of Elk1, and binding of SRE. Electromagnetic field exposure system. Two exposure units maintained at 20-21\(^\circ\)C provided simultaneous sham and experimental exposures. Exposures used calibrated Helmholtz coils energized by a function generator. A digital ammeter measured the field intensity. Field parameters were monitored with a Hitachi V-1065 100MHz oscilloscope and a calibrated inductive search coil. Sham and active coils were each enclosed separately within Mu metal containers (\sim 9 feet apart) to minimize stray fields during EM field exposures. Antibodies and probes. Antibody to phosphorylated Elk1: Ab91; (New England Biolabs). Antibody to Elk1 and the SRF, the blocking phosphopeptide for Ab91, and the oligonucleotide containing the SRE sequence from the c-fos promoter (nCCATATn) (Santa Cruz Biotechnology Inc.). Anti hsp70 (StressGen Inc.). Temperature, Protein lysates, Protein kinase assays, Electrophoretic mobility shift assays, Western blots. As previously described in Lin et al. [J Cell Biochem (2001) 81:143]) The density of the bands was measured using image analysis software (ImageJ v1.38, NIH).

Results. Short exposures of an 80mG (8\(\mu\)T) 60Hz sinusoidal EM field induced accelerated head and tail regeneration in Planaria; during the first 3 days post-surgery both the heads and tails grew faster than sham exposed heads and tails. These differences in growth rate
correlated with increased hsp70 levels, SRE and activation of injury-specific factors in the MAPKinase cascade.

**Conclusions.** The regenerative ability of Planaria is accelerated by electromagnetic field exposure through activation of hsp70 and protein elements associated with the MAPKinase pathway. These experiments suggest potential benefits for clinical application of electromagnetic fields in the repair of peripheral nerves.

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P-9 EXPERIMENTAL TMS APPARATUS FOR THE TREATMENT OF MIGRAINE WITH AURA.

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Summary of Abstract. A small size experimental TMS apparatus was designed to treat migraine with aura.

Objectives. According to Mohammad et al. from Ohio University (48th meeting of the American Headache Society, 2006), a single TMS pulse applied at the back of the head could help manage migraine with aura. The TMS pulse can interfere with the development of the attack and in a significant number of cases even stop it completely. An apparatus was designed in our laboratory to determine the modalities of this therapy in a future clinical assay.

Methods. A simple TMS apparatus was designed. It is attached to a 11 cm diameter circular coil. It can deliver a TMS pulse of ca. 0.55 T close the coil centre. The pulse is a 200 $\mu$s period half-sinusoid with both polarities available. To avoid overheating, the maximum number of pulses that can be delivered continuously is about one per minute. However, following a TMS pulse, a new one can be triggered after about 20s. A switch is included in the coil handle for the patient to trigger the pulse when he is ready. The level and the polarity of the TMS pulse can be adjusted by the physician through holes in the plastic container, thus preventing an uncontrolled adjustment of pulse characteristics by the patient.

Results. The TMS pulse is in accordance with the planned characteristics, in particular the pulse period is close to 201 $\mu$s and the maximum B field near the coil centre is close to 0.55 T. The current density induced in the human brain was calculated using a simple brain model with conductivity 0.2 S/m. The maximum current density computed at a distance of 2.5 cm from the coil was about twice the motor threshold. There should be a sufficient margin to reach the threshold in the target area.

Conclusions. The apparatus is now ready for clinical studies. A research department at the Pellegrin hospital in Bordeaux, specialized in the management of pain, is planning the first clinical trial.

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P-10 ACCURATE ASSESSMENT OF THE MRI BENCHMARK FOR IMPLANTED LEADS

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Summary of Abstract. The interlaboratory comparison of a magnetic resonance imaging (MRI) benchmark study as defined by the Food and Drug Administration (FDA) revealed a significant variation among the data, thus preventing the derivation of the true values [2]. In this study, the true values were assessed numerically, validated in the most accurate 1.5T birdcage test system (ZMT, Switzerland) and evaluated using DASY5NEO and EASY4MRI (SPEAG, Switzerland). In addition, the benchmark was extended to 3T MRI scanners. The current ASTM standard is insufficient and must be replaced by a more rigorous approach [1].

Objectives. Medical devices implanted in patients represent serious safety hazards when interacting with the radiofrequency (RF) fields of the MRI system during examinations. The current standard testing method to measure the heating produced by RF interaction with implants [1] suffers from serious shortcomings, some of which are addressed in [2]. The interlaboratory comparison of a simple and well-defined benchmark resulted in highly significant differences in the temperature rise, making it impossible to derive the true value. The objectives of this study were to determine the true value and to extend the benchmark to a 3T MRI scanner.

Methods. The specific absorption rate (SAR) distribution in the body phantom filled with a saline solution and exposed to the fields of an MRI birdcage at 64MHz (1.5T) and 128MHz (3T) was simulated with the FDTD method in three different landmarks with and without the generic implant. The implant consists of a 200mm long insulated wire with bare tips (10mm). All computations were performed using the integrated simulation platform SEMCAD X. The local SAR distribution around the tip and the temperature rise were validated using the most accurate 1.5T birdcage test system (ZMT, Switzerland) that was designed for demonstrating the safety of implants. The induced field distributions were measured with DASY5NEO (SPEAG, Switzerland) and the temperature rise was determined using EASY4MRI (SPEAG, Switzerland).

Results. The whole body SAR, Peak Spatial Average SAR and the induced temperature rise were evaluated for three different positions of the ASTM body phantom inside the birdcage coil at two different frequencies. Measurements of the E and H fields in the unloaded coil, the SAR and the temperature rise in the ASTM phantom were in excellent agreement with the simulations. A comprehensive uncertainty analysis was performed.

Conclusions. The results demonstrate that accurate measurements can be obtained if appropriate tools and procedures are applied. Unreliable results are obtained using commercial MRI scanners and poorly defined procedures. The current ASTM standard is insufficient and must be replaced with a more rigorous approach [1].
Acknowledgements. This study was greatly supported by Schmid and Partner Engineering AG, Zurich, Switzerland and Zurich MedTech (ZMT), Zurich, Switzerland.
P-11 DEVELOPMENT OF ANATOMICAL CAD MODELS OF CHILDREN FOR THE ASSESSMENT OF EM FIELD EXPOSURE

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Summary of Abstract. This study presents the development of six anatomical CAD models of children covering an age range of 5 to 14 years. The models are used to discuss age-dependent changes of the exposure to ELF and RF sources using the finite element method and the FDTD algorithm.

Objectives. Most current studies on the whole-body exposure of children use prevoxeled adult models scaled to the body dimensions of children, or models of children that are composed of CT image sets from different bodies. In order to minimize the exposure to ionizing radiation during the CT scan, the resolution of these models along their body axes is frequently lower than 5mm. Higher resolutions and improved soft tissue contrast can be reached using MR scans. In order to complement the two child models of the Virtual Family Project [1], four new anatomical models of children of both sexes have been developed. The models are used to study EM field absorption for various types of sources, such as induction cooking hobs, MRI scanners, and various RF transmitters, covering a frequency range from ELF to several GHz.

Methods. The models of the children are developed from high-resolution MR images of four volunteers. The images were taken on a 1.5T Siemens Avanto Scanner at resolutions of 0.5 x 0.5 x 1.0mm³ for the head and 0.9 x 0.9 x 2.0mm³ for the body. The segmentation of the images distinguishes 84 different tissues. For all organs and tissue layers, CAD objects with smoothed surfaces were reconstructed. This technique allows the discretization of the body models in the computational grid at an arbitrary resolution without loss of information due to the multiple sampling of the fine tissue structures.

For the calculation of the current densities in the low frequency range, a finite element solver has been developed for magneto-quasistatic simulations.

Results. The developed anatomical models of children cover an age range of 5 to 14 years, body masses of 16kg to 50kg, and body heights of 1.07m to 1.55m (Figure 1). The magneto quasistatic solver uses inhomogeneous rectilinear meshes, which allow the straightforward representation of fine anatomical details and an easy integration into the FDTD environment.

Conclusions. Age-dependent changes in induced current density and SAR for the various applications listed above will be discussed in detail.
**Acknowledgements.** The authors wish to thank the Pediatric Department and the Radiological Department of the Friedrich-Alexander-University, Erlangen, Germany. This study is generously supported by the Netherlands organization for health research and development (ZonMW) and the German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz).

**Figure 1.** Anatomical models of children (left to right): 11-year-old girl, 8-year-old girl, 6-year-old boy, 14-year-old boy, 8-year-old boy, 5-year-old girl.

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**P-12 ANALYSIS OF POWER ABSORBED BY CHILD HEADS AS A RESULT OF NEW USAGES**

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**Summary of Abstract.** This paper gives a first comparison of specific absorption rate (SAR) induced in different heads as a result of new usages of mobile phone. The new usage different from the primary usage, i.e. voice call and phone near to the ear, is the text messaging which implies the phone to be in front of the head. For this purpose two child head models 9 and 15 years old and one adult head model “the visible human” are considered. Two sources are used in this study, a tri-band mobile having a patch antenna and the IEEE mobile phone.
Objectives. The aim of this study is to estimate the SAR induced in the different head models with the new usage of mobile phone. Several configurations have been performed to analyze the power budget and SAR in walkie talkie like position. The objective of this paper to analyze in a first step the influence of the new usage on SAR induced in the different head models where the distance of the mobile phone to the head is fixed at 10cm. The second step analyzes the influence of the hand and trunk and the influence of the distance between the mobile and the head on SAR induced in the head. The differences between the results for adult and child heads are given at 900, 1800 and 2100MHz for the tri band mobile phone and at 835, 1900 and 2100MHz for the IEEE mobile phone. All the peak average SAR over a mass of 10g, the SAR contiguous over 1g in each tissue and the power budget are determined using the finite-difference time-domain method.

Methods. For this study, three head models are used: an adult head model named Visible Human (VH), and two child models 15 years and 9 years old. The heads used follow the human morphology and are heterogeneous. Two mobile phone models have been used. The first model is the IEEE mobile phone. The length of the antenna is 71 mm for 835 MHz, 36 mm for 1900 MHz and 32 mm for 2100MHz. The second one is a tri-band mobile phone having a patch antenna and is contained in a parallelepiped of 44 x 16 x 103 mm3, is composed of the basic elements, namely a battery, a patch antenna, a ground plane and a plastic layer surrounding the handset. The “SAR10g” is the maximum of the 10g averaged SAR, which is obtained by averaging the SAR around each point in the volume adding the nearest points until an averaging mass of 10 g is obtained, the resulting volume has the shape of a portion of sphere. The SAR over 1g contiguous” is estimated by averaging the local maximum SAR, adding the highest SAR volume in a given tissue until a mass of 1g is reached. On the other hand, the peak SAR in an organ as the eye tissue is obtained by averaging all the local SAR volume in the given tissue.

Results. All results are normalised to 1 Watt. In the first step, the handset is in front of the head and the distance between the head and mobile is d = 10 cm. For the two handsets and for each frequency, the power absorbed in the adult head is slightly more significant than the one in the child head models (Tables I&II). It is found that the peak SAR for this exposure is always located in the noise and the SAR10g value is almost the same in the three exposed heads. In the second step, when the distance is changed increasingly: d= 2.5, 10, 14, 18 and 40 cm, the value of SAR over 10g in the head decreases. In our simulations, the calculated local SAR is lower than the limit of 2 W/kg given by ICNIRP (International commission on Non Ionising Radiation Protection). Figure 1 shows the SAR induced in the eye for each model, it is found that the SAR induced in the eye of the child is slightly higher than the one for the adult head.

Conclusions. A comparison of the Specific Absorption Rate (SAR) induced in different heads models using two source models (Tri-band mobile phone having a patch antenna and IEEE mobile phone) are given at the three operating frequencies of each mobile phone. Both average SAR in the head and the power budget are determined using the FDTD method. It is found the power absorption in the adult is slightly more significant than that for child head models, while it remains at a weak level of exposure. No important differences in the SAR over 10g are found between the child head models and the adult head model.
It is significant to put these results into perspective owing to the fact that they are valid only for the investigated cases (specific models of mobile phone, child and adult head models).

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![Figure 1.](image)

**P-13 EXPOSURE ASSESSMENT IN THE VICINITY OF WIMAX BASE STATION.**

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**Summary of Abstract.** Exposure assessment in the vicinity of WiMAX base station.

**Objectives.** In addition to wide spread telecommunications technology (GSM, UMTS) a new Worldwide Interoperability for Microwave Access (WiMAX) which is a technology aimed at providing wireless data over long distances in a variety of ways, from point-to-point links to full mobile cellular type access, is being introduced. Because of economical and environmental issues site sharing is a common method for WiMAX base stations installation. Thus, it is necessary to evaluate the contribution of WiMAX system to the total exposure from all combination of the sources. In this research analytical and numerical calculations of electric field strength in the vicinity of the WiMAX base stations were done. In addition, exposure assessment for different base station configurations (GSM, UMTS, WiMAX) was made.
Methods. Calculations were performed numerically by simulation software EFC-400 (Narda-STS). This calculating procedure is in line with standard CENELEC EN 50383. Exposure assessment around WiMAX base station was done according to ICNIRP guidelines [2] for general public exposure for antennas with beamwidth of 60\(^\circ\) (Gain=17 dBi), 90\(^\circ\) (Gain=15.5 dBi) and 120\(^\circ\) (Gain = 5 dBi) at input power of 1, 2, 5 and 20 W respectively. Relatively large size of antenna regarding to compliance boundary does not allow approximation of antenna with point source. Antenna needs to be segmented to smallest parts.

In addition, numerical calculations were used to analyze different combinations of simultaneously operating base stations and determine of each contribution to total exposure ratio. For GSM system base station with 48 W transmit power and for UMTS base station with 20 W transmit power were assumed. GSM transmit antenna was Kathrein 739624 with gain of 18 dBi, horizontal beamwidth of 65\(^\circ\) and vertical beamwidth of 7\(^\circ\). UMTS transmit antenna was Kathrein 742213 with gain of 19.5 dBi, horizontal beamwidth of 63\(^\circ\) and vertical beamwidth of 4.7\(^\circ\). Due to antennas radiation patterns which are already contained in EFC 400, calculations take into consideration real antennas radiation pattern with all side lobes. For WiMAX system was used configuration with 2 W transmit power, antenna with 17 dBi gain, 60\(^\circ\) horizontal beamwidth and 6.5\(^\circ\) vertical beamwidth.

Results. Compliance boundary according to ICNIRP guidelines for general public exposure is limited to 0.3 m for typical 2 W WiMAX base station and less than 2.3 m for the most powerful 20 W WiMAX base station. Results of compliance boundary are shown in table 1.

Base station antennas are generally mounted higher than 10 m above ground and, thus, general public exposure is at least 50 times lower than ICNIRP limit values, even in case of configuration with 20 W transmit power.

To evaluate the contribution of WiMAX system to total exposure ratio on locations where also GSM and/or UMTS systems are presented, we calculated electric field strength for all combinations of WiMAX, GSM and UMTS system. The results clearly show that the compliance boundary increases by less than 0.2 m (+21 \%) when WiMAX system is added to any combination of the GSM or UMTS base stations (see table 2).

Conclusions. After placing WiMAX base station next to GSM and UMTS base station, compliance boundary remains nearly the same as before. WiMAX base station enlarges compliance boundary only for a minimal extend, therefore contribution to total exposure ratio from additional WiMAX base station next to existent GSM and UMTS base station is very insignificant.

Calculations done for simultaneous operation of different configuration show that contribution from WiMAX base station to total exposure ratio is very low. Compliance boundary is mostly dependent on system with maximum transmit power. General transmit power of WiMAX base station is approximately 10 times lower than transmit power of GSM and UMTS base stations, therefore it is necessary to take into consideration particularly these base stations. Calculations for simultaneous operation of WiMAX base station, GSM and UMTS base station show slightly increase of the compliance boundary. In case of WiMAX base station with 2 W transmit power and GSM base station with 48 W transmit power,
compliance boundary is enlarged by 3%. In case of WiMAX base station with 2 W transmit power and UMTS base station with 20 W transmit power, compliance boundary is enlarged by 21%.


P-14 STATIC MAGNETIC FIELD THERAPY: A CRITICAL REVIEW OF TREATMENT PARAMETERS

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Summary of Abstract. Static magnetic field (SMF) therapy, applied via a permanent magnet attached to the skin, is used by people worldwide for self-care. Despite a lack of established SMF dosage and treatment regimens, multiple studies are conducted to evaluate SMF therapy effectiveness

Objectives. Our objectives in conducting this review are to: 1) summarize SMF research conducted in humans; 2) critically evaluate reporting quality of SMF dosages and treatment parameters 3) propose a set of criteria for reporting SMF treatment parameters in future clinical trials.

Methods. We searched 27 electronic databases and reference lists. Only English language human studies were included. Excluded were studies of electromagnetic fields, transcranial magnetic stimulation, magnets placed on acupuncture points, animal studies, abstracts, posters, and editorials. Data was extracted on clinical indication, study design and 10 essential SMF parameters. Three reviewers assessed quality of reporting and calculated a quality assessment score for each of the 10 treatment parameters.
Results. Fifty-six studies were reviewed, 42 conducted in patient populations and 14 in healthy volunteers. The SMF treatment parameters most often and most completely described were site of application, magnet support device and frequency, and duration of application. Least often and least completely described were characteristics of the SMF: magnet dimensions, measured field strength and estimated distance of the magnet from the target tissue. Thirty-four (61%) of studies failed to provide enough detail about SMF dosage to permit protocol replication by other investigators.

Conclusions. Our findings highlight the need to optimize SMF dosing parameters for individual clinical conditions before proceeding to a full scale clinical trial.

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P-15 SIMPLE ESTIMATION METHOD BASED ON ELECTRIC FIELDS ON A TWO-DIMENSIONAL PLANE FOR SAR MEASUREMENT

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Summary of Abstract. The SAR measurement methods with respect to wireless mobile terminals for the compliance test were standardized by the IEC [1] and other standardization bodies. Since the standard SAR measurement is very time-consuming, it is desirable to shorten the SAR measurement time. In order to solve this problem, some studies have been conducted on SAR estimation methods that enable us to reduce SAR measurement time significantly [2]-[4]. We have also proposed the SAR estimation method that theoretically estimates the SAR, which applies Maxwell’s equation and the equivalence theorem to achieve this goal [5].

Objectives. In order to shorten the SAR measurement time by the simpler procedure than our previous method while keeping SAR estimation accuracy, this paper presents a new SAR estimation method that can also theoretically estimate three-dimensional (3D) SAR distribution. The verification results of the estimated results based on the proposed method by numerical calculations are presented in detail.

Methods. Since the estimation procedure of magnetic field is required in the process of SAR estimation in our previous method [5], the electric fields measurement on two different planes are necessary. Therefore, the SAR measurement procedure and measurement configuration employing proposed estimation method are so complicated. In order to address this problem, we proposed a new SAR estimation method that can estimate 3D SAR distribution by measuring the electric fields on only one two-dimensional (2D) plane (observation plane). Although a proposed new method basically employs the equivalence
theorem as well as our previous method, it is able to simplify the estimation equation by introducing image theory to the equivalence theorem [6]. The estimation equation can be summarized by

\[ E_{est}(x, y, z) = \frac{1}{2\pi} \int \{(n \times E') \times \nabla' \phi\}dS \] (1)

According to Eq. (1), we can estimate the electric field (i.e. SAR) distribution based on the amplitude and phase of electric fields on only a 2D plane. In order to validate the effectiveness of the newly proposed method in SAR measurement, numerical calculations were performed. The FDTD calculation results, including the amplitude and phase of the electric fields, are used as replacements for the measurement data. A cubic acrylic container (200 mm × 200 mm × 200 mm) filled with the tissue-equivalent liquid was employed in this study. Radiating sources were reference dipole antennas and the tested frequency bands were 900 MHz, 1950 MHz and 2450 MHz.

**Results.** The 3D SAR distribution was estimated based on the electric fields on the observation plane \((x-y)\) plane in 5.0 mm depth from the phantom surface. The intervals of the electric fields data on the observation plane is 1.0 mm. Figure 1 shows the estimated SAR distributions in the phantom depth (z-axis) compared to the original FDTD calculated results. The terms, which are ”Method (I)” and ”Method (II)”, mean the estimated results based on our previous estimation method and that of the new estimation method, respectively. All the SAR values in Fig. 1, are normalized to the maximum SAR values on the phantom surface at each frequency. As shown in Fig. 1, the estimated SAR distributions are in good agreement with the original calculated results. The estimated errors of spatial averaged SAR over 1g and 10g mass indicate an approximate difference of less than 1.0% compared to the calculated results.

**Conclusions.** This paper presented numerical verification results of the proposed new SAR estimation method for shortening the SAR measurement time. As a result, it is confirmed that the proposed method is enough accurate for the SAR measurement and can estimate the 3D SAR distribution and spatial averaged SAR values at a high accuracy level regardless of the frequency bands. Furthermore, proposed method can be applied to SAR measurement more easily compared to the previous method.

**References :**

Figure 1. Estimated SAR distributions along z-axis compared to the original SAR distributions calculated using FDTD at 900 MHz, 1950 MHz, and 2450 MHz.

**Summary of Abstract.** For effective dosimetric measurement, we proposed a Specific Absorption Rate (SAR) measurement method using a multiple-probe-embedded flat solid phantom. Employing multiple probes contributes to shortening the measurement time, and the solid phantom features stable dielectric properties and easy handling [1]. By scanning the radio device under test over the phantom, a three-dimensional SAR distribution can be obtained, which is necessary to estimate the spatial-average SAR. The impact of the size of the E-field probe and the distance between the E-field probes on the SAR measurement results was also evaluated in [1] using two E-field probes. Our method can be applied to the measurement procedure for the radio devices intended to be used at a location near the human body such as worn on the body, body supported, and in front of the face, which is being standardized by the International Electrotechnical Commission (IEC) [2].
Objectives. The objective of this paper is to evaluate the applicability of our SAR measurement method to some kinds of RF sources using multiple E-field probes at 1950 MHz.

Methods. In the measurement of three-dimensional SAR distribution at 1950 MHz according to [2], the horizontal grid step shall be not more than 8 mm, and the minimum size is 30 mm by 30 mm by 30 mm. Seven E-field probes, of which the depths are staggered in 5 mm steps (4.7, 9.7, ..., 34.7 mm), can realize such conditions. Therefore, our SAR measurement configuration comprises a flat solid phantom and seven isotropic E-field probes embedded in the phantom, as shown in Fig. 1. The solid phantom has the relative permittivity of 41.8 and the conductivity of 1.4 S/m at 1950 MHz, i.e., the differences from the target values of tissue-equivalent liquid described in [2] are +4.5% and ±0%, respectively. The 8-mm diameter probes are calibrated in tissue-equivalent liquid in advance, and the distance between adjacent probes is 32 mm, as shown in Fig. 1. Because each probe can obtain a two-dimensional SAR distribution at each depth while the RF source is scanned over the phantom in steps of 8 mm, a three-dimensional SAR distribution can be finally obtained. The interpolation and extrapolation scheme described in [2] is applied to obtain the average SAR. In this study, the RF sources are 1) a standard dipole, 2) a monopole with a base plate, and 3) a planar inverted F antenna (PIFA) with a base plate. The average SARs of the three RF sources described above are also obtained using the conventional SAR measurement configuration (DASY3 [3]) using the flat phantom filled with a tissue-equivalent liquid.

Results. The differences in the average SAR obtained using our measurement configuration are summarized in Table I compared to those obtained using the conventional SAR measurement configuration. For all RF sources, the differences in both the 10 g and 1 g average SARs are within 10%. It is also confirmed that the SAR distributions obtained using both configurations are almost the same.

Conclusions. This method achieves fast SAR measurement with stable dielectric properties of the phantom without sacrificing measurement accuracy.

Fig. 1. SAR measurement configuration using the multiple-probe-embedded flat solid phantom.

**P-17 STATISTICAL ANALYSIS OF 3G-WCDMA EMITTED AND RECEIVED POWERS FOR TYPICAL USES**

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**Summary of Abstract.** This study deals with the analysis of the real exposure due to emissions of 3G mobile phones for typical uses. This analysis is based on a statistical formalism allowing the study the influence of some factors such as the model of mobile or the network setup on the emitted and received power, and therefore on the public exposure.

**Objectives.** International standards dedicated for assessing the compliance of radio communications equipments to the exposure limits to radio-waves are based on a conservative and a maximized approach. Mobile phones are tested for example by setting the emission power to the maximum possible value (peak power) to verify the compliance in terms of SAR (specific absorption rate) to the limits. These procedures are standardized and they are performed in laboratories to master emissions and to minimize uncertainty. The goal is in this case is to provide reliable, reproducible and conservative values.

This approach, although being conservative and therefore reassuring towards the general public does not give a clear and a typical estimation of the people exposure in real use and does not reflect the real exposure and the time variation of the power.

If all the mobiles put into the market are conform in term of exposure, the real emitted/received power is strongly related to the conditions of use, the environment and the
characteristics of the cellular network.
The variability of the environment and the uses situations has long been considered an obstacle to this kind of studies because of the representativeness of such analysis. However, the use of statistical tools overcomes this problem and we can see nowadays a large number of publications in this field with very convergent results. However, in many cases, the conclusions are limited to extract global statistics such as mean or standard deviation to characterize a series of measures with respect to a given location.

**Methods.** This paper focuses on the 3G technology. The 3G technology based on the access mode CDMA (code division multiple access) is increasingly being used by the general public for it performances in terms of throughput. The CDMA uses a fast power control with speed of 1500Hz, compared to GSM where control power is made to a maximum of 16.6 Hz (once every 60 ms).
The study covers the radiated power (Tx) and received (Rx) in a real communication. It focuses on the influence of some factors such as the type of handset, the network setup and the used service (voice, video, data...).
The main challenge of the study is to establish a statistical model through random measurements which can be used to demonstrate and to extract the influence of the studied factors.
The measurements are harvested using mobile traces connected to a laptop controller. Measurements are stored all 0.5s because of delays in processing control software. For each set of measurement we extract the probability distribution function (PDF) and the cumulative distribution (CDF).
The analysis of the PDF function shows that the power distribution is Gaussian. We observe that the maximum authorized power (21dBm for 3G phones type4) is very rarely achieved.
The cumulative distribution follows a log-normal law built from the mean and standard deviation logarithmic power samples.

**Results.** The first study concerning the error on the estimator of the average calculated using linear and logarithmic samples. It is shown that the “log” average is very sensitive to time variations of the signal where the linear average is only affected by high values.
On the other hand, the mean of log-values (equivalent to median) is stable regardless of the sampling rate while the average of linear power samples is very sensitive to the sampling rate. That is why, the use of the median or the mean of the logarithmic value of a series of samples seems to be the best way for avoiding sampling problem and comparing stables observables.
The influence of the service has been studied by comparing the distributions of Powers issued from different measurement performed at the same time and in the same conditions to a voice call. The obtained results show a strong link between the used service (data, video, streaming...etc) and the throughput frames rate. For example, a visio call (CS64) rated at 64Kbps gives a 4 dB power increase compared to voice call while a data transfer at 384kbps (PS384) induces 13dB to 14dB increase in the same conditions compared to a voice call.

the study of the distribution of the emitted power of two identical and synchronized handsets connected to two different 3G cellular networks shows a difference of 4 to 5dB in a dense
urban environment. This can be related to the network density of to the network load and demonstrate that even being in a comparable geographical area, the exposure can be highly different from one network to an other. The quality of services (QoS) is a major parameter for public exposure. 

Also, this study shows that it is possible to carry out an on site measurement of the bodyloss by comparing the power samples obtained from a handset near a head phantom with a reference handset. In our case, the bodyloss was found to be of about 5dB at 1950 Mhz. the difference between two different handsets in terms of exposure was also analysed and the radiated efficiency was found to be the unique influencing parameter in this case. 

Finaly, a large set of measurement where performed to output a general value defining the typical exposure of the public in different areas (urban, rural, in-car, indoor ...etc). This study shows that the real exposure is well below the one obtained for the maximum authorized power which is used for calculating the maximum exposure. It is shown that the maximum values are rarely reached and that the mean exposure is about 0.1 Watt.

**Conclusions.** This analysis has enabled us to establish the statistical procedure and to extract reliable observable. We have indeed highlighted the significant impact of certain factors (network setup, handset model, service...etc) on the emitted power and by the way on the exposure although samples still below the maximum possible power due to the fast power control used in CDMA.

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**P-18 INDIVIDUAL RF EXPOSURE DUE TO TETRA BASE STATIONS**

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**Summary of Abstract.** Comparison of the individual exposure due to mobile communication base stations and TETRA base stations in Vienna have shown that the typical exposure from TETRA base stations was below of the exposure arising from GSM base stations. Exposure was well below current limits in both cases.

**Objectives.** In recent years exposimeters suitable to identify individual RF exposure patterns were developed. Several studies on individual exposure were performed in different countries, e.g. France, UK, Hungary or Austria. The main focus of these studies was set on the exposure due to mobile communication systems, i.e. GSM and UMTS up – and downlink signals. However, information on the exposure due to other RF sources is rather scarce. Therefore it was decided to perform investigations on the individual exposure arising from TETRA base stations operated in the city of Vienna.
Methods. The exposimeter EME SPY 120 from Antennessa was used to identify RF exposure in the city of Vienna. Recent studies performed in Vienna have shown that the highest exposure due to GSM base stations was identified in underground stations and during metro rides. It was decided therefore to investigate exposure patterns arising from GSM, UMTS and TETRA base stations in the whole underground system of Vienna. Moreover, exposure on street level was examined in the vicinity of TETRA base stations in the 1., 10. and 12. district of Vienna. In all examined cases the measured TETRA signals were compared to the downlink signals of GSM 900, GSM 1800 and UMTS networks.

Results. The maximum TETRA signal measured in the underground system was 0.29 V/m being considerably lower compared to GSM 900 and GM 1800 downlink maxima: 2.8 and > 5 V/m, respectively. The maximum UMTS downlink field strength was 0.24 V/m. The situation was similar on the street. The maximum TETRA downlink signal was 0.78 V/m being again considerably lower compared to the maximum mobile communication downlink signal measured in the GSM 1800 band being above 5 V/m. The situation is similar when looking at the mean field levels of all outdoor measurements performed in areas accessible for the general public: for TETRA 0.07 V/m were obtained. Levels were somewhat higher for GSM 900 and GSM 1800: 0.12 and 0.16 V/m, respectively. For UMTS the situation was slightly different, 0.06 V/m were measured. The values obtained for TETRA are in line with reference measurements performed with a spectrum analyser.

Conclusions. Taken together, it has been shown that the exposure arising from TETRA base stations is well below the reference levels for the general public of the ICNIRP guidelines of 1998. In most cases the values are also lower compared to signals arising from GSM 900 and GSM 1800 base stations. The results indicate that the exposure from TETRA base stations might be similar to the exposure from UMTS base stations. When dealing with exposimeter measurements in the RF range one has to be aware that such devices give an approximation of the exposure, but not the real exposure of a person. It is therefore important to perform studies on the relation between exposimeter reading and the exposure of a person carrying such a device on the body. Moreover it is important to notice that the sensitivity of the exposimeter used is limited to a range from 0.05 V/m to 5 V/m. The software of the exposimeter sets each value below 0.05 V/m to a value of 0.05 V/m leading to an important overestimation of the average exposure. Hence, the development of methodologies to handle non-detects in a suitable way can be highly recommended.

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**P-19 BROOKS FINITE DIFFERENCE TIME DOMAIN (FDTD): C LANGUAGE VERSION**

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**Summary of Abstract.** The Brooks Dosimetry Project is a joint effort between Naval Heath Research Center Detachment and Air Force Research Laboratory researchers located at Brooks City-Base, Texas. As government-funded research efforts, the products of this research have been released to the public as technical reports, a variety of anatomical models, and several versions of the Brooks FDTD code. These products are being used by laboratories all over the world, providing the first tools allowing for independent inter-laboratory comparison of modeling results. They are also being incorporated into The International Electromagnetic Field (EMF) Dosimetry Project (http://www.emfdosimetry.org).

**Objectives.** Here, we introduce a completely rewritten C language parallelized FDTD code. The advantage of C over Fortran 90 is that the GNU C compiler (http://gcc.gnu.org) is available on virtually every computing platform as are a number of freely available implementations of the Message Passing Interface (MPI) library. The GCC compiler and MPI are usually easily installable on most Linux systems using the standard update tools. This greatly increases the ease of installing the necessary software to support compiling and running this code. Because, the source code is available to the user, it can be easily modified to meet the particular needs of the research.

**Methods.** The code is currently being validated using MIE scattering solutions (Bell et al, 1979) and comparisons to empirical results and results from the Brooks Fortran 90 FDTD code. Currently, the code supports either far field or point sources. The point source accepts pulses in the form of a sinusoidal wave, a Gaussian pulse, or an arbitrary waveform injected into a single voxel. The pulse will then propagate from the point of injection into the air or down adjacent material which could form an antenna. The ability to inject an arbitrarily shaped pulse is unique to this source. Other sources will be added as the need arises.

**Results.** As with the Fortran 90 version, a perfect matching layer (PML) allows modeled objects to be placed closer to the outer boundary of the modeled volume reducing memory requirements. The figure below compares MIE results with FDTD results with 2 and 20 layers of air between the PML outer boundary and a 4.5 cm radius sphere of tissue equivalent material (TEM) composed of 1-mm cubed voxels.

**Conclusions.** In the past, the Brooks anatomical models and FDTD codes were available on the Brooks anonymous FTP site. Unfortunately, this site has been closed. Hopefully, the files will eventually be incorporated into a new web site. Until that time requests for the models and software may be by email to: jason.payne@brooks.af.mil or john.ziriax@brooks.af.mil. This work was funded by the U.S. Air Force and U.S. Navy. The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as official Department of the Air Force, Department of the Navy, Department of Defense, or
The aim of this work is to define an in vitro exposure setup in order to expose BBB (Bone Brain Barrier) models into 12 well plate with inserts, and perform the dosimetry of the setup. An open TEM cell is chosen to hold the 12 well plate with inserts inside the dishes (for biological experiments on a model of BBB located in the bottom of inserts), in order to understand biological mechanisms and to complete previous in vivo studies results. The SAR distribution in the 12 well plates is computed with the FDTD method, and experiments are performed under SAR values of 6 W/kg. Measurements with optical probes were performed to validate thermal conditions.
Objectives. While bioelectromagnetics researchers focused their attention mainly on the rapid but safety proliferation of personal wireless devices, it became clear that in vivo biological studies are necessary to better understand the interactions between electromagnetic waves and biological tissues. Previous in vivo studies on the BBB of rats have shown changes in functional markers (RAMP 2001, BCRD12-02, ACI 2003 projects) at 900 MHz under the thermal threshold. These results are in accordance with other in vivo experiments [2] [3] (for SAR level<2W/kg). Biologists have performed a new in vitro BBB model [1], that can be used for in vitro studies in order to complete the previous in vivo results and understand mechanisms in order to evaluate effects of GSM exposure for a SAR value from 0 to 6 W/kg. This paper describes the methodology of detailed dosimetry for this in vitro study. To analyse the interaction between electromagnetic radiations at GSM frequencies and brain cells, a project has been accepted by la Fondation Sante Radiofrequence to choose, design and perform the dosimetry of the exposure setup dedicated to the analysis of this in vitro study. The dosimetry is based on electromagnetic simulations which permit to estimate SAR levels in well-controlled numerical models.

Methods. A three-dimensional numerical model was developed to predict the distribution of electromagnetic fields. The Maxwell equations are solved by the Finite Difference Time Domain method. For an accurate dosimetry the analysis of the interactions and the resonances in biological tissues is required. First, the cells are exposed in a 12 well plate (with inserts inside the dishes) which is located into a large open TEM Cell, in an incubator. Secondly, the temperature is controlled into the exposure setup with an optical probe. The whole exposure system is monitored. Finally, simulation results and experimental measures are compared for validation.

Results. A detailed analysis of all the parameters allows to performe the dosimetry of the large TEM cell, in order to determine accurate SAR values in the whole volume of solution exposed, and locally in the bottom of the insert, where the thin membrane of BBB model is located. The TEM cell (420*170*60 mm) is chosen because of the homogen E field distribution, even if the E field levels are low. The TEM cell allows to expose biological solutions into a 12 well plate holder (COSTAR : 125*85 mm with 12 dishes, 26 mm diameter and inserts inside the dishes, 14 mm diameter). The E field repartition into the TEM cell is homogeneous and the SAR values into the volume is around 0.4 W/kg/Winc, and the local SAR value in the bottom of the inserts located in the 12 well plate is around 0.25 W/kg/Winc. These results has been experimentally validated with well-controlled conditions thanks to the automation of the experiment and an optical probe to control temperature.

Conclusions. To expose the BBB model into the 12 well plates, a large exposure setup is required. The large open TEM cell gives a good E field homogeneity and have been chosen, even if there is low coupling between E field and cells. The temperature in the TEM cell is controlled and the biological experiment is monitored. A detailed and accurate dosimetry of the exposure setup has been performed for adequate interpretations and valuations of in vitro results.

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**P-21 EXPOSURE SYSTEMS FOR TESTING HYPOTHESES OF SITE AND MECHANISM OF INTERACTION IN THE HUMAN BRAIN**

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**Summary of Abstract.** There is increasing evidence that pulse-modulated radio frequency electromagnetic fields (RF EMF), such as those emitted by mobile phones, can alter brain physiology [Huber R. et al., J Sleep Res, 2002]. Changes in EEG, regional cerebral blood flow (rCBF) and cognitive function have been reported. Subsequent studies must be designed to obtain information about the site of interaction as well as the interaction mechanism. Novel tools and setups for human brain EMF exposure were developed to achieve focused and distinguished exposures of selected functional brain regions with a variety of exposure signals. These setups will be employed in the Swiss Research Program NFP57 to test the following hypotheses: 1) the modulation is a key parameter and 2) the thalamus is the main site of interaction.

**Objectives.** The main objectives of this study were to provide the exposure and dosimetric means to test the above hypotheses which includes:

1) to extend the simulation platform SEMCAD X for the dosimetric analysis of functional subregions of the brain
2) to develop an exposure system that allows different modulation schemes and differences
in the exposure of the thalamus by a factor of 10 while keeping the exposure of the cortex the same.

**Methods.** A novel postprocessing module was implemented in SEMCAD X that subtracts and analyzes the dosimetric information for all the functional subregions of the Talairach-Space (1105). Transformation of any brain can be conducted automatically by defining eight distinct landmarks in the brain. The setups have been developed using this numerical tool while maintaining the concept of the exposure system of [Huber R. et al., J Sleep Res, 2002].

**Results.** The analysis has shown that the exposure of the thalamus can be reduced by a factor of larger than ten while keeping a similar exposure of the cortex as in [Huber R. et al., J Sleep Res, 2002] when applying a patch antenna operating at 2.45 GHz or higher. The corresponding exposure setup including hardware was built, validated using DASY5 and installed for double-blinded protocols. Furthermore, the signal generation and control hardware of [Huber R. et al., J Sleep Res, 2002] was enhanced to allow any pulse modulation scheme. Since spatial peak exposures of bursts of larger than 60 W/kg were applied, special safety measures including watchdogs were incorporated to avoid any accidents. The uncertainty and variation analysis of the functional subregions revealed intriguing information about setup dependent exposure parameters.

**Conclusions.** Novel tools and setups for human brain EMF exposure were developed to achieve focused and distinguished exposures of selected functional brain regions with a variety of exposure signals. The implemented Talairach transformation will substantially enhance future dosimetric analyses, e.g., the assessment of exposure differences between children and adults.

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P-22 THERMAL PROPERTIES OF FRESHLY EXCISED DIFFERENT HUMAN BRAIN TISSUES

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Summary of Abstract. see results

Objectives. Driven by the availability of high resolution human models including delicate anatomical details and increasing computational power, numerical RF-dosimetry has recently extended his focus to the modeling of complex thermal transient processes (e.g. extended Pennes Bioheat Equation, DIVA, ...). In literature a large number of contributions and discussions regarding the dielectric properties of different human tissue is available, however, only a few publications are dealing with the accurate measurement of thermal tissue properties. Especially for tissues not in the main focus of current research, as e.g. the pineal gland, no thermal properties are available in literature at all.

Here we present a new type of calorimeter which has been developed for determining thermal properties and specific mass density of tissue samples of masses as low as 1g. First measurements were performed on 3 different types of freshly excised human brain tissues: on grey matter, white matter and on the pineal gland. The here presented calorimeter represents a prototype, and is under further development.

Methods. The physical concept consists of a heat source and a well controlled heat transfer over the tissue sample to a defined heat sink. The whole thermal processes takes place in a well isolated and closed thermal system (Figure 1). As heating source a DC coil with a special resistive material with constant electrical conductivity (ISOTAN® CuNi44) and a wire diameter of 0.08 millimeter was used. For the temperature measurements highly sensitive calibrated miniature NTC thermistors were used. Two points are considered for temperatures measurements: one point on the heat source, and the second one on the heating sink. The operating range of the system varies from 25 (room temperature) up to 40 degree Celsius, in order to avoid thermal damage of the biological sample tissue. The measurement time-cycle was optimized by FEM simulations to 90 minutes, consisting of a 60 minutes heating sequence (for approximately 15 degree temperature increase) and in a 30 minutes cooling sequence (Figure 2).

The thermal properties of the sample can be determined from the temperature curves continuously monitored by the control software. The specific mass density can be calculated from the volume and the sample mass determined with a precision scale (sensitivity better 0.001 gram); determination of the sample volume is done by measuring the height (using a micrometer screw) of the tissue column inside an acrylic cylinder with precisely known inner diameter.

The calibration of the system is done by measurements on known sample materials and determination of the system parameters via corresponding FEM simulations. The thermal sensitivity of the system for the specific heat capacity of the system was optimized for 1 gram of sample mass.
The measurement uncertainty for the specific heat capacity for the actual prototype is better 3%, for the thermal conductivity better 5%; for the specific mass density better 0.1%.

**Results.** Table 1 shows the results of the measurement campaign for the 3 different freshly excised types of brain tissue: grey matter, white matter and first measured values for the pineal gland.

The newly designed calorimeter for biological tissues was built and optimized by using the Finite Elements Method (FEM). It allows to determine the specific heat capacity, the thermal conductivity, and the specific mass density of the tissue sample under investigation. All procedures related to excision and handling of human tissue were approved by the Ethics Committee of the Medical University of Vienna.

**Conclusions.** It has can be shown, that the presented concept of this FEM optimized calorimeter is well suited and a practicable solution for biological tissues with masses in the range of 1 gram or less.

A further advantage of this system is the possibility to determine at the specific mass density of the tissue sample under investigation.

For the RF dosimetry and the thermal modeling of transient processes in the future more discussion regarding thermal parameters of different human tissue is desirable.

**Acknowledgements.** This work was approved by the Ethics Committee of the Medical University of Vienna. This project was supported by the Federal Office for Radiation Protection, Germany.

![Schematic overview and construction details of the developed calorimeter](image)
P-23 ELECTROMAGNETIC ELF EXPOSURE OF GENERAL PUBLIC DUE TO 150-36/11 KV SUBSTATIONS


Summary of Abstract. The electromagnetic ELF fields of large substations transforming voltages of 150 and 36 kV to 11 kV are investigated for general public exposure and safety distances for these substations are determined. In total 142 field measurements were performed. The cumulative distribution function of the measured magnetic-field values follows a lognormal distribution. When comparing the average exposure with the value of 0.4 $\mu$T, maximal safety distances of 8.1 m (day average) and 7.1 m (year average) are obtained for the investigated substations in Brussels.

Objectives. Substations that typically transform voltages of 150 and 36 kV to 11 kV (noted as 150-36/11 kV substations), can be located close to places where people are present, certainly in urban environments. The objective of this paper is to determine the exposure of the general public due to extremely low frequent (ELF) electromagnetic fields of these substations in Brussels, Belgium. The fields will be compared with the ICNIRP guidelines [1] and the 0.4 $\mu$T value mentioned in epidemiological studies. Moreover it is our goal to determine the safety distances for the 150-36/11 kV-substations.

Methods. The substations can be categorized in underground substations, detached substations, and substations between houses (in building). From the 50 substations in Brussels, two substations have been selected to perform measurements based on potential high exposure of the general public. Underground substations are not considered because the exposure will be very limited. Selected substation 1 is located in a densely populated area. This substation is located in a building between a primary school and a house. In this substation one 150-kV underground cable and underground cables of 36 kV and 11 kV are
present. Substation 2 is a detached substation located in a less densely populated area. Different companies border on the substation. People are thus exposed to the fields during the day. For substation 2, 150-kV, 36-kV, and 11-kV underground cables and a 150-kV transmission line (above ground) are present.

The fields are measured using an electric- and magnetic-field probe of type PMM EHP-50C. The magnetic fields depend upon the current load through the cables. Therefore, the course of the currents through the different cables of the substations is measured each 15 minutes during 24 hours of the day the field measurements are performed. The average, maximum, and nominal exposure due to the magnetic fields can then be calculated using the momentary measurement values and the course of the current, assuming that the course of the magnetic fields during 24 hours is similar to the course of the current. The measurement procedure is described in [2]. The field values are determined at 1.5 m above the ground for the two considered substations. In total 142 field measurements were performed: 91 measurements of the magnetic field and 51 measurements of the electric field.

Results. Maximum magnetic and electric fields of $13.2 \mu T$ and $270.0 \text{ V/m}$ are obtained, respectively. The electric field measured around the substations never exceeds $5 \text{ kV/m}$. The value of $100 \mu T$ is never exceeded for momentary values during a measurement period of 2 to 3 minutes at each of the investigated locations. The maximal measured currents during the measurement day are 289 A for the 150-kV lines and 317 A for the 36-kV lines. Fig. 1 shows the cumulative distribution or CDF of all the measured magnetic field values (i.e., $\text{Prob}[B[\mu T] <= \text{absissa}]$). The figure shows that mostly low B-field values are measured at locations where the public is exposed: the 95th percentile of the B-field values is 4.37 $\mu T$. The mean value $\mu_{\text{meas}}$ of all data is 1.27 $\mu T$ and the standard deviation $\sigma_{\text{meas}}$ is 2.02 $\mu T$. This empirical CDF is fitted to a lognormal distribution function using a least-squares algorithm. Fig. 1 shows excellent agreement between empirical and fitted CDFs. This results in estimates $\mu_{\text{fit}} = 1.45 \mu T$ of the mean value and $\sigma_{\text{fit}} = 2.92 \mu T$ of the standard deviation of the fitted lognormal distribution function. This shows that the magnetic-field values closely follow a lognormal distribution and that measured field values can be predicted using this lognormal distribution.

Table 1 shows the safety distances $D$ (magnetic fields) for the different sides of the substations for average ($0.4 \mu T$), maximal exposure (day and year, $100 \mu T$), and nominal exposure ($D_n$, 100 $\mu T$). The value of $100 \mu T$ is never exceeded for maximal exposure during a day or a year, resulting in safety distances smaller than 0.25 cm in Table 1. When comparing to the 0.4 $\mu T$ value, the maximal safety distances are 7.4 and 8.1 m for substations 1 and 2, respectively.

Conclusions. In total 142 electromagnetic ELF field measurements are performed in the neighborhood of large 150-36/11 kV substations. The magnetic and electric fields of the investigated substations satisfy the ICNIRP guidelines. The cumulative distribution function of the measured magnetic-field values follows a lognormal distribution. When comparing the average exposure with the value of 0.4 $\mu T$, safety distances of maximally 8.1 m (average day) and 7.1 m (average year) are obtained.

REFERENCES


**Figure 1.** CDF of momentary field values $B$ [$\mu$T] and lognormal fit at 1.5 m height for both substations.

**P-24 BOUNDARY EFFECTS IN SAR-PROBE CALIBRATION AND SAR MEASUREMENT**

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**Summary of Abstract.** We investigated the boundary effect in the SAR probe calibration and the SAR measurement setups by numerical simulation. In the setups simulated in this study, we found that the boundary effects were almost the same level in both setups.
**Objectives.** In the measurement of the SAR, a miniature probe is inserted into the phantom liquid. Though the probe tip diameter is very thin, it affects to the E-field distribution to some extent. Particularly, the effect is not negligible on the measured data near the phantom shell. The term “boundary effect” represents a change in the sensitivity of the SAR probe when the probe is located close to media boundaries (IEC Std. 62209-1). Few discussions have been made about the detail of this effect so far, although it significantly affects to measured peak SAR which usually appear around the internal boundary between the shell and the liquid. In commercial SAR-measurement systems, the correction factor of the boundary effect is estimated based on the calibration data of SAR-probe obtained in the waveguide setup. However, there is a possibility that the boundary effect in the waveguide setup is different from that in the actual SAR measurement, because the exposure condition is different. Therefore, the influence of the boundary effect in two typical setups for the SAR-probe calibration and the SAR measurement will be examined using the FDTD computation.

**Methods.** Figure 1 shows schematic diagrams of the setups and their numerical models; the waveguide for the SAR-probe calibration, the SAR measurement setup consist of a dipole and the flat phantom as most simple and typical SAR measurement setup, and dimension of the SAR-probes. As shown in Fig 1 (a), the flat phantom was filled with the head-equivalent phantom liquid and was irradiated by the half-wave dipole antenna at 2450MHz. On the other hand, the calibration waveguide system consists of an open-ended waveguide, which is partitioned with the dielectric slab (matching window or spacer) and whose upper region above the slab is filled with the phantom liquid. Two types of the SAR-probes (Probes (A) and (B)) are modeled as air tube, and their tip diameters are 6.8 mm and 2.6 mm respectively. These models were investigated using a commercial FDTD simulator (SEMCAD). The relative permittivity and conductivity of the head tissue-equivalent liquid are 39.2 and 1.80 (S/m). In this study, squared value of the electric field strength in the center of the sensors in the probes was considered to be a probe output and the deviation from the reference E-field was examined. The reference E-field, which does not include the boundary effect, is obtained by computation without probe. In the SAR measurement setup, the spacing distance between the dipole antenna and phantom shell is 10 mm, and the length of the dipole element is 51.5 mm. Dimension of the waveguide is IEC R22, and the waveguide model is excited by the E-field of TE10 mode under the spacer.

**Results.** Figure 2 shows the deviation of square value of the calculated E-field strength at the observation point (position of E-field sensor) in each probe to the reference E-field strength. As shown in the Figure, the deviation increases suddenly near the boundary of the phantom liquid (z = 0 mm), which clearly shows the boundary effect. From the Figure, little difference is observed between the waveguide and the flat phantom. Moreover, when the distance between the sensor and the boundary is larger than 10 mm in Probe(A), the deviation becomes smaller than 2% for both setup. For probe(B), that distance is 6 mm. Therefore, the boundary effect is more dependent on the probe tip size than the difference of the setup.

**Conclusions.** In this paper, we investigated the boundary effect in the SAR probe calibration and the SAR measurement setups. As a result, the influence of boundary effect was
the same level in these setups. This supports that current SAR measurement systems with the compensation of the boundary effect based on the SAR-calibration setup can provide appropriate SAR measurement. On the other hand, the probe size has more effect to the boundary effect, and deviation was little for the smaller probe. In further study, comparison with the measurement will be necessary.

**Figure 1.** Probe calibration and measurement setups with FDTD computational models

**Figure 2.** Deviation between the calculated E-fields with/without probe for each setup.
P-25 DEVELOPMENT OF THE SAR-PROBE CALIBRATION SYSTEMS USING A REFERENCE DIPOLE ANTENNA IN HEAD-SIMULATING LIQUID—IMPROVEMENT OF A PROTOTYPE SYSTEM OF 900MHZ AND 2.45GHZ

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Summary of Abstract. The SAR-probe is usually calibrated using a rectangular waveguide with a matching dielectric spacer below 3 GHz [1]. However, the probe diameter is comparable with the cross-section area of the waveguide above 3 GHz and it can deteriorate the accuracy of the calibration. Therefore, we have examined an alternative method for calibrating the SAR-probe; a standard E-field method using a reference antenna in tissue-equivalent liquid. The reference antenna is calibrated by two-antenna method in the liquid [1]. In this report, we have built a prototype of the calibration system in order to position the antenna and the SAR-probe more accurately. We also evaluated the calibration factors of SAR-probes in head-tissue equivalent liquid at 900 MHz and 2.45 GHz and found that the calibration factors evaluated by this system were almost same as those evaluated by the waveguide system.

Objectives. We have proposed a SAR-probe calibration system with a reference antenna in the head-simulating liquid because the probe diameter is comparable with a cross-section area of the waveguide above 3 GHz. In the previous study [3], we have built a prototype of the calibration system and determined calibration factors of a SAR-probe at 2.45 GHz. However, we found some problems in the previous system, which has not good reproducibility of the evaluated calibration factors. The possible causes are described below:
1. It is very difficult to control the position of the reference antenna.
2. It is not easy to measure the distance from the SAR-probe to the reference antenna.
3. The angle of the SAR-probe to the E-field polarization is not proper in view of the axial isotropy of the SAR-probe.

We considered that those were mainly caused by the horizontal arrangement of the antenna and the SAR-probe as shown in Fig. 1. Therefore, we have manufactured a new system with vertical arrangement as shown in Fig. 1, and a reference antenna for 900 MHz. Then we have calibrated the absolute gains of these reference antennas and determined the calibration factors of SAR-probes in the head-tissue equivalent liquid at 900 MHz and 2.45 GHz. In order to validate our calibration system, we also compared the calibration factors with those obtained by the conventional waveguide calibration system.

Methods. In the new system, a SAR-probe and a reference antenna are arranged on a vertical axis, as shown in Fig. 1. The phantom tank is a cube of one side of 500 mm. The reference antenna is set at a position of 150 mm above the center of the bottom of the phantom. The reference antenna is a resonant dipole optimized in the tissue-equivalent liquid. The antenna elements are arranged horizontally. The lengths of the antenna elements are 25 mm and 19 mm at 900 MHz and 2.45 GHz, respectively. The reference antennas are equipped with an impedance matching circuit. For calibrating the gain of the reference
antenna, another antenna identical to the reference antenna is used for the two-antenna method. The antenna is attached to a jig of a robot arm. Therefore, we can easily move the antenna to an appropriate position. The gain of the reference antenna in Fresnel field is determined\[^2\],[^3]\). In SAR-probe calibration, the probe is attached to the jig of robot arm. The antenna and the SAR-probe are arranged on the vertical direction by the robot.

**Results.** Table 1 lists calibration results of reference antenna gain. The Fresnel region gain $G_{F,\text{dB}}(r)$ at distance $r[\text{m}]$ is shown Eq. 1. And $G_{\text{dB}}$ is the far-field gain, and $C \& D$ are constants related to the Fresnel field. Table 2 lists calibration factors of SAR-probes (SPEAG ET3DV6 & EX3DV4). The Factor-Antenna represents the calibration factors determined by the new system. Factor-Waveguide represents the calibration factors determined by the waveguide system for purpose of comparison. It is shown that the deviations of the calibration factors obtained by the new system of the results of the waveguide system are within 10\%. [The calibration uncertainty of the waveguide system is 11.8 \% (k=2).]

**Conclusions.** There is necessary for alternative SAR-probe calibration technique above 3 GHz. In this paper, we reported a new calibration system with vertical arrangement of the reference antenna and SAR-probes. It is shown that the deviation of the calibration factors determined by the new system from those obtained by the waveguide system at 900 MHz and 2.45 GHz are within 10 \%. In future, we will extend our proposed calibration technique for frequencies above 3 GHz, as well as its uncertainty analysis.

**Acknowledgements.** The authors thank to Mr. Benjamin Loader with National Physical Laboratory, United Kingdom, for his suggestion about the basic structure of this calibration system.

**Summary of Abstract.** Specific Absorption Rate (SAR) measurement procedures for testing wireless devices with simultaneous multi-band transmission have been developed by the IEC [1]. Multi-band transmission means that the device can transmit multiple frequencies at the same time, e.g., 2 GHz for Wideband Code Division Multiple Access (W-CDMA) system and 2.45 GHz for Wireless Local Area Network (Wi-LAN). On the other hand, the basic restriction of the localized SAR (SAR\textsubscript{limit} 2 W/kg of the spatial average SAR over a 10 g mass (SAR\textsubscript{10g}) at frequencies between 100 kHz and 10 GHz [2]. Regarding this, any device with the time-averaged output power below 20 mW cannot generate an exposure level exceeding this restriction. The reason for this is that when all the transmitted power from a device is absorbed within 10 g of tissue, the SAR\textsubscript{10g} equals 2 W/kg. In general, the time-averaged output power of a secondary system such as the Wi-LAN is a few tens of milliwatts or below and is much lower than that of the primary system such W-CDMA. However, the SAR\textsubscript{10g} produced from the simultaneous multi-band transmitter such as that indicated above has the potential to exceed 2 W/kg even though the output power of the secondary transmitter is below 20 mW because of the summation of SAR distributions by two transmitters.

**Objectives.** Clarify the exclusion procedure with respect to SAR measurement for the simultaneous multi-band transmitter.
**Methods.** The procedure to determine the exclusion for the simultaneous multi-transmitter is described hereafter. For the sake of simplicity, two transmitters in a device are assumed in this paper. 1) Calculate the maximum time-averaged output powers of two transmitters. 2) Determine the primary transmitter by comparing calculated power levels. 3) Measure the peak SAR\(_{10g}\) (SAR\(_{primary}\)) of the primary transmitter. 4) Calculate the available power (\(P_{available}\)) according to Eq. (1).

\[ P_{available} = (\text{SAR}_{limit} - \text{SAR}_{primary}) \times 0.01 [\text{W}] \]  

5) Compare \(P_{available}\) to the output power of the secondary transmitter (\(P_{secondary}\)). If \(P_{secondary}\) is less than \(P_{available}\), SAR measurement for the secondary transmitter is not necessary. Otherwise, SAR measurement of the secondary transmitter should be conducted according to [1].

**Results.** For example, when the measured SAR\(_{primary}\) is equal to 1.0 W/kg, then \(P_{available}\) = 10 mW is obtained using Eq. (1). Consequently, if \(P_{secondary}\) is less than 10 mW, the worst case SAR\(_{10g}\) is automatically satisfied in the basic limit.

We note that all the output power of the secondary transmitter (\(P_{secondary}\)) is not absorbed by the human body. This means that the absorbed power (\(P_{absorbed}\)) from the secondary transmitter is actually lower than \(P_{secondary}\). It was reported that \(P_{absorbed}\) is approximately less than 50\% of \(P_{secondary}\) at around 2 GHz [3]. If \(P_{absorbed}\) can be measured, \(P_{secondary}\) can be replaced by \(P_{absorbed}\). Our idea is to use the total radiation power (TRP) measurement [4]. \(P_{absorbed}\) can be obtained using the TRP measurement with and without a phantom.

**Conclusions.** This paper presented an exclusion procedure when assessing the SAR of multi-band transmission. It is efficient to reduce the number of SAR measurements for a multi-band transmission device. This procedure can be applied to a device with more than two transmitters.

**References:**

**P-27** THERMAL INFLUENCE OF SKIN IN 3D MODELING OF TEMPERATURE ELEVATION INDUCED IN HUMAN BODY BY RADIOFREQUENCY ELECTROMAGNETIC EXPOSITION

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**Summary of Abstract.** In this paper, the influence of the consideration of skin tissues in 3D finite element modeling of temperature distribution is studied.

**Objectives.** Human body exposition to radiofrequency electromagnetic fields waves has been widely modeled in term of electromagnetic field and temperature elevation induced. Right now, these numerical simulations are mainly based on Finite Difference Time Domain (FDTD) method or Finite Element (FE) method. A comparative study has been performed for evaluating results accuracy and similarity of these methods [N. Siauve et al., ”Comparison of FDTD and FE methods in numerical dosimetry for the treatment of cancerous tumours with electromagnetic fields”, 15th Conference on the Computation of Electromagnetic Fields, Shenyang, Liaoning, China, June 26-30, 2005]. These methods vary on many points of view, it has been shown that predicted results are quite similar in the tissues. Nevertheless, it has been pointed out that skin tissues are difficult to model with the FE model due to their small thickness. However there is important thermal exchanges in skin and muscles, and temperature can vary in a large range for maintain the 37 °C body core temperature. Therefore, the aim of this paper is to evaluate thermal significance of each tissue layer by taking the example of the forearm. The temperature distribution in the forearm layers has been modeled and several configurations more or less simplified have been evaluated so as to propose an equivalent layer that takes into account thermo-physical properties of the neglected layers in the 3D FE model already developed.

**Methods.** A 1D dimensional numerical model of the forearm region described in Table 1 is examined. Forearm is considered as an homogeneous five layers structure : Epidermis (E), Dermis (D), Hypodermis (H) or fat, Muscle (M), Bone (B). Temperature in tissues is described with the well-known Penne’s bio-heat equation. On epidermis surface a convective transfer condition is consider with a constant flux of 1200 W/m\(^2\) absorbed on the surface. Inside human body, on the most internal face of the bone the temperature is assumed to be constant and equal to 37 °C. At each interface, continuity of temperature and temperature gradient is considered [C. Lormel, L. Autrique, B. Claudet, “Mathematical modelling of skin behaviour during a laser radiation exposure” 2nd European survivability workshop, Noordwijk, Pays Bas, March 2004].

**Results.** Several configurations described below have been evaluated with the multilayers thermal model of the human forearm. The temperature reached on the epidermis surface and at the different layers interfaces are tabulated in Table 2.

− Case 1 : E/D/H/M/B reference configuration
The temperature difference between skin surface and respectively the E/D interface and the D/H interface is evaluated to 0.4 °C and 1.7 °C. That mean there’s a small temperature variation in the two first layers.
– Case 2: H/M/B configuration
Simulation has been done with the configuration usually imposed in 3D FE model developed due to the difficulty to mesh thin thickness tissues layers. In this configuration thermo-physical properties of epidermis and dermis layers are suppressed and replaced by those of hypodermis (fat). Results shown (Figure 1) a temperature difference close to 11 °C between epidermis surface calculated from the reference configuration and from the H/M/B configuration.

– Case 3: Equivalent Layer (EL) configuration
In order to reduce the discrepancies linked to the meshing difficulty, several equivalent configurations have been proposed. The initial five layers structure has been gradually reduced and the first removing layers have been substituted by an Equivalent Layer (EL) which thermal properties calculated from the arithmetic average of thermal properties weighted by thickness. For example the equivalent thermal conductivity $\lambda_{EL}$ that replacing the epidermis thermal conductivity $\lambda_E$ and the dermis thermal conductivity $\lambda_D$ is calculated as follow: $\lambda_{EL}=(\lambda_E\chi_{E}+\lambda_D\chi_{D})/(\chi_{E}+\chi_{D})$ with $\chi$ the thickness of the respective layers.
Three tests have been done. In the first one 3.a, the epidermis and dermis layers have been replaced by the equivalent layer. By comparison with the reference results (1) few errors (less than 0.2 °C) are generated. In the second one 3.b the equivalent layer replaces the E/D/H layers. A 3 °C difference is observed on surface. The last substitution 3.c concerns E/D/H/M layers, and 1.5 °C variation is observed on surface. This difference is lower than for the 3.b configuration.

Simulation results for the different configurations described in Table 2 are depicted on the Figure 1, when the steady state is reached.

Conclusions. This study has emphasis importance of taking into account the thermo-physical properties of human skin in a 3D FE method. Three different equivalent layers reducing temperature error on skin surface have been proposed for replace the standard configuration in 3D FE method. Therefore the 3D FE model developed must be improved with an equivalent layer created at body surface. However due to body complexity, it would be probably necessary to identify and define accurately a surface boundary that will contain the information of the equivalent layer with the adequate properties.
**P-28** FDTD-COMPUTATIONS OF ULTRA WIDEBAND POWER ABSORPTION IN BIOLOGICAL TISSUE


**Summary of Abstract.** see Results

**Objectives.** The interest in Ultra-Wideband (UWB) applications in communications as well as in biology and medicine is still increasing. However, despite a few publications especially dealing with breast cancer diagnosis and therapy (e.g., Converse et al. IEEE Trans MTT Vol. 54, pp. 2169-2180, 2006), relatively little is know about UWB-absorption in the body. The aim of this work is to investigate UWB-absorption on various body parts and to determine the uncertainty introduced by inappropriate modelling of the dielectric tissue parameters, i.e., neglecting their dispersive behaviour).

**Methods.** The FDTD computations were carried out using the SEMCAD X simulation platform. So far, as tissue models both a flat homogeneous brick, corresponding to muscle tissue, as well as a flat layered tissue model, consisting of skin (0.5 mm thick), fat (3 mm thick), muscle (9 mm thick), bone (4.5 mm thick) and “inner tissue” were considered. The thickness of the “inner” tissue was approximately 200 mm and therefore acts as a quasi-infinite boundary of the model at the back side (far from the source). In general, the dielectric properties according to Gabriel et al. 1996 were used. In order to estimate the uncertainty caused by neglecting the frequency dependence of the tissue properties the computations were carried out both, once while considering the dispersive tissue behaviour according to a three pole Debye model and once while considering (non-dispersive) tissue properties at the center frequency.

**FIGURE 1.** Forearm profilts temperature.
As source a plane wave electric field strength of Gaussian shape, resulting in an UWB signal of approximately 6 GHz (-10 dB) bandwidth at 6.85 GHz center frequency was used. The computation of the total Specific Absorption (SA) inside the tissue models was done by MATLAB routines, based on the FDTD results in time domain exported from SEMCAD.

**Results.** Figure 1 shows a comparison of the SA for the dispersive and the non-dispersive tissue treatment versus depth in the tissue model for the homogeneous muscle model. Figure 2 does the same for the layered tissue model. As it can be seen from the figures the uncertainty due to neglecting tissue dispersion can become significant, especially in deeper (> 5 mm depth) tissue regions.

**Conclusions.** Based on the results obtained so far, this work will be extended to exposure situations using anatomical models and more realistic source models. Corresponding results will be presented at the conference.

**Acknowledgements.** This work was supported by the German Federal Office of Radiation Protection.

![Figure 1](image-url)
P-29 INCREASE OF LOCAL CURRENT DENSITIES IN THE SURROUNDING OF METALLIC IMPLANTS DURING EXPOSURE TO MAGNETIC FIELDS IN THE 50 HZ TO 125 KHZ RANGE

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Summary of Abstract. Using FDTD computations it has been shown that body current densities induced by welding cables and RFID reader equipment can be significantly increased in the surrounding of metallic implants.

Objectives. When persons are exposed to high local magnetic field strengths it is important to provide solid evidence that the basic restrictions in terms of current densities inside the body are not exceeded, even in the case the spatially averaged derived exposure limits in terms of magnetic field strengths are met. This is even more important in situations where it can not be excluded that the exposed person carries metallic implants, e.g., hip prosthesis or plates and screws for fixation of bone fractures. The objective of this study was to estimate the maximum body current densities in the surrounding of a metallic hip prosthetic and a metallic fixation of an upper arm fracture in a person exposed to the magnetic fields of welding cables and an inductive RFID card reader antenna.

Methods. All computations were carried out using the SEMCAD X simulation platform and a male whole body model derived from the visible human dataset. The hip prosthetics and the fracture fixation were modeled manually and put anatomically correct in place using the CAD capabilities provided by SEMCAD X. As source models representing typical welding scenarios a straight single as well as double conductor carrying the welding currents
of 1000A/50Hz or 10A/5kHz were put close to the left elbow (approx. 3 cm from the arm’s surface (figure 1). Furthermore the exposure to a 125 kHz inductive RFID card reader was simulated by a simple loop antenna producing a magnetic field strength of 8 A/m at 5 cm distance from the antenna, which can be seen as a realistic value for real devices of this kind. This RFID loop antenna was placed close to the left elbow (containing the fracture fixation) as well as close to the left hip (containing the hip prosthetics). The computational domain was discretized by a non-uniform grid with step size 0.5-5 mm, while keeping it below 1 mm in the areas of interest (surrounding the implants). The FDTD computations were carried out with an excitation frequency of 1 MHz and were scaled down to the target frequencies using the well known frequency scaling method described by Gandhi et al. 1992 (Bioelectromagnetics Supplement 1:43-60). Tissue dielectric properties according to the “Gabriel 1996” dataset were used. For evaluation of the tissue current densities FDTD cells belonging to the implant and the interface layer between the implant and tissue were excluded. Current densities were averaged over 1 cm$^2$ perpendicular to the current direction for comparison with the basic restrictions defined in the ICNIRP Guidelines 1998.

**Results.** The results clearly demonstrated that the presence of the metallic implants significantly increases the maximum 1cm$^2$ averaged current density in the surrounding of the implants (see table 1 and figure 2, respectively). It can be seen that even without the implants the maximum current densities are partly beyond the limits values for the general public valid for head and trunk according to ICNIRP 1998.

**Conclusions.** The presented results indicate that metallic implants inside the body can significantly increase current densities in the surrounding of the implants and that the maximum current densities might exceed the basic restrictions for head and trunk, even under realistic exposure conditions. Therefore it is recommended to identify relevant exposure scenarios with high local magnetic field levels in practice (e.g. welding, RFID, metal detectors, etc.) where implant carriers might be exposed, and to analyze the respective body current densities carefully in order to avoid adverse incidents. Especially implants used in the head (e.g., aneurism clips in the brain) and trunk (e.g., coronary stents) are of interest for further work.
**Figure 1.**

8A/m, 125 kHz RFID antenna

**Figure 2.**

Fracture fixation and welding cable (single conductor)
**P-30** SAR BASED COMPLIANCE BOUNDARIES FOR COMMON BASE STATION ANTENNAS


**Summary of Abstract.** SAR measurements and full wave SAR simulations have been performed. Expressions based on the SAR results defining compliance boundaries for common base station antennas have been developed.

**Objectives.** The objective of this work was to develop accurate expressions that are easy to use and communicate, defining complete compliance boundary volumes for common base station antennas used for mobile communications in the frequency range 800-2200 MHz.

**Methods.** SAR measurements and full wave SAR simulations were performed in order to determine the compliance boundary expressions. All measurements were performed using the universal flat phantom from APREL Laboratories together with the DASY4 professional near-field scanner (software version 4.6) by Schmid & Partner Engineering AG. The measurements were performed according to the European standard EN 50383 [4], by positioning the antennas in various orientations at different distances from the phantom. The SAR simulations were performed by positioning a human phantom in various orientations around CAD models of base station antennas, using the commercial FDTD solver SEMCAD by Schmid & Partner Engineering AG. The antenna input power was set to a known level in both the measurements and the simulations and the results were scaled to obtain compliance boundaries for different input power levels. Figure 1 shows examples of antennas that were used for SAR measurements or modeled for SAR simulations.

**Results.** For transmitted powers up to 50 W the general public compliance distances in the back direction for all investigated antennas were less than 0.1 m. The results also indicate that the general public compliance distance above and below both ground plane backed and omni-directional antennas never exceeds 0.1 m for transmitted powers per element up to 10 W. Based on these results and those from Thors et al. [3] complete compliance boundaries have been developed.

**Conclusions.** Accurate expressions that are easy to use and communicate, defining compliance boundary volumes for common base station antennas, have been developed.

[1] ICNIRP, ”Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, International Commission on Non-Ionizing Radiation Protection (ICNIRP), Health Physics, vol.74, pp 494-522, April 1998


[4] CENELEC EN 50383, ”Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations
and fixed terminal stations for wireless telecommunication systems (110 MHz – 40 GHz)”, European Committee for Electrotechnical Standardization (CENELEC), August 2002.

**Figure 1.** Examples of antennas used for SAR measurements or simulations.

**P-31 PRACTICABLE DETERMINATION OF A PERSON’S EXPOSURE TO MULTIPLE DIFFERENT RF SOURCES**


**Summary of Abstract.** Increasing mobile communication in occupational and private areas of life results in a rising number of different sources of high frequency electromagnetic fields contributing to the population’s exposure. A practicable procedure on the basis of numerical computations of the dissipated rf power in anatomical human bodies is presented, which allows the assessment of whole-body and localized SAR values in cases of multiple exposure.

**Objectives.** In a ‘real-world’ environment, a substantial variety of sources emitting electromagnetic radiation in the frequency range between 100 kHz and 10 GHz contributes to the specific absorption rate (SAR) distribution within the human body. Thereby, apart from the shape, mass, posture, and organic topology of an exposed person, the effective share of each single source depends on its frequency and radiated power, on its location and radiation pattern with respect to the person, on the properties of the transmission path and on influences of the environment such as reflection and diffraction. According to the ICNIRP guidelines, the total SAR yields from the summation of the SAR distributions due
to the single sources.
The goal of this research project embedded in the framework of the ‘German Mobile Telecommunication Research Programme’ is the development of a practicable computational procedure for the determination of the actual exposure in complex exposure scenarios with several different radio frequency (rf) sources.

**Methods.** In order to consider an arbitrary combination of (existing or future) multiple sources a modular concept is developed. It is essentially based on a bulky catalogue of datasets for particular ‘source − human body’ or ‘field − human body’ scenarios (module A). The datasets have to be provided in advance by means of numerical computations and consist of normalized distributions of the dissipated power PD within the human body from which the requested SAR values are derived. Apart from the selected body model, the PD distributions are determined by the features of the source or of the exposure field. Source types are distinguished by their distance to the body: Sub-module A1 contains PD distributions for body-worn sources, e.g. mobile phones. Data for sources operated near the body (e.g. notebooks with PCMCIA transmitters, DECT base stations, W-LAN routers) are stored in sub-module A2. The fields of sources which are located far from the body are characterized by (one or more) uniform plane waves. Accordingly, the voluminous sub-module A3 covers PD distributions due to uniform plane waves of multiple frequencies hitting on the body under various angles and with different directions of polarization. For the normal user of the practicable procedure, the datasets are fixed sheets, but the catalogue is expandable at any time by new sources or other models of the human body, if expertise is available.

In module B the sources of the actually interesting multiple exposure scenario are selected and described. The more specifications of the sources and their environment (position, average radiated power, directivity, gain, polarization, topography of propagation path) can be provided by the user the more precise is the determination of the weighting factor to be applied to the source-specific PD datasets.

Finally, in module C the exposure assessment is performed by adding the weighted PD distributions, by determining the whole body SAR, by searching the maximum of the localized SAR (10g avg.), and by relating the total SAR values to the recommended thresholds.

**Results.** For the preparation of SAR datasets numerous FDTD computations based on two anatomical body models (standing and sitting adult (work on adolescent in progress)) derived from the data set of the ‘Visible Human Project’ were performed. The spatial resolution was chosen as 4 mm, since this results in a number of values per dataset which seems to be the upper limit for a handling on usual PCs in a reasonable time period. It was approved that this resolution allows the determination of SAR values with a sufficient accuracy for practical purposes.

PD data available from other projects were also transformed to the chosen 4-mm format, especially for sources in contact with the body or near the body.

At present, the catalogue comprises data for the following scenarios including the mentioned nearby sources:

1. Standing adult with a mobile phone (GSM 900 MHz and 1800 MHz) in touch with the left ear.
2. Adult sitting at a desktop in front of a notebook with PCMCIA-card or USB stick transmitting GPRS 900 MHz, UMTS 1.950 MHz, W-LAN 2.450 MHz, or Bluetooth 2.450 signals.

3. Same as 2., but with the notebook placed on the lap.

4. Adult sitting at a desktop with a W-LAN router placed at a distance of 1 m.

5. Adult standing near a wall with a W-LAN router mounted at a distance of 0.4 m.

6. Adult (both standing and sitting) with a W-LAN router placed on the ground at a distance of 0.4 m.

7. Adult (both standing and sitting) in front of a desktop with a DECT base station placed at a distance of 0.5 m.

The main part of the deposited data, however, concerns the dissipated power $PD$ evoked by uniform plane waves. Since the far-fields of the following sources should be considered, the computations were performed for the respective frequencies:

- AM broadcasting station (500 kHz);
- Base stations for TETRA/GSM/UMTS (450 MHz, 900 MHz, 1.800 MHz, 2.100 MHz);
- DVB-T broadcasting station (700 MHz);
- DECT base station (1.900 MHz);
- W-LAN router (2.450 MHz).

For further saving of computer resources the number of considered directions of incidence towards the body model was limited to 32 for each frequency, namely to 8 azimuthal angles $\phi$ with 45° spacing and to the 4 elevation angles $\alpha = 90^\circ - \theta = 0^\circ$, 15°, 30° and 45°.

Altogether, 20 distributions of dissipated power $PD$ for fixed scenarios and 900 PD data sheets for uniform plane wave exposure are available which can be combined to assess numerous user-specific situations. While the above mentioned scenarios 2 – 7 represent typical indoor cases, scenario 1 as well as all the UPW cases may contribute to exposure situations indoor and outdoor. Five different propagation models (free-space, 2-ray, Okumura-Hata, COST231, window penetration) and three channel models (LOS, NLOS, additional reflection) were implemented in order to apply the adequate model according to the specific frequency range and environment.

**Conclusions.** In the presentation the practicable computational procedure will be explained in detail for different examples.

**Acknowledgements.** Factual and financial support by the German Federal Office for Radiation Protection and by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is gratefully acknowledged.
**P-32 SAR MINIMIZATION OF WIRELESS COMMUNICATION TERMINALS OPERATED NEAR THE BODY**


**Summary of Abstract.** From numerical calculations of the SAR distribution with help of computer models for the human body as well as for the communication terminals, the two important characteristic parameters, whole body SAR and maximum localized SAR $^{10g}_{max}$ are derived and related to the recommended basic restrictions. By change of the topology of the antenna or of the entire device the potential for minimizing the SAR is investigated.

**Objectives.** Many wireless communication terminals are operated neither in direct contact to the human body nor far away, but often at distances of some centimetres to some decimetres. Typical examples are base stations of cordless phones, wireless LAN routers and network cards for PCs or notebooks.

The objective of this project embedded in the framework of the ‘German Mobile Telecommunication Research Programme’ is to examine how the specific absorption rate (SAR) of wireless communication terminals operated near the human body is influenced by e.g. the antenna topology, the topology of the entire device or by the choice of the transmitter frequency. Minimum values of the SAR of these devices are to be identified. The influence on the communication characteristics of the devices is likewise to be considered in this process.

**Methods.** Four highly resolved anatomical body models derived from the data set of the ‘visible human project’ are used (adult and adolescent, both standing and sitting). The computer models for the terminals are developed with special attention to the antenna design. The models for the human body and for the terminal under test are embedded in a user-typical environment. Since the test volume is not too large, the related field problem is solved with the FDTD method implemented as a parallelized in-house code running on a multiprocessor system. The resulting SAR values are taken as a reference for the next step: The topology of the terminal and/or the antenna design is modified and the effect on the SAR is investigated. In case that the SAR should decrease as a consequence of the design modifications it is necessary to check whether the quality of communication is maintained what is done here by comparison of the mean effective gain (MEG). For the investigations the following 4 types of wireless communication terminals are selected: PCMCIA network card for operation of GPRS, UMTS and W-LAN, Bluetooth USB adapter, W-LAN router and DECT base station.

**Results.** In the following the results of two exemplary scenarios are presented involving a sitting adult at a desk.

The first scenario concerns the exposure of the adult by the PCMCIA data card (WLAN mode at 2450 MHz, $P_{transmit}$= 100 mW) for two different positions of the card in the notebook on desk (figure 1). In the first case, the card is positioned at the left side of the keyboard, in the second case at the rear side of the display. The absolute SAR values are substantially lower for the rear position. The whole body SAR reduces by a factor of 2.0 (from 157 $\mu$W/kg to 77 $\mu$W/kg) and the maximum of the localized SAR ($SAR^{10g}_{max}$) from 18.6 mW/kg to 5.3 mW/kg. This reduction is contributed by the shielding of the mainly
metallic display of the notebook. At the same time, there is almost no change of the MEG value.

The second scenario concerns the exposure of the adult by a router (2450MHz) at the same position on desk (figure 2) with a single antenna \( (P_{\text{transmit}} = 100 \, \text{mW}) \) or 2 antennas \( (P_{\text{transmit},1} = 50\, \text{mW}, P_{\text{transmit},2} = 50\, \text{mW}; \lambda/2\text{-distance}) \). The whole body SAR for the router with two antennas reduces by a factor of 1.78 (from 4.32 \( \mu \text{W/kg} \) to 2.43 \( \mu \text{W/kg} \)) and the maximum of the localized SAR \( (\text{SAR}^{\text{10g, max}}) \) from 2.01 mW/kg to 1.28 mW/kg. At the same time, the MEG value improves by 0.5 dB.

Further examples will be shown in the presentation.

**Acknowledgements.** Factual and financial support by the German Federal Office for Radiation Protection and by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is gratefully acknowledged.

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**Figure 1.** Sitting adult at the desk with notebook. 3D representation (a), side (b) and rear (c) position of the PCMCIA data card plugged into the notebook.

**Figure 2.** Sitting adult at the desk with router. 3D representation (a), router with one antenna (b), router with two antennas (c).
**P-33 A SIMPLE MODEL TO PREDICT THERMAL RESPONSES IN HUMAN SUBJECTS SUBJECTED TO WHOLE-BODY RF HEATING**

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**Summary of Abstract.** Accurate simulation of the thermal effects of RF exposure requires a method for predicting the localized SAR values, coupled with a whole-body heat transfer model. Typically, this is done using a tissue-segmented, voxelized model of a human with a fairly high spatial resolution. Using high resolution models to predict local SAR and temperature values in sequence over the course of an exposure requires significant computing resources and results in extensive run times. In cases where the primary concern or interest is whole-body or core temperature heating (distinct from localized tissue heating), it may be possible to use a simple, two node bio-heat transfer model to predict the thermal effects of RF exposure. This may be appropriate for whole-body exposures at or near the whole-body resonant frequency, which allows the SAR to be described - at least approximately - as an energy source term which is distributed uniformly throughout the body. A two node model is much simpler than one based on a voxelized model, and can be run on a standard desktop personal computer.

A two node model of physiological thermoregulation was used to predict the core temperature rise in humans exposed to 100 MHz RF (far-field). Core temperatures predicted from the model agreed with published, experimental measurements in human subjects under similar exposure conditions.

**Objectives.** The objective of this work was to determine whether an existing two-node human bio-heat transfer model would predict core temperature responses - over time - which are consistent with published experimental results from human exposures at 100 MHz (far field).

**Methods.** A two-node model of physiological thermoregulation (ASHRAE, 2005) was implemented using Microsoft Excel. The model was tested by simulating exposures to high ambient temperatures (without RF exposure). The results were in close agreement with published results from controlled human exposures to hot environments (Stolwijk and Hardy, 1966).

The RF exposures simulated were consistent with the human exposure of Adair et al. (2003). Exposures were simulated at each of three ambient temperatures (24 C, 28 C, 31 C) and 40% RH. An energy term was added to the metabolic rate, equivalent to the estimated SAR at each of two power densities (4 mW/cm\(^2\), 8 mW/cm\(^2\)). A sham exposure (0 mW/cm\(^2\)) was also simulated at each ambient temperature. The power densities correspond to whole-body SAR values of approximately 0.27 and 0.54 W/kg. Each exposure consisted of a 30 min. equilibration period (no RF), followed by 45 min. whole-body exposure at constant power density (0, 4 or 8 mW/cm\(^2\)) and a 15 min. cool-down (no RF).

**Results.** Figure 1 shows the core temperature results for one exposure (8 mW/cm\(^2\), 31 C ambient) compared with published results from measurements under similar conditions (Adair et al., 2003). Other exposure conditions produced similar levels of agreement between model and experiment.
Conclusions. A two-node model of physiological thermoregulation was used to simulate whole-body human exposure at 100 MHz. Results suggest this relatively simple model can be used to estimate core temperature accurately during whole-body exposure at 100 MHz and at power densities of up to 8 mW/cm$^2$. The two-node model also may be useful for predicting levels of thermal discomfort associated with RF exposure. It is not known whether the model is useful at higher power densities, or at other exposure frequencies.

Figure 1: The change in core temperature (relative to the core temperature at the onset of the RF exposure) for an equilibration period of 30 minutes, followed by a 45 minute exposure to 100 MHz RF energy (whole body SAR = 0.068 [W/kg]/[mW/cm$^2$], power density = 8mW/cm$^2$), followed by a 10 minute cool down period is shown. The ambient temperature was a constant 31$^\circ$C.

P-34 THE VASCULAR STRUCTURE MODEL FOR IMPROVED NUMERICAL SIMULATIONS OF THERMAL RESPONSE OF HUMAN TISSUE EXPOSED TO RF FIELDS

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Summary of Abstract. The wide and rapid spread of wireless technologies has induced some concerns in the public and in the scientific community in relation to safety of RF exposure. Present RF exposure safety standards (IEEE C95.1-1999 and IEEE C95.1-2005
Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields from to 3 kHz to 300 GHz and International Commission on Non-Ionizing Radiation Protection (ICNIRP) 1998 Guidelines for Limiting Electrical, Magnetic, and Electromagnetic Fields (Up to 300 GHz) limit the level of exposure based on the Specific Absorption Rate (SAR), recognizing the well established adverse effects of possible tissue overheating by strong RF fields. In recent years there has been considerable interest in accurate simulations of the thermal response of the human body exposed to RF energy. The most widely used model to simulate the heat exchange in the exposed tissue is based on Pennes’ bio-heat equation (H. H. Pennes, Journal of Applied Physiology, vol. 1, pp. 93-102, 1948), which takes into account the effect of blood perfusion by means of macroscopic parameters assuming constant blood temperature. Although this model is suitable for predicting the temperature rise in many exposure conditions, it is an approximate model which does not take into account many details of heat exchange between the tissue and blood and does not account for changes in blood temperature itself. More advanced models based on discrete vascular structure representation and heat exchange between the vessels and tissue have been also developed (e.g. Mooibroek and Lagendijk, IEEE Trans. on Biomed. Eng., vol. 38, no. 5, May 1991). In particular this model has been implemented for the vascular structure of the human eye where it had been demonstrated that the conventional Pennes model may produce similar results as the discrete vascular thermal model provided that proper macroscopic thermal parameters are used in the bio-heat equation (V. Flyckt et. al, Phys. Med. Biol. 52, 2007). This is possibly the most relevant example of direct comparison between different thermal models used for human body RF exposure. The development of vascular structure of other tissues or organs for thermal analysis of RF exposure remains an important task as it may provide better prediction of thermal response of tissues exposed to RF energy and serve as reference for other simplified models.

Objectives. The goal of this work is to develop an algorithm to construct the realistic vascular structure for various tissues and organs of human body based on numerical anatomical models and coarse representation of the major vasculature. The vascular models developed using this algorithm are suitable for integration into FDTD simulation models for the analysis of tissue temperature rise in different RF exposure conditions.

Methods. Relatively large vessels may be constructed using the techniques similar to those used to develop the DIVA model (Kotte et al, Phys. Med. Biol. 41 1996). However the inclusion of small capillaries is more difficult and may be better described by the blood perfusion coefficients associated with each voxel in the tissue model not otherwise perfused by blood vessels. One approach could be to use the constant blood perfusion coefficient similar to one defined for the conventional bio-heat equation. On the other hand it is possible to define a more realistic blood perfusion distribution in the tissue based on a number of larger discrete veins’ and arteries’ endpoints distributed within the tissue with sufficient density. Those endpoints provide the necessary blood pressure difference forcing blood to flow from arterial endpoints to venial endpoints. This model is similar to the electrostatic field produced by opposite sign charges distributed like the vessels endpoints and is governed by a similar Poisson equation. Therefore the resultant blood velocity features blood flow continuity.
**Results.** Based on the discrete vascular structure and the hydrodynamics model of blood flow, a blood velocity map can be generated in every tissue voxel. This information together with relatively large vascular structure elements can be integrated into the thermal model and provide more accurate simulations of heat exchange between the tissue and blood and better predictions of the tissue thermal response in different RF exposure conditions. This is especially important for the organs with highly inhomogeneous blood flow distribution like the human eye. Several examples of the vascular structure have been developed, specifically to model the human eye vasculature.

**Conclusions.** A techniques to construct the vascular structure and related blood velocity map in human tissue has been developed, which allows more accurate thermal simulations of RF exposure. The blood velocity map and the associated blood perfusion coefficients can be determined for any tissue voxel regardless of the model spatial resolution.
Methods. Calculations and measurements were made of the SAR absorbed into the head from a mobile phone antenna. Firstly, the mobile phone terminal used for measurement was modeled using the SEMCAD - a commercial SAR analysis tool - and using the FDTD (finite-difference time-domain) method. The antenna designed was mounted in the interior, and the SAR value was then calculated when the mobile phone was touched with the right area of the head. When actually measured, the antenna alone was located in the interior of the terminal from which the battery was separated, meaning the mobile phone terminal was modeled in consideration of only the mobile phone terminal case, the key button, and the LCD monitor at the time SAR was calculated. In practice, the conductive tape covers the interior of the terminal case, exclusive of the antenna part, which may have an influence on the distribution and value of SAR, but this study hypothesized that there was no such influence. The antenna proposed was manufactured and mounted on the mobile phone. SAR was measured using the ESSAY-3 device of the EMF Safety Company, and was then compared with the calculated value. At that time, a calculation was made for 0.5 W and 1 W in the inputted power at a frequency of 835 MHz in order to calculate the SAR value for the cellular frequency band. The average SAR values were drawn out for 1 g and 10 g, respectively.

Results. As a result of the SAR calculation, the 1 g average SAR value and the 10 g average SAR value were 0.624 W/kg and 0.421 W/kg, respectively, when the inputted power was 0.5 W; and 1.247 W/kg and 0.842 W/kg, respectively, when the inputted power was 1 W. As a result of the SAR measurement, the 1 g average SAR value and the 10 g average SAR value were 0.462 W/kg and 0.245 W/kg, respectively, when the inputted power was 0.5 W; and 1.239 W/kg and 0.731 W/kg, respectively, when the inputted power was 1 W. All of the results satisfied the standard values of 1.6 W/kg and 2.0 W/kg at the time of the 1 g average and the 10 g average, respectively. The largest SAR value was found around the cheek area in which the antenna was located. Furthermore, the SAR value was greatly influenced by the distance between the antenna and the SAM phantom. The study showed that the distance was 7.48 mm between an antenna located in a terminal and the SAM phantom, when the terminal was actually being measured. The finding enables us to predict that when the antenna is located at the lower part of the terminal, the SAR value in the tilt location will be lower than that at the touched location.

Conclusions. Calculations were made of the SAR value of the antenna usable in the cellular frequency band, which was verified by the actual measurement taken. As a result, both calculated and measured values were lower than the standard values: 1.6 W/kg for the 1 g average and 2.0 W/kg for the 10 g average. There are, obviously, likely clear differences in terms of media, the environment, etc. between the mobile phone terminal modeled for the SAR calculation and any terminal actually used for measurement. Considering possible errors in calculated and measured values, it appears to be necessary to add to these findings more actual data in future SAR calculations. In addition, the antenna can be used in the WCDMA band, for which the SAR analysis is required, and it will be necessary to complement the SAR calculation and measurement at the tilt location in accordance with relevant regulations, and in terms of the location of the wireless device with respect to
the SAM phantom that are set forth in the Technical Requirements for Measurements of Specific Absorption Rate.

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![Diagram of the proposed planar monopole antenna and comparison of simulated and measured VSWR](image)

**Figure 1.** Structure of the proposed planar monopole antenna and comparison of the simulated and measured VSWR on the optimized antenna
INVESTIGATION OF ELECTRIC FIELD STRENGTH EMITTED FROM TV BROADCASTING TRANSMITTERS IN KOREA

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Summary of Abstract. The human exposure to the electric field from TV broadcasting transmitters was investigated. The surveyed results revealed very low levels of electric fields are radiated from them.

Objectives. The concern about the human hazards caused by electromagnetic fields radiated from various types of service such as mobile phone, AM radio, TV broadcasting has increased. In this paper, we described the result of survey on the electromagnetic field strength from TV broadcasting stations at residential areas in Korea.
Methods. Survey of the electric field strength radiated from TV transmitters has been required to demonstrate the compliance of exposure to the TV transmitter with safety limits especially in the residential area or the location permitted to general publics. Receiver system is composed of an Isotropic probe and a spectrum analyzer. The isotropic probe is needed to consider the directional difference of electromagnetic fields strength due to the change of polarization in the far-field. The spectrum analyzer settings are RBW: 6 MHz, Mode: RMS. The distance between transmitter and measurement position was from 183 up to 5,406 m (this is included in far-field region) and measured by GPS receiver. The height of probe was 1.5 m above the ground. The electric field strength was averaged over 6 minute. The transmitting power of the target transmitters is in the range of 5 ~ 30 kW (analog) and 1 ~ 5 kW (digital). The in-situ measurements were carried out over broadcasting time (weekday 12:00~16:00).

Results. The measurement was performed at 59 positions around 19 TV broadcasting sites. The measured electric field strength levels were 75.2~123.3 dBuV/m. This is very low compared with the ICNIRP guidelines for general public (148.9 ~ 151.6 dBuV/m).

Conclusions. This paper reports on survey results of electric field strength radiated from VHF-band and UHF-band TV broadcasting transmitters in Korea. As a result, the electric field strength, over the range of 183 ~ 5,406 m from the transmitters, emitted from 19 TV broadcasting transmitters of 7 sites was at the range of 0.025 ~ 4.86 % compared with the ICNIRP guidelines.

P-37 DEPENDENCE OF FETAL SAR ON POSITION OF FETUS AND PLACENTA UNDER WHOLE-BODY EXPOSURE OF RF ELECTROMAGNETIC FIELDS

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Summary of Abstract. We evaluated detailed SAR characteristics of a fetus exposed to plane waves by numerical simulation using pregnant-woman models with the fetus and placenta in several positions. The fetus-averaged SAR was within the whole-body averaged SAR and it was dependent on the position of the fetus and placenta in the UHF band.

Objectives. In order to estimate electromagnetic-field safety for pregnant women, we previously performed numerical dosimetry using an anatomically realistic whole-body pregnant-woman model at 26 weeks’ gestation (Nagaoka et al., Phys. Med. Biol., pp. 6731-45, 2007 and Togashi et al., EuCAP, 2006). In this model, the fetus was positioned in the left occiput anterior (LOA) of the model’s pelvis, i.e., the fetal occiput was directed toward the model’s left anterior side. However, it is known that the fetal presentation varies
frequently at this stage of pregnancy and that the placenta forms at various locations on the uterine wall. In this study, we evaluated detailed SAR characteristics of a fetus exposed to plane waves (10 MHz to 2 GHz) by numerical simulation using pregnant-woman models with the fetus and placenta in several positions.

**Methods.** We constructed four different pregnant-woman models with which the mass of each tissue agree (Fig. 1): TYPE 1, LOA fetal presentation and anterior placenta; TYPE 2, LOA fetal presentation and posterior placenta; TYPE 3, right sacro anterior (RSA) fetal presentation and anterior placenta; and TYPE 4, RSA fetal presentation and anterior placenta. They consist of $2 \times 2 \times 2$ mm$^3$ voxels and are segmented into 56 tissue types. The finite-difference time-domain (FDTD) method was used to calculate the SAR when the models were exposed to vertically polarized plane wave electromagnetic fields (10 MHz to 2 GHz) and were in free space. The incident waves propagated from anterior to posterior, and the incident power density was 10 W/m$^2$. Perfectly matched layer (PML) boundary conditions were set at positions of 100 cells (200 mm) or more from the nearest parts of the model. The electromagnetic properties of most tissues in the pregnant-woman model were obtained from the 4-Cole-Cole analysis reported by Gabriel (Brooks Air Force Technical Report, AL/OE-TR-1996-0037, 1996). The electromagnetic properties of the inherent tissues of a pregnant woman not described in the above report were calculated on the basis of the report by Schepps and Foster (Phys. Med. Biol., pp. 1149-1159, 1980).

**Results.** The differences in the whole-body averaged SARs of the four pregnant-woman models are within 1%. These SAR values agree well with each other, with the peak values occurring around the whole-body resonant frequency (80 MHz). The frequency characteristics of the TYPE 1 whole-body averaged SAR and of the TYPEs 1 to 4 fetus-averaged SARs are shown in Fig. 2. The peak values of the fetus-averaged SARs also occur at 80 MHz. The fetus-averaged SARs of all the models are close to each other in the VHF band. However, in the UHF band, there is a larger difference (5 dB at most). These results suggest that the position of the fetus and placenta in a pregnant-woman model can affect the fetus-averaged SAR. However, the fetus-averaged SARs for all the models are smaller than the whole-body averaged SAR.

**Conclusions.** We calculated the SARs of fetuses in four different pregnant-woman models for plane wave exposure from 10 MHz to 2 GHz using the FDTD method. We found that the fetus-averaged SAR was within the whole-body averaged SAR and that, in the UHF band, it was dependent on the position of the fetus and placenta. In future work, we will calculate the SARs of pregnant women at other gestational stages.

**Acknowledgements.** Parts of this research were done on the vector supercomputer SX-8R (NEC) at the National Institute of Information and Communications Technology.
**Figure 1.** Pregnant-woman models

**Figure 2.** Frequency characteristics of fetus-averaged SARs
**P-38 EXPOSURE SYSTEM SET UP FOR AN IN VIVO EXPERIMENT ON IMMATURE MICE EXPOSED TO THE WIFI SIGNAL**

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Summary of Abstract. In the last months public concern on WiFi installations and on the possible effects of WiFi signal on the biological systems increased a lot, especially due to the increase of new networks in sensible sites such as schools and hospitals. For this reason some experiments have been planned regarding the exposure to WiFi signal of mice during their life before the sexual maturity (from their born up to 5 weeks of life included). The WiFi signal (central frequency at about 2450 MHz) has a particular modulation that results in strong variations of its amplitude; moreover the daily changes of size and masses of the targets require an accurate dosimetry in order to establish the efficiency of the system during all the exposure period. A TEM cell operating at 900 MHz [1] has been chosen as exposure structure, so the first step in the design of the system has been the exploration of the possibility to use this TEM cell for frequencies higher than its higher order mode cut-off frequency.

Objectives. The design and realization of an exposure system allowing the controlled exposure to WiFi signal of an adequate number of mice from their born to 5 weeks of life included.

Methods. To evaluate the contributes on induced dose in the target of the transverse modes propagating in the cell at 2450 MHz, a numerical code (Computer Simulation Technologies Microwave Studio) has been used. A simplified model of mouse has been considered for simulations with its size changing with the mass, according to the measures on some animals carried out during their first five weeks of life. The model was homogeneous (muscle with epsilon=54.2 and sigma=1.88 S/m at 2450 MHz). A commercial Access Point has been chosen to produce the WiFi signal: the signal is taken from the Access Point during a data transfer from a notebook to a PC. An accurate analysis of signal has been performed in order to evaluate the averaged power and to maintain WiFi signal characteristics after the amplifier. The considered TEM cell allows the simultaneous exposure of 12 animals in three groups of four placed at at least a wavelength distance one to each other. Numerical dosimetry has been performed in order to evaluate the best distance that groups should have to obtain an acceptable level of dose homogeneity among groups. Experimental dosimetry has been carried out on 12 mice every day for five weeks according to the power balance method: the weight-efficiency curve has been defined to assure the chosen dose during all the period of experiment, taking into account the changes in mass of the mice. The complete exposure system has been set up and a software realized in Labview 7.1 environment, allowing both the controlled exposure during all the period of experiment and the blind procedure.

Results. The transversal modes contribute for a fraction of 25 dB on the whole averaged dose, for this reason they can be considered not determinant on the dose induced on the mice exposed in the TEM cell. The best distance among the groups is one wavelength (at 2450
MHz), allowing a total homogeneity of 30% around the averaged dose. The experimental curve weight-dose is showed in Fig.1, where it is evident a variation of efficiency according to the changes in the masses of animals.

**Figure 1.** The curve weight-SAR for 1W input power determined in the 35 first days of 12 newborn mice.

**P-39 EMF-AEM: EMF EXPOSURE CHARACTERISATION USING PERSONAL EXPOSIMETERS AND AN ACTIVITY EXPOSURE MATRIX**

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**Summary of Abstract.** The main goal of the study is to find a proper measure of exposure to electromagnetic fields for usage in epidemiological studies to define highly vs. lowly exposed persons. An Activity Exposure Matrix is being developed describing the estimate of the exposure level for everyday activities per frequency band. The exposure can be estimated based on a combination of this Activity Exposure Matrix and a questionnaire on the activity pattern. In the first part of the study the matrix was filled based on ELF and RF exposimeter measurements during commissioned everyday activities. In the second part the exposure of volunteers during their activities will be estimated as well as measured to validate the method.
Objectives. The main goal of the study is to find a proper measure of exposure, characterizing the exposure to extremely low frequency (ELF) and radiofrequency (RF) electromagnetic fields (EMF), for usage in epidemiological studies to define highly vs. lowly exposed persons. The study aims to build an Activity Exposure Matrix (AEM), describing for 30 common, everyday activities in 1 ELF and 12 RF frequency bands the estimate of the exposure level. In this way the exposure to EMF can be estimated based on the AEM and a questionnaire on activity patterns without the need to actually measure.

Methods. In the Dutch Electromagnetic Fields and Health (EMF&H) Research Programme the "EMF exposure characterisation using personal exposimeters and an Activity Exposure Matrix (EMF-AEM)" is one of the five first granted studies. The project started in 2007 and will finish by the end of 2009. The outcomes of the EMF-AEM study will be made available for the follow up studies in the EMF&H Research Programme.

The EMF-AEM study is performed by a multidisciplinary team consisting of physicists, psychologists and biostatisticians of the National Institute for Public Health and the Environment (RIVM), engineers of the Radio Communications Agency, and epidemiologists of the Institute for Risk Assessment Sciences (IRAS) of Utrecht University. The study is divided into three stages: the preparation stage; the pioneer study and the field test. We also submitted proposals for a cohort study and a multidisciplinary study in which we will use the developed AEM.

In the preparation stage we have prepared all tools such as questionnaires, time-activity patterns, a diary format and a list of initial everyday activities to be measured. The main criteria for the activities are: contrasting in exposure, common under a substantial part of the population and distinguishable from the recorded time series. Since the power transmitted by the sources depends on the time of day and the surroundings, the activities will be layered, for example "Traveling by bike — Morning rush hour — City". For the ELF band we purchased Emdex Lite exposimeters measuring in a frequency range 40 – 1000 Hz. For the RF bands we purchased the EME Spy 121, measuring 12 frequency bands: FM, TV3, TV4/5, uplink bands and downlink bands for GSM, DCS and UMTS, DECT, Tetra and WLAN. The EME Spy exposimeters have been tested in a GTEM to determine the measurement uncertainty per exposimeter and per frequency band.

For the pioneer study we have hired temporary workers and commissioned them to perform the preliminary identified list of activities included in AEM, while carrying the EME Spy 121 RF-exposimeter, the Emdex Lite ELF-exposimeter, and a GPS. Based on these measurements and the characteristics of the exposure during the activities an exposure classification scale will be constructed. In the AEM per frequency band the relevant activity will be classified. Also spot and exposimeter measurements will be performed to characterize certain (indoor) activities. The first part of the pioneer study consists of a pilot study of approximately 100 hours of measurements. Based on intermediate analysis the kind of activities and the number of hours and the number of sampling sessions may be adjusted.

In second part of the pioneer study the rest of the 600 hours of measurements will be gathered. The GPS data will be used as a tool to point out locations with exceptionally high or low field strengths. At these locations spot measurements with more sensitive, exact measurement devices with a broader measurement range of frequencies can be performed. The third stage, the field test, is a validation of the developed tools. Firstly, the exposure
will be estimated based on a combination of this AEM and a questionnaire on the activity pattern. Secondly, this exposure estimate will be compared with the exposimeter data in combination with a diary. In this field test a number of participants, preferably from existing cohort studies, with an everyday activity pattern will be selected. This will not be a representative sample for the general population, but will be a test population for the AEM and the questionnaire.

**Results.** The first results of the pioneer study measurements will be presented at the meeting.

**Acknowledgements.** We thank the Netherlands Organisation for Health Research and Development (ZonMw) for funding this study (http://www.zonmw.nl/en/programmes/all-programmes/electromagnetic-fields-and-health-research/).

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**P-40** WHOLE-BODY SAR IN SPHEROIDAL ADULT AND CHILD PHANTOMS IN A REALISTIC EXPOSURE ENVIRONMENT

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**Summary of Abstract.** The compliance of the ICNIRP reference levels to the basic restriction in case of a realistic exposure has been investigated for spheroidal human body phantoms in the frequency range 150 MHz – 2 GHz. It is observed that whole-body averaged SAR for a realistic exposure exceeds in up to 58 % of the examined samples the worst-case single plane wave exposure. Moreover, the ICNIRP reference level does not always comply the basic restriction in the child phantoms considering a realistic exposure.

**Objectives.** The compliance of the ICNIRP reference levels [1] to the basic restrictions for radiofrequency (RF) electromagnetic fields (EMF) are mostly investigated using the worst-case single incident plane wave exposure. The objective of this work is to evaluate the compliance to the basic restrictions if realistic exposure scenarios are used.

**Methods.** The statistical multipath exposure method presented in [2] has been used to investigate the whole-body averaged SAR (SAR\_wb) in several spheroidal human body phantoms in an urban macrocell environment in the frequency range of 150 MHz – 2 GHz. Five different sizes of the spheroid phantoms have been selected representing an average man, an average woman, a 10-year-old child, a 5-year-old child, and a 1-year-old child. The dimensions of these phantoms have been taken from [3]. The dielectric properties of head tissue suggested by IEC 62209 [4] for compliance testing have been used for the homogeneous tissue of the phantoms. The root-mean-squared (rms) value of the incident electric field averaged over the entire phantom was set equal to the ICNIRP reference level as specified in [1].
Results. The results show that SAR_{wb} for a realistic exposure exceed the worst-case plane wave exposure in 11% to 58% of the examined exposure samples. Moreover, realistic exposure samples have been observed for which the ICNIRP reference level does not ensure the compliance to the basic restriction. The results for the GSM downlink frequency of 950 MHz are shown in Table 1 and Figure 1. Table 1 shows the whole-body averaged SAR for the worst-case single plane wave exposure and for a realistic exposure in an urban macrocell environment. The rms incident electric field averaged over the phantom was set equal to the ICNIRP reference level, i.e. 42.38 V/m. For the worst-case single plane wave exposure, the whole-body SAR and the corresponding worst-case polarization (E, H or k: see [3]) are listed in Table 1. For the realistic exposure the SAR_{wb} has been determined for 10000 exposure samples. The 99th percentile of SAR_{wb} (p_{99}) as well as the percentage of realistic exposure samples which result in a whole-body SAR higher than the worst-case plane wave exposure (n_{s>pw}), and the percentage of realistic exposure samples which result in a whole-body SAR higher than the basic restriction (n_{s>BR}) are shown in Table 1. One observes that the whole-body averaged SAR at 950 MHz increases with decreasing phantom size. Table 1 also shows that the realistic exposure samples exceed the worst-case plane wave exposure in 22.1% to 58.8% of the exposure samples. Moreover, for a 1-year-old child SAR_{wb} exceeds the ICNIRP basic restriction of 0.08 W/kg in 7 samples of a total of 10000 realistic exposure samples (0.07%). All the results at 950 MHz are summarized in Figure 1, which shows the single plane wave exposures (E-, H- and k-polarization) on top of the cumulative distribution functions (cdf) of SAR_{wb} in an urban macrocell environment for an rms electric field averaged over the phantom equal to the reference level, i.e. \langle E_{rms} \rangle_{phantom} = 42.38 V/m.

Conclusions. The compliance to the basic restriction in case of a realistic exposure has been examined. It has been shown that the worst-case single plane wave exposure is not a conservative approach for a realistic exposure. The highest SAR_{wb} values have been obtained in the 1-year-old child. Moreover, the ICNIRP reference level does not always ensure the compliance to the basic restriction for the 1-year-old child.

Acknowledgements. REFERENCES
Figure 1: The whole-body averaged SAR for the single plane wave exposures and the cumulative distribution function of the whole-body averaged SAR for the realistic exposures at 950 MHz.

P-41 CORONA DISCHARGING AEROSOL EMITTED FROM HIGH VOLTAGE TRANSMISSION LINE

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Summary of Abstract. The final goal of this study is to estimate the charged aerosol and respiratory diseases of people living near high voltage transmission lines (HVTL) caused by the corona phenomenon surrounding HVTL.

Objectives. In this study, we investigated the relationship of PM 10, PM 2.5 (diameter of particle matter less than 10 or 2.5 micrometer) concentration and air condition with the corona phenomenon.

Methods. In this study, we measured the circumference of 154kV HVTL by corona, and obtained the charged aerosol value, electromagnetic field, and particle matter under the power transmission line.
Measurements were performed at six sites (154 kV power transmission line), such as a

**Results.** The results obtained from those six sites are summarized in the following. The average value of charged aerosol concentration levels order is D>I>S>H4>H2>H3. The average value of charged aerosol concentration was $1.36 \pm 3.71$ fA in D site (hospital). The average value of PM 10 and PM 2.5 concentration in D site was 41.9, 26.5µg/m$^3$ as a 24-hour mean, respectively. This study’s results suggest that humid weather has an average value of charged aerosol, whereas dry weather has a high value.

**Conclusions.** In conclusion, it was found that there was a significant relationship between the concentration of charged aerosol, humidity, and electronic current power. Further studies are needed to clarify the relationship of charged particles and humidity.

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**Figure 1.**
**P-42** THE EFFECT OF REFLECTED ELECTROMAGNETIC FIELD FROM ELEVATOR WALLS ON THE SAR OF A MOBILE-PHONE USER: -COMPARISON BETWEEN SAR IN AN ADULT AND CHILDREN-

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**Summary of Abstract.** An investigation to compare the specific absorption rate (SAR) of an adult and children inside an elevator at 900 MHz, that employs realistic human models and an actual elevator size, is presented in this paper. The 10-g SAR of the adult was found to be 22 % larger than the maximum value obtained in the children in the free space. Similar percentage was obtained when the models are located in the same position in the elevator, implying that the increase in 10-g SAR due to reflection in the elevator is almost the same for the adult and children. The whole-body average (WBA)-SARs of the children are 2.7~4.6 times larger than that of the adult for both free space and elevator cases. The maximum value of the WBA-SAR, obtained from the 3yrs child, is 15 % of the ICNIRP guideline.

**Objectives.** In the previous investigations on the RF exposure of a mobile phone user in the elevator, we have shown that although there is a reasonable increase in the SAR of the adult passenger in the elevator due to multi-reflections of the electromagnetic fields from the walls, the maximum values obtained were below the ICNIRP guideline[1]. Children, due to their small body size, their head with an antenna can be placed much closer to the walls than the adults. Since the SAR values were found to depend on the passenger...
position from elevator walls [1], it is necessary to study the children SAR, especially when positioned closer to the walls where strong coupling is expected. In this paper, we investigate the SAR of the children using a mobile phone in the elevator and compare the maximum values obtained to those of the adults.

**Methods.** The elevator model having metallic walls is similar to the one used in [1]. The mobile phone was modeled as a half wavelength dipole antenna placed at a distance of 16 mm from the head with a transmitting power of 250 mW, corresponding to the maximum power of the some of the mobile handsets used in Japan. The non-uniform mesh FDTD technique was used to minimize computer resources [1]. The models of 3yrs, 5yrs and 7yrs Japanese children are used [2]. The same electrical properties of tissues, derived from Gabriel technical reports [3], are used for both the adult and children.

**Results.** Table 1 lists the SAR of the children and adult in free space at 900 MHz. WBA-SAR values of the children are larger than that of the adult, this is expected from the weight difference between the models. The 10-g SAR is found to increase with the age of the models. Table 2 contains SAR values when the models are placed at the same position inside elevator. In this case the model were placed at a distance, $x = 252$ mm and $y = 170$ mm, where $x$ is the distance from the elevator wall in the side of the head with the phone and $y$ is the distance from the front elevator wall [1]. This position was chosen because it provides a maximum 10-g SAR in adult (see Fig1a). The results for 10-g SAR show that when the models are placed at the same position, the percentage increase in the SAR over the free space values is almost the same between the adult and children model, about 15%.

Fig 1 shows the SAR dependence on the model position in the elevator for the adult and 3 years old child. The peaks of the sinusoidal SAR curves are approximately determined by the equation $d = (2n + 1)\lambda/4$, where $n = 0, 1, 2,$. In large distance away from the walls, the curves for adult and children were found to follow similar pattern of the slowly decaying sinusoidal form. However, for $x < \lambda/4$, the case observed in Fig 1b, the values of SAR start to increase rapidly. At the minimum valid distance of $x = 66$ mm for the 3yrs old child, the maximum SAR values obtained is 1.02 W/kg. We found that when the antenna is brought closer to the wall for $x < \lambda/4$, its resistances start to decrease steadily. This low input impedance results in increased antenna current when the input power is normalized, i.e. $I = \sqrt{P/R}$. Previous studies reported that antenna current strongly correlate with the local SAR of the human head exposed to near-field of the antenna. However, in actual case, decrease of antenna input impedance results in the increase of return loss due to the mismatch between the antenna input impedance and the feed line impedance. So actual input power is generally lower than the normalized input power.

**Conclusions.** An increase in maximum 10-g SAR due to electromagnetic reflection in the elevator is almost the same between the adult and children when positioned a quarter-wavelength away from the walls. However, if the children are within a quarter-wavelength from the wall, their 10-g SAR is found to increase rapidly. This phenomenon however seems unrealistic because significant change of the antenna input impedance results in decrease
of the input power. Adults due to their large body size cannot be placed within quarter-wavelength from the walls.

In the free space, the WBA-SARs of the children are 2.7∼4.6 times larger than that of the adult. A similar trend is observed in the elevator. However, the maximum value obtained is 15 % of the safety guidelines.

Reference

Acknowledgements. Calculations in this work were performed using SX-8R series supercomputer provided by the National Institute of Communications and Technology.
Figure 1. Variation of 10g-SAR of a passenger against distance (a) Adult, (b) 3yrs child
**P-43** SPECIFIC APPARATUS FOR POST-PRODUCTION SAR EVALUATION THROUGH DIFFERENTIAL MEASUREMENTS

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**Summary of Abstract.** We investigate on the evaluation of a complete fast SAR post-production evaluation system, enabling individual testing of mobiles on a production line, under affordable time and cost. In this paper, we focus on the design and optimization of the differential measurement system parameters as well as the multi-probes sensor.

**Objectives.** Determining the Specific Absorption Rate SAR in accordance with standard recommendations [1] results in quite complex and tedious protocols, incompatible with mobile phone production constraints. Furthermore, the SAR is specific to each individual mobile device and must be systematically evaluated. Real-time SAR-measurements are consequently expected.

**Measurement principle:**
In the context of mobile phones, the objective is to develop a fast SAR evaluation system. In order to reduce the data-acquisition time, the basic idea is to proceed with a reduced number of appropriate measurement points, and to determine the effective SAR value through a comparative analyse provided from a reference certified SAR measurement.

The electric fields distribution is determined by five fixed miniature sensors immerged in a liquid modelling the human tissues electrical properties. They are illuminated by the mobile phone under test. The wireless radio connection is established within a rectangular flat phantom, containing the mobile phone, the probes sensor, the emulator antenna, the liquid.

**Methods.** As a differential SAR evaluation is expected, we have simplified the probes sensor. Previous internal experimental investigations stated that the electric field component perpendicular to the mobile phone is negligible compared to the others. Consequently, we only use two planar dipoles for simplifying the measurement system and we evaluate various sensor configurations.

Each probe is composed of two dipoles to capture both X-Y E-field components. A schottky diode is connected between the dipole pads for ensuring the quadratic detection of the RF incident signal. The DC detected voltage is transferred by resistive lines to external connectors, ensuring simultaneously a convenient decoupling from data transfer system and incident RF-fields.

A comparative analysis has been performed in order to optimize the multi-probes sensor. We evaluate, through specific modelling procedures using CST Microwave Studio® software, the isotropic performances of each probe, as well as coupling phenomena and sensitivity values, depending on the dipoles relative positioning, shapes, and environment.

**Results.** The coupling and the isotropic performances were simulated for optimizing the multi-probes sensor. Several measurements have been performed in the air to validate the differential E-field determination procedure. An electromagnetic (EM) scanning is done on
a selected reference plane (5 mm above an emitting reference dipole) for evaluating and mapping the radiated electric field. These measurements are compared to the simulated field of the reference antenna (see figure 3).

Similar investigations are now in progress considering the equivalent tissue liquid.

Complete system:
The system will be composed of a shielded box to prevent interaction with the surrounding electronic devices. The use of a flat phantom drastically simplifies the system design. For the dimensioning, we proceed with EM rigorous analysis for evaluating the incidence of the different elements. The electromagnetic simulation software MicrostripesTM was selected to compute the E-Field, local and 10g SAR distributions. These values are compared with those of a reference system constituted of an infinite flat phantom and perfect absorbers. In a second time, simulations are accomplished taking into account a realistic model (with absorbers, generic mobile phone, emulator antenna...). The shielded box and the fast-SAR measurement apparatus have been optimized among 150 simulated configurations leading to the following dimensions (see figure 1): L = 400 mm, W = 300 mm, phantom Tph = 100 mm, Ha = 90 mm, Ta = 30 mm.

Conclusions. We propose in this paper a complete post-production SAR extraction system for measuring the SAR values of mobile phones under quasi-real-time conditions (approximately 10 seconds per mobile). Simulations and measurements have been discussed for the determination of the optimal dimensions of the shielded structure, as well as the multi-probes sensor specifically designed for the E-field measurement.

References:
[1] ICNIRP Guidelines, ”Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, Health Physics, Apr. 1998


Figure 1. : Differential SAR measurement system
Figure 2. : Multi-probes sensor

Figure 3. : E-field measurements — comparison with simulations
P-44 COMPARING THE SAR INDUCED BY WIRE AND PLANAR ANTENNAS IN A FLAT PHANTOM

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Summary of Abstract. Earlier we reported our results on canonical dipole, monopole, and planar antennas relating antenna bandwidth with the SAR or threshold power corresponding to the SAR \cite{1}–\cite{2}. More recently we have proposed a newly developed mathematical relationship that can be used to estimate the threshold power for low directivity antennas operating within 2 to 25 mm from a phantom and within the frequency range of 300 to 6000 MHz \cite{3}–\cite{4}. This paper examines the differences in SAR between wire and planar antennas in more detail.

Objectives. The objective of the current paper is to compare and examine the SAR induced by different wire and planar antennas (wire dipoles, wire monopoles, and single and dual band planar inverted-F antennas (PIFAs)) in a flat phantom and explain their differences in SAR from an intuitive near-field/far-field point of view.

Methods. Cylindrical dipoles of lengths $\lambda/15$, $\lambda/8$, $\lambda/4$, and $\lambda/2$ at discrete frequencies between 300 and 6000 MHz were chosen. The wire radius of the cylindrical dipoles was 1.8 mm. Quarter-wave wire (1.8 mm radius) monopoles were placed at the center of the top surface (40 by 19 mm\textsuperscript{2} surface) of a metal box (100 mm by 40 mm by 19 mm). Printed inverted-F antennas (PIFAs) were considered on top of a metal box (on the top edge of one 100 by 40 mm\textsuperscript{2} surface) measuring 100 mm by 40 mm by 10 mm. The dielectric properties and conductivities of the flat phantom are defined in the IEEE Std 1528 \cite{5}. Dipole antennas were placed at distances of $h = 5$, 10 and 20 mm from the flat phantom. The distance ($h$) was always measured from the antenna feed-point to the phantom-shell interface. For monopole antennas $h$ was 12 and 20 mm while for the planar antennas, distances of 13 mm and 20 mm were considered due to the dimensions of the metal boxes. SAR normalized to a 1W of continuous wave power was computed using XFDTD and measured using the DASY3 system.

Results. Computed spatial peak averaged SAR induced by $\lambda/15$ dipole antennas at $h = 5$, 10 and 20 mm from the flat phantom are plotted in Fig. 1(a). For each case SAR increases rapidly with frequency up to a certain frequency, then it decreases and then levels off, converging to the far-field value. For instance, for 5, 10, and 20 mm distances the SAR peaks at approximately 3000, 2000, and 1300 MHz, respectively. Clearly the presence of the antenna in the very close near field of the phantom results in the rapid increase in SAR with frequency, primarily due to the increased energy focusing at the higher frequencies, as well as the increase in tissue conductivity. It is interesting to note that for $h=20$ mm SAR data start to vary monotonously with frequency when the frequency is above about 3000 MHz. For electrically small antennas, the boundary between the near and far fields are characterized by $(\lambda/2\pi)$ which at this frequency is 15.9 mm. Since the antenna to phantom separation is 20 mm the SAR is primarily governed by the antenna far-field radiation intensity. Thus even though the tissue conductivity increases with frequency...
the decrease in the antenna field intensity compensates for that which results in a nearly constant SAR at the higher frequencies at this distance. This phenomenon is also apparent for \( h = 5 \) and 10 mm, although it cannot be seen completely in Fig. 1(a) since the frequencies are not high enough to allow far-field distance. In Fig. 1(b) SAR data of two dipole and a monopole antenna are shown for \( h = 20 \) mm. The small dipole induces higher SAR than the \( \lambda/2 \) dipole and the quarter wave monopole as expected. Note that at higher frequencies each antenna shows monotonous SAR variation with frequency due to the above mentioned reasons. Finally, SAR induced by a number of antennas operating at 900 MHz are compared in Fig. 2. Clearly the wire dipole antennas induce higher SAR than the other wire and planar antennas indicating their suitability as primary reference antennas for a conservative SAR estimation particularly for cases where the transmitter emits low power.

**Conclusions.** In this paper, different antenna types were analyzed, with the purpose of analyzing the near-field and far-field behaviors with regards to SAR in a human body phantom.

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**Acknowledgements.** This work was supported by the Mobile Manufacturers Forum (MMF), Brussels, Belgium and the GSM Association (GSMA), London, UK.
Figure 1. (a) Computed peak average SAR (10-g) of $\lambda/15$ dipole antennas at $h = 5, 10$ and $20$ mm from a flat phantom and (b) SAR (10-g) of dipole and quarter-wave monopole antennas at $h = 20$ mm.

Figure 2. SAR bar chart for wire and planar antennas at 900 MHz and $h = 10$ mm (except for PIFA, $h = 13$ mm and for monopole antenna, $h = 12$ mm).
RESPONSE OF DOSIMETRIC PROBES TO SIGNALS IN EMERGING WIRELESS TECHNOLOGIES


Summary of Abstract. Typically, dosimetric probes for Specific Absorption Rate (SAR) measurements are calibrated using a sinusoidal continuous wave (CW) signal, even though they are used for measuring more complex signals from wireless devices. It is important to characterize the response of dosimetric probes to these signals to make sure that they do not significantly underestimate or overestimate the SAR.

Objectives. The objective of this study is to measure the SAR of signals having random amplitude modulations (e.g., W-CDMA, Wi-Fi, WiMAX) and analyze the diode detector response in their presence.

Methods. SAR is proportional to the electric-field intensity and can be computed from its magnitude and the dielectric and physical properties of the medium. Dosimetric probes employ a short dipole loaded with a diode detector and a low pass filter, which gives a DC output voltage proportional to the average power of the incident electric field co-polarized to the dipole. Diode detector response deviates from an ideal square-law detector at high input powers and this response is corrected using a compensation algorithm derived from calibrating the probe with a sinusoidal waveform. This inherent nature of the diode detector, measuring average power, tends to mask any modulation effects associated with the emerging complex signaling schemes and hence needs to be investigated to see if an overestimation or underestimation of SAR is introduced. This study, requested by IEEE International Committee on Electromagnetic Safety Technical Committee 34, Sub-Committee 2, Working Group 1, is an extension to the work performed by DiNallo et al., ”Effect of Amplitude Modulation of the CDMA IS-95 Signal on SAR Measurements”, IEEE Transactions on Electromagnetic Compatibility, 48:552-562, 2006.

A vector signal generator was used to generate signals representing E-UTRA/LTE, TD-SCDMA, W-CDMA, CDMA2000, IEEE 802.11 a/b/g/n (Wi-Fi) and IEEE 802.16 (WiMAX) standards. These signals were generated at 1.88 GHz and fed into a WR430 rectangular waveguide (operating range: 1.7 – 2.6 GHz) with the input and output power monitored as shown in Figure 1. A miniature isotropic E-field probe (SPEAG ER3DV6) was used to measure the E-field components at the center of the rectangular waveguide, using a SPEAG DASY5 measurement system. By varying the input power to the waveguide, SAR was computed over a range exceeding 0.1-100 W/kg from the measured E-field magnitude, considering a conductivity of 1.4 S/m and density of 1000 kg/m$^3$.

Results. The measured SAR is plotted versus the average input power to the waveguide in Fig. 2. The SAR is corrected for diode compression by the probe manufacturer. It is seen that the curves are hard to distinguish from one another in this figure, which indicates that the percent errors are relatively small over most of the measured range. At higher power levels, the curves begin to separate. All of the curves exhibit the same behavior, which is linear over most of the range, but flattens out at lower input power levels due to the diode characteristic. The flattened portion of the curves is not an issue, as it exists at very low
SAR levels.
A more detailed view of the data is shown in Fig. 3, which depicts the percent error in the measured SAR with respect to that of CW for the various wireless signals. It is seen that five of the eight signals exhibit errors within ±5%, even at SAR levels as high as 100 W/kg. Three of the signals exhibit higher SAR errors. The highest errors are for IEEE 802.16 and TD-SCDMA. SAR levels up to 100 W/kg were studied (due to requirements of IEEE Standard 1528-2003), except for IEEE 802.16 which was limited to 50 W/kg due to the limitations of the signal generator. However, in practice, local SAR levels from portable wireless devices typically range from 0 to 10 W/kg. Over this range, the errors are less than 5%.

**Conclusions.** The response of average power sensors present in SAR probe to signals representing the emerging wireless technologies have been measured and analyzed. An insight into the resulting underestimation or overestimation of SAR is discussed.
**Figure 1.** Experimental setup showing E-field probe measuring at the center of WR430 waveguide with the power monitored at both input and output terminals.
Figure 2. Measured SAR in waveguide vs. Average power at the waveguide input for various wireless signals. The SAR is corrected for diode compression.

Figure 3. Percent error in measured SAR when measuring various wireless signals using a dosimetric probe that has been calibrated using a CW signal. The SAR is corrected for diode compression.
P-46 VALUATION OF THE SPECIFIC ABSORPTION CHARACTERISTICS WITHIN THE TISSUE SLICES EXPOSED TO PULSED WAVES

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Summary of Abstract. In this abstract, the method of Specific Absorption calculation on frequency domain has been discussed.

Objectives. Background
The concept SAR (Specific Absorption Rate) has been broadly used in the evaluation of energy absorption in dosimetry studies. Defined as the time derivative of the incremental energy \( dW \) absorbed by (dissipated in) an incremental mass \( dm \) contained in a volume element \( dV \) of given density \( \rho \) \[1\], SAR is able to present the "rate?" of energy absorption, rather than the total quantity of the absorbed energy, which is also needed in some cases. Therefore, another concept SA (Specific Absorption) has been defined in order to express the total energy absorption in certain time segment, such as the whole exposure range or just one pulse.

There have been several previous studies on SA in dosimetry and microdosimetry fields. The FDTD technique is used to evaluate the electric field interaction with human body and quantify the SA on time domain \[2\]. The SA calculated by this method is based on the point electric field values, which are not easily reachable for the commercial software based simulations. Therefore, a convenient method for calculating SA is needed.

Methods. Methodology
SA is defined as the quotient of the incremental energy \( dW \) absorbed by (dissipated in) an incremental mass \( dm \) contained in a volume \( dV \) of a given density \( \rho \) \[1\], as shown in equation (1):

\[
\text{SA} = \frac{dW}{dm \cdot dV \cdot \rho}
\]

Derive the relationship between SA and SAR in the discrete value sequence form:

Based on equation (2), there are two methods to calculate the SA: one is calculate from the E-field (similar to the method in reference \[2\]) as shown in equation (3), the other one is calculate from the known SAR as presented by equation (4).

where \( E_i \) are the E field magnitudes at different time points measure by the E-field probe.

where \( \text{SAR}(k) \) is the total SAR value on frequency domain, and \( Y(k) \) is the DFT of the all-one signal \( y(n) \). \( \text{SAR}(k) \) is commonly available in the post processing part of commercial software package, which can be conveniently used in the evaluation of SA. This method has been verified by calculating the known signals both on frequency domain and time domain.

Results. The tissue slice exposure system is a dielectric filled vertical transmission line system, which can delivery various signal types. The example signal here is the Gaussian Pulse on 200MHz \( \sim \) 3GHz as shown in Figure 1.

Based on the method shown in equation (3), which is calculated on time domain, the \( E_i \) are time sequence at one special point, centre of the tissue slice. The calculated SA by this
method is 8.0087e-010 J/kg. By selecting appropriate starting examine frequency, the SA can be obtained by the method shown in equation (4) (calculation in the frequency domain), which is 1.0671e-10 J/kg, with the same order as the time domain method.

**Conclusions.** It is observed what the frequency domain result is lower than the point SA calculated by the time domain method. That is because the total SAR used in the frequency domain method is the averaged value of point SARs, so it is reasonable to be lower than the point SAR.

The frequency domain SA calculation method can be extended to some other scenario, such as the rectangular pulse and modulated CW pulses in dosimetry and microdosimetry studies. It can also be used to estimate the temperature rising with the known specific heat capacity.

**References**


**Acknowledgements.** References


References


P-47 SAR IN HUMAN SUBJECTS AT 100 MHZ: COMPARISON BETWEEN THE FINITE DIFFERENCE TIME DOMAIN (FDTD) METHOD AND EMPIRICAL MEASUREMENTS

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Summary of Abstract. Computational modeling techniques, such as the Finite Difference Time Domain (FDTD) method, are often used in order to predict the absorption of radio frequency (RF) energy within biological samples. These techniques, combined with realistic voxelized anatomical models, have allowed researchers to predict both whole body...
and localized specific absorption rates (SAR) within the body in the RF range. These computational SAR calculations have become increasingly used in order to assess health and safety risks and to set RF safety standards. Therefore, it has become critically important to validate the accuracy of these techniques for real-life exposure conditions and to detail any possible limitations.

**Objectives.** Computational modeling techniques, such as the Finite Difference Time Domain (FDTD) method, are often used in order to predict the absorption of radio frequency (RF) energy within biological samples. These techniques, combined with realistic voxelized anatomical models, have allowed researchers to predict both whole body and localized specific absorption rates (SAR) within the body in the RF range. These computational SAR calculations have become increasingly used in order to assess health and safety risks and to set RF safety standards. Therefore, it has become critically important to validate the accuracy of these techniques for real-life exposure conditions and to detail any possible limitations.

**Methods.** An ongoing research effort at Brooks City-Base has measured the temperature rise on the surface of the skin of human subjects exposed to 100 MHz RF energy. This data was then post-processed in order to find the SAR values on the skin for each subject. The FDTD method was used to predict the SAR for a 1 mm resolution anatomical body model. The SAR values, as measured empirically and calculated using FDTD, were then compared to study the accuracy of the FDTD calculations.

**Results.** Preliminary results indicate a range of possible absorption values on the skin. These values are influenced by a complex interaction between the geometrical properties of each subject. Therefore, a parametric analysis of the geometry for the anatomical body model has been performed. However, this process is limited to slight changes in the voxel dimensions for available body models, and cannot fully capture the broad range in human body shapes. It does, though, provide a basic understanding of the effect of body dimensions on SAR values, and can predict a range of expected possible absorption values.

**Conclusions.** Computational techniques, such as FDTD, will continue to play an important role in RF dosimetry. In the future, it is expected that advancements in these techniques, and the availability of a larger number of high resolution anatomical models, will only increase their usefulness for RF dosimetry calculations.
TOTAL RADIATED POWER AND TOTAL RADIATED SENSITIVITY OF MOBILE TERMINAL EQUIPMENTS MEASURED BY USING A BROADBAND SOLID PHANTOM

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Summary of Abstract. The paper looks at the comparison of the Total Radiated Power (TRP) and Total Radiated Sensitivity (TRS), generated by Mobile Terminal Equipments (MTE), measured in presence of a Broadband Solid Anthropomorphic Mannequin and a traditional Narrowband phantom.

Objectives. CTIA \cite{1}, in the past, and 3GPP \cite{2}, nowadays, have defined the experimental method to evaluate the TRP and the TRS of an MTE. The MTE is checked for TRP and TRS both in free space and in presence of a phantom, to determine the load effect of the user. When describing the head phantom characteristics, 3GPP refers to the Specific Anthropomorphic Mannequin (SAM) as used for Specific Absorption Rate tests \cite{3-4}, filled with a tissue equivalent liquid. The use of a liquid, to fill the SAM phantom, could be not practical when used inside an anechoic chamber, furthermore when the liquid is narrowband, the overhead necessary to manage the traditional phantom could be not practical neither time efficient. The objective of the paper is to compare TRP and TRS measured in presence of a Solid Broadband SAM phantom and in presence of a traditional SAM phantom filled with narrowband tissue equivalent liquids.

Methods. TRP is a measure of how much power the MTE radiates. TRP is defined as the integral of the power transmitted in different directions over a closed surface:

\[
\text{TRP} = \frac{1}{(4\pi)} \int \left[ \text{EIRP}_\theta(\Omega,f) + \text{EIRP}_\phi(\Omega,f) \right] \mathrm{d}\Omega
\]

where \(\Omega\) is the solid angle, \(f\) is the frequency, \(\theta\) and \(\phi\) are the orthogonal polarizations, \(\text{EIRP}\) is the transmitted power-level in the corresponding polarization. TRS is defined as

\[
\text{TRS} = \frac{4\pi}{\int \left[ 1/\text{EIS}_\theta(\Omega,f) + \text{EIS}_\phi(\Omega,f) \right] \mathrm{d}\Omega}
\]

where the Effective Isotropic Sensitivity (EIS) is defined as the power available at the antenna output such as the sensitivity threshold is achieved for each polarization. TRP and TRS are checked in free space and in presence of a phantom simulating the user. The phantom has a sensible effect on the MTE radio performances since the load effect on the radio frequency stage, changing TRS, TRP and radiation pattern. Due to the change of the electromagnetic characteristics of the human tissues as a function of the frequency, different properties for the phantom have to be used. Traditionally the SAM phantom is filled with a tissue equivalent liquid whose characteristics are frequency dependent so the phantom - or the liquid - has to be changed when measuring at different operational modes (GSM900, DCS1800, PCS1900, UMTS, WiFi) leading to a procedural hoverhead. The use of a Solid Broadband phantom \cite{5}, fig. 1, is of interest since it is not necessary to change the liquid filling SAM and it is not necessary to manage liquids inside a sensible environment as could be an anechoic chamber.

Results. Figures 2-3 show the difference on TRP and TRS when measured in presence of the Solid SAM and with SAM filled with the narrowband tissue equivalent liquid (missing bar means no difference). The analysis, at the moment, is performed on 3 MTE and shows
that differences in TRP are limited to 1.1 dB while they are limited to 2 dB for TRS. The greater difference on TRS is expected since it is checked at very low field levels where measurement system detection limits and uncertainties could have a greater effect.

**Conclusions.** Even if the analysis is proceeding checking different type of MTE, taking into account for different case’s shape and operational modes, to have a more extended statistic, these first results indicate a correlation when measuring TRP and TRS by using a Broadband Solid SAM and a Narrowband liquid filled SAM. A further analysis has to be done in order to understand if differences are due to the properties of the phantoms or have to be associated to the measurement uncertainty.

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[3] IEC 62209-1, Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedures to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz), 02/2005.
[4] IEEE Std 1528, IEEE Recommended practice for determining the peak spatial-average Specific Absorption Rate (SAR) in the human head from wireless communications devices: measurement techniques, 12/2003
Figure 1. : The Broadband Solid Phantom
**Figure 2.** Difference analysis on TRP

**Figure 3.** Difference analysis on TRS
P-49 POWER TRANSFER ALONG THE WIRE OF A MOBILE PHONE HANDS FREE KIT

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Summary of Abstract. For credible hands free kits dosimetric assessments, it is necessary to approach a realistic worst exposure case. The use of a folded section on the hands free kit wire allows to maximize the RF induced power in the phantom head. The effects of the different parameters are studied by the mean of numerical simulations.

Objectives. The use of hands free kits (HFK) with mobile phones should decrease the user head exposure to the RF power because the distance between the phone antenna and the head is larger in this case. However the wire of HFK is metallic and the RF currents induced on this wire can be the sources of power deposition in the user head. Consequently, it is necessary to study the HFK SAR, especially to be able to propose an argued measurement protocol. The problem is separated in three different parts: the coupling between the phone and the HFK wire [1], the propagation of the current and the radiation on the wire, and the coupling between the end of the wire and the user head [2]. This paper presents the effect of the RF power propagation along the wire.

Methods. The RF power propagation along the HFK wire depends upon several parameters: the wire geometry, the wire length, the frequency... This problem is very complex, especially due to the variability of the wire geometry, that is why we choice a rectilinear wire between the phone and the user head. The objective of this study is to find an experimental method that maximizes the user head exposure and to implement it for HFK dosimetric measurements. This method allows to obtain a worst case for the exposure.

It is first possible to use a simple model. This model consists in a long rectilinear monopole, a ground plane perpendicular to the monopole, a voltage source between the monopole and the ground plane and a resistive load near the end of the monopole (figure 1.a). The ground plane and the voltage source simulate the mobile phone, the monopole simulates the HFK wire and the resistive load the exposed biological tissue. The insertion of a folded section wire with a given length and at a given location on the wire allows to maximize the dissipated power in the resistive load.

The second part of the study consists in the validation of the precedent model and in a parametric study. The user head is a half space with EN50361 standard dielectric constant and conductivity values. The HFK wire has two rectilinear parts: one is parallel to the surface of biological tissue and the second is tilted with an angle $\alpha$ and contains a folded section as in part one.

Figure 1: a)Monopole with a resistive load near the end, b)Monopole with a resistive load and a folded section, c)User head and HFK wire modelling.
**Results.** The total length of the wire is 110cm corresponding to a typical value for HFK. The frequency is 897MHz.

The first part of the study consists in the evaluation of the proportion $P$ of the active power which is dissipated in the resistive load by the mean of NEC2 software. The resistive load $R$ varies from $250\Omega$ to $700\Omega$ and the length $l$ varies from 10 to 40mm. For each value of the pair $R$ and $l$, it is possible to maximize $P$ and the result is presented in the figure 2. $P$ varies from 46 to 49%, that is to say that about half the power is dissipated in the resistive load and only the other half is radiated.

Figure 2: Proportion of the active power, which is dissipated in the resistive load for the figure 1.b model.

The second part of the study consists in the evaluation of effect of the location $d$ and the length $l_s$ of the folded section. IE3D calculates the electric near field in the biological tissue and a specific software calculates the maximum SAR 10g value from this electric field. The figure 3 shows the variations of the relative maximum SAR 10g as a function of $l_s$ and $d$, for $l_c=20$mm and $\alpha=45^\circ$. The variations are quasi periodic following $l_s$, with a half wavelength period. The ratio of the first maximum and the first minimum of the curve is larger than 10. The folded section location has quite no effect in the first period of the curve.

Folded section length (mm)
Figure 3: Variations of the relative maximum SAR 10g following $l_s$ and $d$.

**Conclusions.** This study shows that it is possible to maximize the SAR 10g induced by a HFK in the phantom head by the mean of a folded section on the wire in order to approach a realistic worst exposure case. The choice of the length and the location of the folded section allow the maximalisation. It is necessary to complete this study for parameters effects understanding. Then it will be possible to suggest an argued measurement protocol for HFK dosimetric assessments.

References

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Figure 1. 

Figure 2.
Figure 3.
P-50 UNCERTAINTIES STUDY FOR DETECTED PROBE WAVE GUIDE CALIBRATION

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Summary of Abstract. The probe calibration has an important influence on the accuracy of dosimetric measurements. This paper presents a study which estimates the calibration error of the detected probe in wave-guide.

Objectives. Detected probe calibration is a very important step in dosimetric measurement, especially in term of accuracy. The detected probe calibration consists in two steps for each probe dipole, respectively the determination of the sensitivity in the quadratic area and the non-linearity for larger field values. The non-linearity is evaluated for a given probe location by the mean of the applied power variations, and doesn’t present any particular or different inaccuracy aspect comparatively with the quadratic sensitivity measurement.

There are two main calibration method kinds: wave-guide and reference antennas methods. Supélec has introduced an easy to use wave-guide calibration method a few years ago [1]. This method is easier to implement than previously published methods [2]. Power conservation is used instead of the continuity of the tangential component of the electric field at the interface between the two media, to evaluate the reference field in the equivalent liquid. This method allows the direct calculation of the reference field in the equivalent liquid. Only measurements at one location in the wave-guide are needed instead of 10 or 20 locations.

Methods. The quadratic sensitivity or calibration factor Fc of the dipole of the detected probe is related to the measured detected voltage Vd and the reference high frequency field E by the mean of the following relation:

\[ Fc = \frac{Vd}{(E.E)} \]  (1)

The logarithmic differentiation of relation (1) gives:

\[ \frac{dFc}{Fc} = \frac{dVd}{Vd} - 2 \frac{dE}{E} \]  (2)

For a given reference field E the detected voltage Vd depends upon the frequency (pulsation \( \omega \)) and the properties of the equivalent liquid real and imaginary parts of the relative complex permittivity \( \varepsilon' r \) and \( \varepsilon'' r \):

\[ Vd(\omega, \varepsilon' r, \varepsilon'' r) \]

\[ dVd = [dVd/d\omega]d\omega + [dVd/d\varepsilon' r]d\varepsilon' r + [dVd/d\varepsilon'' r]d\varepsilon'' r + dVd_{measured} \]  (3)

The reference field in the liquid filled part of the wave guide depends upon (figure 1) the frequency, the transmitted power Pa in the liquid, the dimensions of the used wave guide a and b, the longitudinal distance between the beginning of the liquid filled part of the wave guide and the dipole location and the properties of the equivalent liquid \( \varepsilon' r \) and \( \varepsilon'' r \):

\[ E(\omega, Pa, a, b, z, \varepsilon' r, \varepsilon'' r) \]

The transverse error on the probe location has no effect on the reference field due to the geometric properties of the TE10 wave-guide mode.

The differential of the reference field is:

+ \left[ \frac{dE}{d\epsilon''} \right] d\epsilon'' (4)

The three first terms of dVd are characteristic of a given probe and have to be furnished by the probe designer. The fourth term dVdmeasured is the error due to the detected voltage measurement, typically less than 1%. The different terms of dE are characteristic of the calibration method and the used material for its implementation, and we are in interest with these terms in this paper.

For practical considerations it is better to use relative error for \(\omega\) and \(Pa\), and absolute error for \(a\), \(b\), \(z\), \(\epsilon'\) and \(\epsilon''\).

\[
\delta E/E = C_{\omega} \frac{\delta \omega}{\omega} + C_{\epsilon'} \frac{\delta \epsilon'}{\epsilon'} + C_{\epsilon''} \frac{\delta \epsilon''}{\epsilon''}
\]

(5)

Figure 1.a: Calibration wave-guide. Figure 1.b: Errors diagram for wave-guide calibration.

**Results.** The figure 2 presents the values of the different error coefficients on the reference field E for typical size wave-guides. The relative error coefficient on the frequency is very low leading to negligible frequency errors.

Figure 2: Errors coefficient on the reference field E.

It is possible to take typical values for the other different errors: \(\delta a = \delta b = \delta z = 0.5\) mm, \(\delta Pa/\epsilon' = 2\%\), \(\delta \epsilon'' = 2\) and \(\delta \epsilon'' = 1\). In these conditions the main error is due to \(\delta z\), following by \(\delta \epsilon''\), \(\delta Pa\) and \(\delta \epsilon'\) (figure 3).

Figure 3: Different relative errors on the reference field E.

**Conclusions.** This study allows the knowledge of different errors occurring for detected probe wave-guide calibration. The level of the different errors is determined leading to the global error value. It is also possible to minimize the global error by the mean of the minimization of the main errors, especially \(\delta z\) and \(\delta \epsilon''\).

**References**


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**Figure 1.**

**Figure 2.**
Figure 3.
**P-51 DEVELOPMENT AND CHARACTERIZATION OF THE MICROCUVETTE: AN EXPOSURE DEVICE FOR REAL-TIME OBSERVATION OF ELECTROPORATIVE MOLECULAR UPTAKE**

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**Summary of Abstract.** We have developed and characterized a device designed for exposing cell cultures to intense pulsed electric fields (PEFs) under real-time microscopy. This “microcuvette” consists of a microscope slide with two precisely separated attached metal electrodes. We present a simple and reproducible technique for creating microcuvettes based on common microfabrication techniques. Microcuvettes were batch-fabricated producing highly robust devices capable of successfully being reused in hundreds of electroporation experiments with electrode separation distances of $80 \pm 4 \mu m$ and electrode heights of $19 \pm 5 \mu m$. Finite element model (FEM) electrostatic simulations are performed to assess the degree of electric field variation experienced by cells resting between the microcuvette’s electrodes for a number of different electrode heights and separation distances. The effect of this electric field variation on electroporative uptake is demonstrated in an experiment where we induce asymmetric propidium iodide (PI) uptake in HL60 human leukemia cells using a $40 \mu s$ PEF with a nominal field intensity of 1.6 kV/cm.

**Objectives.** The primary objective of this work was to develop a device for monitoring microscopic cell cultures under real-time microscopy during exposure to intense PEFs for experimental electroporation research. The device was to be robust, easily fabricated, and capable of producing the PEF intensities required in nanosecond pulse-range electroporation (i.e., hundreds of kV/cm) using accessible electronics. Use of such a device in experimental research requires an assessment of post-fabrication tolerances and the variation in electric field intensity experienced by cells within the device.

**Methods.** Microcuvettes were produced from gold/titantium-coated glass microscope slides using common photolithographic and electroplating techniques. At least 20 $\mu m$ of AZ P4620 photoresist was spun on a Au/Ti-coated glass microscope slide at 500 rpm for 45 seconds (Fig. 1(a)). The photoresist-coated slide was softbaked at 110 $^\circ C$ for 2 minutes, covered with a photolithographic mask, and exposed to UV light at an intensity of 7.5 mW/cm$^2$ for 50 seconds (Fig. 1(b)). The device was then submerged in AZ 400K developer solution mixed 2:5 with deionized water until the unwanted regions of photoresist were dissolved (Fig. 1(c)). Nickel was electroporated in the gold-exposed regions of the device (Fig. 2(d)) to form two electrodes. The remaining photoresist was removed using acetone (Fig. 2(e)) and the Au/Ti coating was removed using GE-8148 Gold Etchant followed by thorough rinsing and submersion in 1:100 HF:H$_2$O for 5 minutes. Microcuvette electrode chamber dimensions were measured using a profilometer. The electric field heterogeneity between the microcuvette’s electrodes was determined using a FEM electrostatic simulation.
software package for 1 V excitation relative to the nominal electric field value ($E_n$), defined as the electrode excitation voltage divided by the electrode separation.

**Results.** *En face* views of a completed microcuvette can be seen in Fig. 2 (right three images) at increasing magnifications moving from left to right. Microcuvette electrode separation distances of $80 \pm 4 \mu m$ and electrode heights of $19 \pm 5 \mu m$ were measured. FEM simulation data detailing electric field variation is provided in Table 1. It can be seen that the deviation in field intensity from the nominal field value is generally greatest when electrode height is at its lowest. To demonstrate the effect of this field non-uniformity on electroporative uptake, we conducted an experiment where the nominal electric field was set to be approximately the field strength required to induce transient electroporation in HL60s ($E_n = 1.6$ kV/cm) in the presence of PI, a plasma membrane integrity indicator. This scenario was expected to preferentially induce PI uptake near the electrodes of the microcuvette. The right three images in Fig. 2 show fluorescence images from this experiment at the indicated times after PEF exposure. As expected, regions near each electrode experience greater amounts of electroporative PI uptake.

**Conclusions.** The microcuvette fabrication technique presented has produced a number of devices for use in experimental electroporation research meeting requirements of ease in fabrication, robustness, and the capacity to produce the intense PEFs required for electroporation when using sub-microsecond pulsewidths. Though the electric field non-uniformity between the microcuvette’s electrodes is an issue that should be considered when interpreting experimental data obtain from our device (and others similar to it), this field variation does not pragmatically limit its experimental use since these variations are predictable and quantifiable.

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![Illustration of the microcuvette microfabrication process.](image)
FIGURE 2. Images of completed cell-loaded microcuvette under bright-field (left 3 images) and fluorescence (right 3 images) microscopy.
P-52 USE OF NETWORK DATA TO APPROXIMATE INDIVIDUAL DIFFERENCES IN MOBILE PHONE EXPOSURE FOR EPIDEMIOLOGIC STUDIES

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Summary of Abstract. Over 30 different research groups have performed recent case control studies to examine possible correlations between mobile phone use and brain tumors, with almost half of these participating in the recent IARC INTERPHONE study. Many groups have published findings with mixed results. Although no consistent evidence exists across studies for a correlation with short-term mobile phone use, there is some indication from recent meta- and pooled-analysis that may raise questions regarding 10+ years and/or ipsilateral use. Many of the study authors have identified possible limitations in the study design, including tumor latencies that extend beyond 10+ years, vague stratification schemes, selection bias in the control groups, and potentially significant recall error. However, other elements of the exposure assessment associated with mobile phone technology and its evolution over the past few decades may equally contribute to exposure uncertainty. In particular, there is a question whether significant inter- and intra-individual differences in average exposure may be associated with different geographical regions or across time. The following presentation will attempt to assimilate targeted network data to predict spatial and temporal differences to better predict individual exposures for future epidemiologic studies.

Objectives. To facilitate a better approximation of individual exposure assessment for epidemiologic studies

Methods. Network operator data from targeted areas in the US will be used to predict spatial and temporal differences in inter- and intra-individual exposure levels

Results. Recent studies have employed software modified mobile phones that record data on dynamically changing transmit power levels as well as minutes of use to evaluate individual exposure over time and recall bias [1-3]. Some findings suggest significant intra-individual, inter-individual, and geographical differences in average exposure levels. However all these studies are limited by several complex factors influencing RF exposure that are difficult to control. Further, the number of software modified phones that can be developed and deployed in the field is limited. The present study uses network signal coverage information to predict phone transmit power across a much larger population of users in an effort to define more accurate predictors for individual exposure assessment.
**Conclusions.** While the need for epidemiologic studies may be justified to address public concern, such studies should not outpace efforts to accurately define individual exposure and produce robust data. Questions regarding possible differences in inter- and intra-individual exposure between different geographical regions as well as across time have been identified in some studies. This presentation outlines a potential strategy that could better approximate individual exposure assessment in support of epidemiologic studies.

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References:

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**P-53 EFFECT OF SUB-CHRONIC GSM EXPOSURE ON GLIA**

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**Summary of Abstract.** Low power electromagnetic fields (EMF) are suspected to produce biological effects in the nervous system. The study of AL Mausset et al. (December 2004) showed an increase of a specific marker of glial cells, the GFAP (Glial Fibrillary Acidic Protein), in striatum, hippocampus and cortex, 72 hours after a 15 min exposure to GSM-type radiation at a local SAR of 6 W/kg (head). This study is confirmed by Brillaud et al (2007).

**Objectives.** The aim of our experiment was to determine if that effect is persistent (sign of a potential gliosis) after sub-chronic exposure (2 months) when the rats were exposed to GSM signal for 45 min at a SAR = 1.5 W/Kg and for 15 min at 6 W/Kg and sacrificed 3 and 10 days later.

**Methods.** Exposure system:
Animals were placed in Plexiglas rockets with an individual loop antenna placed above the rat’s head. Four animals were exposed at the time. Loop antennas were connected to a generator and emitted a GSM signal (900 MHz, pulsed at 217 Hz, 1/8 duty factor) 5 days / week for 8 weeks
Experimental group:
48 Sprague-Dawley male rats were randomly assigned to 8 different groups: (24 rats were sacrificed 3 days later and 24 rats 10 days later). For each delay of 3 or 10 days after exposure the following was performed:
- 6 rats exposed 15 min at SAR = 6 W/Kg
- 6 rats exposed 45 min at SAR = 1.5 W/g
- 6 rats sham controls (3 for 5 min and 3 for 45 min, SAR = 0 W/Kg),
- 6 rats without any treatment and manipulation (cage control)

Immunohistochemical studies:
Animals were sacrificed with paraformaldehyde 4% intra-cardiac perfusion, then brains were recovered and cut in 50 µm sagittal sections. Slices were then processed as free-floating sections for GFAP immunolabeling.

Percentage of staining was determined in different areas: prefrontal cortex (PfCx), cerebellum cortex (CCx), dentate gyrus of hippocampus (DG), lateral globus pallidus of striatum (LGP), and caudate putamen (Cpu).

**Results.** After statistical analysis (one way ANOVA test). Rats exposed to sub-chronic GSM signal at 1.5 W/kg induce increase of GFAP in different structures of brain after 3 days. GFAP amount stays some after 10 days but the difference at that time is no longer significant. The power below 80% cannot generate that there is no more effect at that time. Sub-chronic exposed animals for 15 min at SAR = 6W/Kg show a increase of staining in PfCx, DG and LGP more important on day 10 compared to day 3 (Fig 1), statistically significant compared to sham animals (p < 0.05). But significant differences observed in CCx after 3 days were not observed after 10 days.

**Conclusions.** GFAP increase when persistent suggests gliosis. Previous studies showed that acute exposure to GSM signal at 6 W/kg induced glial reactivity after 3 days, but no longer after 10 days. In contrary, our results show that sub-chronic 2 months exposure at GSM signal 900 MHz with a SAR of 6 W/Kg induce astrogliosis in rat’s brain persistent after 10 days.

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P-54 FACTORS AFFECTING RADIOFREQUENCY POWER OUTPUT OF MOBILE PHONES

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Summary of Abstract. None

Objectives. Epidemiologic studies have primarily relied on self-report of duration and frequency of usage to assess radiofrequency (RF) exposure from mobile phones. This approach ignores other potential sources of RF exposure variability such as service communications protocol, format of phone, use of hands-free devices, location of phone use (e.g. indoor vs outdoor), and other factors. In a series of studies we examined the influence of various factors on mobile phone RF output.

Methods. Software-modified GSM phones were issued to volunteers in three geographic locations (San Francisco, New York City and New Jersey). The circumstances of each call were recorded in a logbook (e.g. location, motion or stationary, use of hands-free devices, and other factors). Data on the power output setting were recorded in the phone memory, linked with logbook information and analyzed using ANOVA models. In the second study, RF output data were recorded with a mobile data recording system installed in a vehicle traveling over specified urban, suburban and rural routes in the San Francisco Bay Area. This system enabled the capture of phone RF output measured by a probe inside the head of an anatomical phantom for analog, TDMA, CDMA and GSM systems. RF output data
were analyzed by communications protocol, mobile phone type, type of route, stationary versus moving, time of day, and other factors using ANOVA and regression methods.

**Results.** In the SMP study, 53 subjects logged 2,537 calls. Higher RF output (as reflected by power control settings) was observed by geographic location; outdoor locations had lower RF levels; no differences were observed by day of week. Overall 12% of the RF variability was explained by study area, movement while using phones, location (work, home, office, etc.), use of hands free device and urbanicity. We observed higher RF levels for analog phones and significantly lower levels for CDMA phones and rural routes had modestly higher levels than urban and suburban routes. No differences were noted for RF levels by time of call or day of week.

**Conclusions.** Exposure assessment in epidemiologic studies of mobile phones would benefit by including protocols to capture information on type of technology used (service provider would serve as a proxy for this), geographic region, use of hands-free devices and whether phones are frequently used in rural areas.

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**P-55 RECALL STUDIES OF REPORTED MOBILE PHONE USE: ANALYSIS OF LONGER-TERM RECALL ACCURACY: SUMMARY OF EXISTING RESEARCH AND IMPLICATIONS FOR EPIDEMIOLOGIC STUDIES**

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**Summary of Abstract.** None

**Objectives.** Nearly all epidemiologic studies of cancer risks and mobile phone use published to date have relied on self-reported usage as the primary exposure measure. Self-reported use can provide information on the frequency and duration of mobile phones, but not other potential exposure factors, e.g. energy output of the phone, technology, and other factors. We conducted a recall survey among 60 participants recruited from an engineering consulting company and assessed recall over a three-year historical period to compare accuracy between self report and billing record information.

**Methods.** We conducted a recall survey among 60 participants recruited from an engineering consulting company and assessed recall over a three-year historical period. We review and compare our results to the methods and findings from eight published studies from U.S. and INTERPHONE project.
**Results.** In our study the correlations between self-reported mobile phone use and billing records were approximately 0.7 (Spearman) and 0.6 (Pearson). These results were generally consistent with other recall validation studies that reported similar correlation coefficients, suggesting that self-report use can be useful in reflecting duration and frequency of mobile phone use for epidemiologic studies. INTERPHONE studies suggest a tendency of participants to underreport the number of calls and over report the total duration of calls. Our study and one other non-interphone reported the opposite trend.

**Conclusions.** Despite modest correlations, exposure misclassification is still present and under assumptions of non-differential misclassification appears to bias epidemiologic results towards the null value based on assessment of recall validation studies and findings reported in the studies of mobile phone use and cancer risk (Vrijheid et al, 2006 J Exp Science Environ Epidem; 16: 371-384). Only a few studies have been able to evaluate potential differential recall between cases and controls because most validation study populations were not drawn from case and control populations. Differential recall can bias relative risk estimates in a positive or negative direction. Given the uncertainties about potential differential recall (e.g. are cases more likely or less likely to report amount of mobile phone use), further study is needed. Recall studies have important implications for the interpretation of the current epidemiologic research suggesting continued effort is needed to improve exposure assessment for mobile phone studies and cancer risk.

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**P-56 THEORETICAL EVALUATION OF MAGNETIC FIELD DETERMINANTS FOR RESIDENCES ABOVE ELECTRIC TRANSFORMER ROOMS**

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**Summary of Abstract.** In a number of countries, it is common that electric transformer rooms are placed inside of multi-level apartment-buildings (in the basement or on the first floor). Limited available data indicates that in apartments located immediately above (or next to) these electric rooms, magnetic field exposure is higher than in other apartments on the same floor and in units on upper stories (Ilonen 2007, Szabo et al., 2007). This could provide an opportunity to evaluate the association between residential magnetic field exposure and childhood leukemia incidence in an epidemiologic study of a highly exposed population where the potential for selection bias is minimized or eliminated. A theoretical evaluation of residences above electric transformer rooms was performed to identify key determinates.
of magnetic field levels. A range of electric transformer rooms were visited in Toronto and engineering data was collected. A computer model of a typical transformer room was created. This model was used to calculate magnetic field levels in apartments located above the transformer room. A sensitivity study of magnetic field determinants was performed to identify key parameters affecting field levels in residences above the transformer room. The main determinants of magnetic fields are: transformer size/loading, location/routing of the low voltage cables or buswork, and distance.

**Objectives.** The study objective was to determine what key factors affect the magnetic field level in residences located above electric transformer rooms. These parameters could then be used to assess and rank magnetic field exposure in residences without visiting the residence for measurements.

**Methods.** A number of transformer rooms were visited and engineering information was collected in Toronto. A 3-D computer model was created of a typical electric transformer room and the low voltage supply cables that feed the building switchgear room (See Figure 1). The computer model was used to calculate magnetic field levels in apartments located above the transformer room. The EPRI EMF Workstation software was used to create a 3-D model. The transformer room was assumed to have a 3.65 meter ceiling with a residence above it. The key elements assumed for a typical electric transformer room included the transformer, high voltage and low voltage cables or buswork, and ancillary equipment such as fuses and switches. A sensitivity study of magnetic field determinants was performed to identify key parameters affecting field levels. For this analysis, typical loading was assumed to be 60% of the transformer nameplate rating (based on consultation with the local electric company). High-side and low-side voltages were used to derive appropriate loads in amperes for all cables or buswork. Current carrying elements of the transformer room were modeled with different loads, including zero amperes, to identify the primary sources of magnetic fields in the space above the electrical room. A total of 14 cases were run to evaluate the transformer room model.

**Results.** Calculated magnetic field levels are provided as contour maps of field strength for a variety of conditions. As expected, the magnetic fields are elevated in residences located above electric transformer rooms. The most dominant source creating magnetic fields in residences above transformer rooms is the low voltage cables or buswork and not the transformer itself. This is because the low voltage conductors always carry many more amperes than high voltage cables. The magnetic field level is affected primarily by transformer size/loading, location/routing of the low voltage cables or buswork (e.g. mounted on ceiling, wall, or floor), and distance.

**Conclusions.** Residences above electric transformer rooms offer an opportunity to evaluate the association between residential magnetic field exposure and childhood leukemia in an epidemiologic study of highly exposed population where the potential for selection bias is minimized or eliminated. The magnetic field level is affected primarily by transformer size/loading, location/routing of the low voltage cables or buswork, and distance away.

**Acknowledgements.** The assistance of Toronto Hydro, Roger Glass and Rob Kavet is appreciated. The work was supported by EPRI.
Figure 1. Computer model of representative transformer room to evaluate determinants of magnetic field exposure in residences located above it.

**P-57 HEALTH-RELATED QUALITY OF LIFE IN ADULTS EXPOSED TO EMF**

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**Summary of Abstract.** This study proposed to compare HRQOL and the relativity of emitting exposure of extremely low frequency electromagnetic fields nearby and away from the power transmission line, underground cable. Among the 2,670 subjects, 1,998 subjects (75%) who filled out the entire questionnaire were analyzed. A statistically significant difference was not found when subjects were divided into three groups; nearby and away from the power transmission line, underground cable.

**Objectives.** There has been increasing attention to the monitoring of health-related quality-of-life (HRQOL) variables regarding EMF exposure in living conditions. This study proposed to compare HRQOL and the relativity of exposure to emission of extremely low-frequency electromagnetic fields in people living nearby and far away from the power transmission line and underground cable.

**Methods.** The data were collected from July 18, 2007 to October 19, 2007. HRQOL was measured using SF-36, a 36-item self-administered instrument. It consists of 36 multiple-choice questions sorted into eight categories, or subscales, that describe the overall health status. Analysis of the collected data was conducted using frequency, percentage, t-test, ANCOVA of SPSS 12/PC.

**Results.** Of the 2,670 subjects, 1,998 subjects (75%) who filled out the entire questionnaire were analyzed. A significant difference was not identified when subjects were divided into three groups: those living nearby and far away from the power transmission line and underground cable, individuals living close to a power transmission line, such as subjects
who lived within 50 m, may be at increased risk for having poor health-related quality of life (HRQOL), which is related to well-being. We could not confirm the association in this study because of the limited sample size of only 12 subjects who lived within 50 m and 14 subjects who lived between 50 m and 100 m from a power transmission line.

Conclusions. In conclusion, HRQOL has no significant association with the distance between the subject's residence and the closest power transmission line. Further studies are needed to clarify the association between living nearby and away from a power transmission line and underground cable and the onset of depression, and further population-based studies with a large sample size and the use of meta-analysis are needed to confirm the finding.

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P-58 HEALTH SUBJECTIVE SYMPTOMS AND NEUROPHYSIOLOGICAL FUNCTIONS OF SCHOOL CHILDREN USING MOBILE PHONES

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Summary of Abstract. I carried out health subjective symptoms through questionnaire survey, EEG and cognitive test to investigate health effects by the mobile phone use of elementary school children. Long term mobile phone use of female elementary school children may affect on reduction of relative ratio of gamma wave and ability to maintain cognitive concentration.

Objectives. In this study, I carried out health subjective symptoms through questionnaire survey, EEG and cognitive test to investigate health effects by the mobile phone use of elementary school children.

Methods. 1,385 school children were participated in questionnaire survey which was performed at area of Incheon and suncheon from May to July, 2007, and 120 volunteers take part in EEG and cognitive tests from July to November.

Results. Mobile phone ownership(42.2%) of school children at incheon city was higher than mobile phone ownership(19.6%) school children at suncheon city. And, mobile phone ownership(39.4%) of female students was higher than male students(19.2%). Among self-reported symptoms, ear burning sensation(5.3%), nervousness(4.0%), physical fatigue(3.3%) were the main self-reported symptoms of male students, and in the case of female students, ear burning sensation(10.8%), problems in concentration(7.30%), physical fatigue(6.1%) were the main self-reported symptoms. The relative ratio of gamma wave(0.07) of female students which had used mobile phone was lower than female students(0.09) which had not used mobile phone. At cognitive test, concentration index(49.5%) of female students which...
had used mobile phone was lower than female students (54.5%) which had not used mobile phone. But in the case of male students, no significant differences were found between groups who reported the mobile phone use and don’t reported the mobile phone use.

Conclusions. Overall, long term mobile phone use of female elementary school children may affect on reduction of relative ratio of gamma wave and ability to maintain cognitive concentration.
Posters: Human studies

**P-59 SWISS NATIONAL RESEARCH PROGRAMME NRP 57: NON-IONISING RADIATION – HEALTH AND ENVIRONMENT**

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**Summary of Abstract.** To provide an overview of the National Research Programme 57 (NRP 57).

**Objectives.** The NRP 57 is a programme of the Swiss National Science Foundation funded by the Swiss government. It was established in 2006 to conduct key research projects concerning potential health related consequences of low-level radio frequency (RF) and extremely low frequency (ELF) electromagnetic fields (EMF) in order to improve assessment of the associated risks. The programme has dedicated 5 million CHF to study four research areas over the next 3 years and is set up to make a substantial contribution to the international research effort.

**Methods.** Eleven projects in four areas of research (“modules”) are supported:

1) **Dosimetry and Exposure Assessment (3 projects):** The aim is to determine the exposure of the foetus to EMF in everyday situations and in an uncontrolled environment; to determine cumulative RF EMF exposure in time and frequency domains of the central nervous system; and to develop an instrument for live cell imaging during ELF EMF exposure.

2) **Human laboratory and epidemiologic studies (3 projects):** They focus on the effects of pulse-modulated RF EMF on brain activity and cognitive function, investigating in particular critical field parameters, sites of interaction and the sensitivity in early adolescence; on the effects of UMTS exposure on cerebral blood circulation and oxygenation as assessed by near infrared imaging; and in the framework of a prospective, epidemiological cohort study on different sources of RF EMF exposure in conjunction with the assessment of health related quality of life.

3) **Cell biology (3 projects):** Their aim is to investigate cellular responses to RF and ELF EMF in the model organism C. elegans; to identify and characterise the effects of ELF EMF on genotoxicity; and to study the effect of RF EMF on stress-response pathways in vitro and in vivo.

4) **Risk perception (2 projects):** The projects focus on the determinants of risk perception and the implications of affect and perception for risk communication.

Single thematic topics have been and will be presented and discussed with national and international experts in a series of four scientific workshops in 2008/2009. A first interdisciplinary workshop entitled “Dosimetry Meets Epidemiology” took place in Zurich in January 2008, a second one “Towards a mechanism-based framework in EMF research” and pertaining to the module cell biology is scheduled in May 2008. A third workshop in the fall of 2008 will focus on the effects of RF EMF on brain physiology and the series will be concluded in the spring of 2009 with a workshop on risk perception and communication.
The respective presentations and a report on each workshop are/will be available on the programme website.

**Results.** The NRP 57 will encourage all research findings to be published in peer-reviewed scientific journals to ensure openness and transparency. Initial results of the NRP 57 are expected to be presented at the joint meeting of BEMS and EBEA in 2009 in Davos, Switzerland, in a separate session. A final evaluation and synthesis of the results in the context of the international research effort will be published by the steering group of the NRP 57 in the course of 2010 and is expected to enhance our knowledge in the areas of risk assessment and communication.

**Conclusions.** More information on the programme is available on www.nrp57.ch.

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**P-60** EFFECT OF THIRTY-MINUTE MOBILE PHONE USE ON THE ANTISACCADE TASK

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**Summary of Abstract.** We investigated the effect of thirty-minute mobile phone use on the antisaccade task. We have found no effect of mobile phone on the cognitive and inhibitory control of saccades.

**Objectives.** Wide use of mobile phone has given rise to growing concerns about its health effect, above all, the effect of the electromagnetic field (EMF) emitted from the mobile phones. Some studies have found possible influence of mobile phones use on cognitive brain function in humans, especially attention. We have also reported no significant effect of EMF on the performance of a hand reaction time task that required cognitive manipulation (Terao et al., 2006). Recent brain-imaging studies have demonstrated that control of visual spatial attention and eye movements (e.g. saccades) share most of the underlying cortical structures, and in this context, it is also important to investigate the effect of EMF on saccades. We have previously reported that thirty-minute mobile phone use has no effect on the performances of elementary saccade paradigms, such as visually guided saccade, gap saccade and memory guided saccade tasks (Terao et al., 2007). Here we investigated the effect of mobile phone use on the antisaccade task that required both cognitive and inhibitory aspects of saccades.
Methods. 10 normal subjects are planned to be studied, who gave informed consent to participate in the following experiments. We used the antisaccade task, in which we required subjects to make a saccade in response to a target moving from the central fixation spot to a location 5, 10, 20 and 30 degrees to the left or right of it. The subject was required to make a saccade toward a mirror symmetrical position of that of the target. For each trial, the latency, amplitude and velocity of saccade were measured. Also, the frequency of saccades that were erroneously made toward the location of the target was counted.

A double blind, cross-over design randomized and counterbalanced within participants was used. The subjects performed the antisaccade task before and after mobile phone use or sham exposure for 30 minutes. A 1.95-GHz wide-band code division multiple access (W-CDMA) signal, which is one of the International Mobile Telecommunication 2000 (IMT-2000) systems and has been used for the freedom of mobile multimedia access(FOMA), was used for the exposure.

We analyzed the behavioral measures using ANOVA to address two aspects of the effect of EMF exposure; first whether the EMF exposure significantly changed task performance relative to baseline (prior to exposure), and second whether the effect, if present, differed from that of sham exposure.

Results. Although the study is still ongoing, so far we have not found any changes in the saccade parameters before and after real or sham EMF exposure. The frequency of directional errors was unchanged as well. Therefore, thirty-minute mobile phone use, whether sham or real, is considered not to affect any of the saccade parameters of the antisaccade task.

Conclusions. In our previous study concerning the effect of EMF on saccades demonstrated no significant effect of mobile phone use on the usual saccade tasks. This supported previous reports that the cortical processing for saccades and attention is not affected by exposure to EMF emitted by a mobile phone. The results of the present study now indicate that mobile phone use for thirty minutes does not affect the cognitive and inhibitory aspects of saccades.

P-61 QUESTIONNAIR SURVEY ON THE MOBILE PHONE USE AND SUBJECTIVE HEALTH SYMPTOMS IN JAPAN

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Chiba, Japan. 4Tokyo Metropolitan University, Tokyo, Japan. 5National Institute of Information and Communications Technology, Tokyo, Japan. 6Kobe University, Kobe, Japan. 7Fukushima Medical University, Fukushima, Japan.

Summary of Abstract. We did the cross-sectional questionnaire survey of Japanese men regarding the mobile phone use and subjective symptoms. This is the first step for the provocation study which elucidates the effects of electromagnetic fields emitted from the mobile phone handset. In this presentation, we summerise the results of the questionnair survey.

Objectives. Wide use of mobile phone has given rise to growing concerns about its health effect, above all, the effect of the electromagnetic fields (EMFs) emitted from mobile phone. Whereas some health effects may be common to every individual, other effects are reportedly observed only in individuals who are especially susceptible to EMF. However, there has been a controversy as to whether the persons who report subjective symptoms actually have more symptoms when exposed to EMF emitted by a mobile phone handset. Therefore, we are planning the provocation study to examine the relationship between the subjective symptoms and EMF from the mobile phone handset. Prior to the provocation study, we did the cross-sectional and population-based questionnaire survey of Japanese men to pick up the subjects for the provocation study. In this presentation, we report the summary of the survey, which shows the prevalence rate of individuals with mobile phone related symptoms in Japanese male people.

Methods. A cross-sectional questionnaire survey was conducted in October 2007, among 7000 men between 20 to 60 years of age, living in Kanto (Greater Tokyo) Area, Japan. Subjects were randomly sampled from the Basic Resident Registers established by the Ministry of Internal affairs and Communications (MIC), Japan. We sent the questionnaire to all 7000 subjects by mail, and the responders, after completing the questionnaire, sent it back to us by mail.

We used the identical questionnaire used in our previous study of Japanese female subjects. It inquired about the current use of mobile phones, the presence or absence of the health problems that are frequently encountered in relation to mobile phone use according to the study of Rubin et al. [2005], and whether the subjects ascribed these health problems to the use of mobile phone, the reason for quitting the use of a mobile phone if they had, the current status of health, general questions about the subjects personal information, and finally whether the subject wanted to participate in the provocation study. Possible health problems related to mobile phone use included malaise, stiff neck, dizziness, insomnia, skin problems including itching and tingling, muscle pain, and nausea. We assessed the severity of health problems associated with the use of mobile phone on a 5-point scale, anchored with the phrases “always present” scored as 5, and “never” scored as 1. Symptoms were considered “mobile phone related” if they persisted always or almost always, and the subjects reported them to be related to the use of mobile phone. The subjects who have more than 1 symptom at level 5 or more than 2 symptoms at level 4 were defined as a subject with “definite” mobile phone related symptoms (MPRS). Other subjects were categorized to “probable” or “possible” MPRS depend on the severity symptoms.
Results. We obtained 3,578 responses (51.1%) to the 7000 questionnaire forms sent out. Out of the 3,578, 185 (5.2%) gave invalid responses, leaving 3393 who gave valid responses. Among the 3,393 subjects, 2,984 (87.9%) are currently using a mobile phone, 35 (1.0%) had used it but are not currently using it, and 103 (3.0%) have never used it. 271 (8.0%) gave no responses about mobile phone use. From the 3,393 subjects who gave valid responses, we further excluded those who had a history of myocardial infarction, epilepsy, and were under medical treatment for some other reasons, leaving 2,821 possible candidates for the following study. Among those, 33 (1.2%) reported that mobile phone was causing some health problem, i.e. were the MPRS subjects according to the definition by WHO. Seven of the 33 subjects were also categorized to “definite” MPRS from our criteria for symptoms.

Conclusions. This cross-sectional survey on Japanese male subjects showed that the approximately 1.2% of the whole population consider that the mobile phone use triggers their own health problems. This value is consistent with our result of the Japanese female subjects survey reported in BEMS 2006 (Kanazawa, Japan). We are now inviting the candidates who picked up from this survey, to the following provocation study.

P-62 EFFECTS OF A 900 MHZ GSM EXPOSURE ON HEART RATE VARIABILITY, AN EXPERIMENTAL PROVOCATION STUDY

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Summary of Abstract. This provocation study investigated the effects of RF exposure (884 MHz, SAR 1.4 W/kg) on heart rate variability in a double blind, cross-over design. The study group included subjects reporting symptoms attributed to mobile phone use as well as symptom free subjects. The results showed no association between RF exposure and frequency domain indices of the spectral analysis of heart rate variability during the exposure sessions.

Objectives. The objective of the present provocation study was to investigate whether exposure to radio frequency fields (RF) caused by mobile phone use has any acute effect on neurophysiologic measurements including heart rate variability (HRV).
Methods. The exposure setup (developed and installed by the Foundation IT’IS, Zurich, Switzerland) was designed to maximize the exposure of brain tissue of the left hemisphere as it may occur during actual usage of GSM phones. The system was based on a low-weight, stacked micro patch antenna fixed on a headset and allowed the subject to move/rotate within a limited area without changing the exposure distribution. A fully computer-controlled signal unit allowed the application of GSM modulated RF exposures for two different subjects. The RF exposure was monitored, controlled and recorded in an encoded file at all times and was in compliance to double blind exposure protocols. The exposure signal consisted of a GSM signal at an average SAR of 1.4 W/kg simulating a conversation, i.e., including periods of DTX and non-DTX. A 2 degree increase in skin temperature of the ear lobe was induced during all sessions by laser heating of a small ceramic plate. Each exposure session lasted three hours (7.30 to 10.30 pm).

The study group consisted of 71 subjects, age 18 to 45, including 38 subjects who reported symptoms in relations to mobile phone use (symptom group). Exclusion criteria were medical or psychological illnesses where association with current symptoms could not be excluded, present medication, sleep disorders, hypertension and ongoing pregnancy. Heart rate was registered by two electrodes (placed at sub clavicle (upper right torso) and lower left torso) and recorded by the EMBLA TM system. The sampling frequency was 200 Hz, giving output of heart rate and R-R intervals (expressed in centiseconds). Five minute segments of data were analyzed by custom-made software for autoregressive spectral analysis of variability in cardiac rhythm (Storck et al., 2001). The auto-regressive coefficients were calculated using the different frequency limits proposed by Bigger et al. (1992) which include total power (TP: 0.0033-0.4 Hz), very low frequency (VLF: 0.0033-0.04 Hz), low frequency (LF: 0.04-0.15 Hz) and high frequency (HF: 0.15-0.4 Hz). VLF includes oscillations with cycle lengths from 25 seconds up to 5 minutes. As the power spectral analysis is made from 5 minute periods, the calculations of VLF power regarding oscillations with cycle lengths close to 5 minutes are unreliable and therefore not presented. For the HRV analysis data from the time period 8 to 10 pm were used.

Data were analyzed with generalized linear models accounting for the serial correlation among the repeated measurements on the individuals (xtgee and logit in STATA 9.2, Stata Corp, USA). The basic model included the factors exposure (RF, sham), group (symptom, non-symptom), session (1, 2) and an exposure*group interaction factor.

Results. Mean heart rate did not differ between the exposure conditions. Heart rate variability during the exposure sessions showed no exposure- or group-related effects with regard to total power, the LF band, the HF band or LF/HF ratio (p<0.05 for all analyses). Additional results concerning heart rate variability during Karolinska Drowsiness Test (Åkerstedt, 1990) will be presented. During the Karolinska Drowsiness Test the participants were seated with their eyes open, focusing for five minutes on a dark blue circle (diameter 5 cm) on a wall in front of them, followed by a five-minute period of eyes closed. The analysis of HRV during KDT provides an opportunity to study HRV during a time period of standardized relaxed activity.

Conclusions. We observed no effect of RF exposure on heart rate variability during a three hour exposure equivalent to a high exposure during GSM mobile phone calls. Further
analyses of HRV during ten-minute periods of standardized relaxed activity will be carried out.

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P-63 PHYSIOLOGICAL AND NEURO-BEHAVIORAL EFFECTS OF AN EXPOSURE TO A 60 HZ MAGNETIC FIELD AT 1800 MICROTESLA

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Summary of Abstract. Various aspects of human behaviours have been studied in response to acute exposure to Extremely Low Frequency (ELF) Magnetic Fields (MF). Recent results show an increase in occipital alpha electroencephalographic (EEG) rhythm with exposure. Interestingly, other studies have demonstrated a modulation of human motor behaviour with ELF MF exposure, showing a reduction of standing balance amplitude and a decrease in physiological tremor intensity. However, to establish a connection between these observations requires a project that, in one procedure, investigates physiological, neurophysiological and behavioural parameters.

Objectives. The main objective of this study is thus to evaluate subtle effects of a 60 Hz 1800 µT MF on human physiology, neurophysiology and motor functions in a single procedure. We hypothesize that MF exposure will (1) decrease peripheral blood flow but not affect ECG, (2) increase EEG power of the alpha rhythm (in occipital regions), (3) decrease standing balance oscillations, (4) not affect performance in voluntary movements of the hands, and (5) decrease physiological tremor amplitude. Effects should appear after several minutes of exposure.

Methods. 93 subjects have been involved in the study and 73 of them completed the experiment (UWO REB #11956E). The experiment consisted in 2 counterbalanced exposure sessions given on 2 separate days (Figure 1a): 1 active (real) and 1 control (sham) session. A double blind computer driven procedure controlling for variables was used such that neither the participant nor the experimenter knew when the real or sham condition occurred. Each session included 4 blocks of testing (15 minutes each) spaced with 15 minutes rest in between (Figure 1a): Blocks of testing were given 15 minutes before the beginning of the exposure, 15 and 45 minutes after the beginning of the exposure, and 15 minutes after the end of the exposure.

During each block, recordings were done following the time frame detailed in Figure 1b:
Resting EEG (Siesta, Compumedics Inc., USA), physiological tremor (dominant index finger, Micro laser sensor, Matsushita Electronic Work, Ltd., Japan), voluntary movements of the hands (Liberty, Polhemus Inc., USA), and standing balance (OR6-7-1000, AMTI, USA). Local blood perfusion (non dominant middle finger) and systolic blood pressure (PF 5010 Laser Doppler Perfusion and blood pressure unit, Perimed, Sweden) as well as ECG (Siesta) are also collected. Specific indexes characterising the above mentioned parameters are computed for each experimental condition and are used as variables in the statistical analysis.

Results. Data are currently analyzed (SPSS 15.0, USA). To date, analyses have been run on EEG alpha amplitude (occipital electrodes O1 and O2, root mean square (RMS) of the time series, 8-13 Hz range), on the sway area (area of the smallest polygon including the entire trajectory of the standing balance, or postural oscillations over a recording), and postural tremor amplitude (RMS of tremor time series). First, a within-subjects ANOVA 2 (session: sham or real) x 4 (block: 1, 2, 3, or 4) x 2 (eyes: open or closed), $\alpha$ set at .05, is used to locate main effects. Second, the analysis is focused on the MF effect during exposure, analyzing blocks 2 and 3 in the real and sham conditions using a within-subjects ANOVA 2 (eyes) x 2 (MF: off or on), $\alpha$ set at .05. So far, the first analysis shows with eyes closed: higher alpha EEG activity in the occipital electrodes (O1: $F=117.2$, $p<.01$), larger tremor amplitude (amplitude: $F=56$, $p<.01$), and larger postural oscillations (sway area: $F=95$, $p<.01$). Interestingly, an interaction effect session x block has been found for postural oscillations ($F=3$, $p<.05$, see Figure 2) showing a smaller sway area in block 3 with real exposure than in block 3 with sham exposure (post hoc Tukey, $p<.05$). No other session or block effect has been found, but analyses are still in process. The second analysis focusing only on blocks 2 and 3 (during MF exposure) confirmed the effect on postural oscillations: sway area is smaller in the real than in the sham exposure condition ($F=4.9$, $p<.05$). No significant effect has been found on EEG or physiological tremor.

Conclusions. This multidimensional approach allows the detection of small changes modulating human neuro-behavior. Indeed, the suppression of the visual input (induced by closing the eyes) has neurophysiological and behavioural consequences which are clearly detected and characterised by this protocol (decreased EEG alpha activity, increased postural tremor amplitude, increased postural oscillations).

So far, no effect of a 60 Hz, 1800 $\mu$T MF exposure has been found either on EEG or on postural tremor (only electrodes O1 and O2 has been analyzed to date). However, we show a decrease of standing balance oscillations during exposure, which is consistent with the finding of Thomas et al. 2001. Note that these are only the first results and they will be completed by those on peripheral blood perfusion, ECG, and voluntary hand movements. Full results will be presented and discussed at the meeting.

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Figure 1. a. Time course of the real and sham exposure sessions. The horizontal black line represents the MF status (OFF when down, ON when up). Vertical grey bands represent the four 15 minute blocks of testing. b. Zoom on the time course of a block of testing (the same for each block). White cells represent resting periods and grey cells represent testing periods (duration is displayed in seconds inside the cells). The table below gives test specifications.

**Figure 2.** The within-subjects ANOVA 2 (session) x 4 (block) x 2 (eyes) have shown a session x block interaction (F=3, p<.05), with a smaller sway area in block 3 real exposure than the block 3 sham exposure (Post hoc Tukey, p<.05).
P-64 EMPIRICAL HUMAN SAR MEASUREMENTS FROM 100 MHZ RADIO FREQUENCY RADIATION EXPOSURES

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Summary of Abstract. The research presented seeks to validate the Finite Difference Time Domain (FDTD) theory by comparing predicted specific absorption rate (SAR) values with human empirical measurements at 100 MHz for energy levels below the IEEE controlled environment exposure limit.

Objectives. Controlled laboratory studies of human responses to imposed radio frequency (RF) fields are meager and usually limited to sensory endpoints. During passive exposure of a human being to an RF field, the pattern of energy deposition will depend on many physical attributes of both the RF source and the biological target. The research presented seeks to validate the Finite Difference Time Domain (FDTD) theory by comparing predicted specific absorption rate (SAR) values with human empirical measurements at 100 MHz for energy levels below the IEEE controlled environment exposure limit.

Methods. Brooks City-Base researchers obtained temperature measurements from different lower leg locations to find if SAR values matched computational predictions, which have seen increased use in RF standards applications and health and safety risk mitigation practices. By obtaining more empirical data, researchers will have confidence in using the FDTD models in additional environments and scenarios. This research also provides important insights into the variability of energy absorption rates in human subjects under nearly identical exposure conditions. This variability may be correlated with the differences in physical attributes of the subjects, such as height, weight, and leg circumference at the location of the temperature probes. Care was taken when selecting exposure conditions to minimize any thermoregulatory responses of the body, thereby isolating the desired absorption data.

Results. Preliminary results indicate a range of absorption rates when comparing between human subjects. These values are influenced by geometrical properties of the subject, such as height, etc.

Conclusions. Variability in individual response to RF energy makes predictive modeling techniques more challenging. However, parametric analysis can provide a suitable range of expected absorption values.
P-65 CYTOGENETIC ANALYSIS OF HUMAN LYMPHOCYTES AFTER A 4 HOUR, WHOLE BODY EXPOSURE TO A SINUSOIDAL 200 $\mu$T 60 HZ MAGNETIC FIELD

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Summary of Abstract. The transmission, distribution and use of electricity for a variety of commercial and residential applications has resulted in chronic exposure of much of the world’s population to an ever-increasing level of extremely low frequency electric and magnetic fields (ELF-EMF). Despite numerous human epidemiological studies, the association between chronic exposure to ELF-EMF and the occurrence of long-term adverse human health effects remains controversial. Of primary concern is the potential of these fields to induce cancer, particularly brain cancer and childhood leukemia. While most in vitro studies have demonstrated no evidence of ELF-EMF-induced genotoxicity, several animal studies have demonstrated some evidence that 60 Hz ELF-EMF can induce DNA damage and cause clastogenic aberrations. The aim of this project is to investigate whether an acute (4 hour), whole-body exposure of 200 $\mu$T sinusoidal 60 Hz ELF-EMF, was capable of inducing detectable levels of either primary DNA damage or clastogenic damage in peripheral human blood lymphocytes from healthy adult volunteers. Blood was collected from 15 healthy males and 15 females, prior to and then immediately following a 4 hour exposure, to 60 Hz 200 $\mu$T ELF-EMF. Cytogenetic effects were analyzed using the cytokinesis-block micronucleus (CBMN) assay while primary DNA damage was assessed using the alkaline comet assay. Data analysis is currently in progress and the study results will be disseminated in June 2008.

Objectives. To assess for DNA damage and micronucleus induction in peripheral blood lymphocytes collected from healthy adult volunteers before and after acute exposure to 200 $\mu$T, 60 Hz EMF.

Methods. Thirty healthy, non-smoking human males and females between the ages of 20 and 45 years were recruited and participated in this project with informed consent. Participants were exposed for 4 hours to either 60 Hz EMF at 200 $\mu$T (n=20) or to a sham exposure (n=10), under blinded conditions. In addition, blood samples from 3 males and 3 female donors were exposed to 0.1, 0.3, 0.5, 1 and 1.5 Gy Cobalt-60 $\gamma$-irradiation to establish dose-response curves for both the CBMN and alkaline comet assays. Peripheral blood samples were collected prior to and following the 4 hour exposure period, with small aliquots collected before ELF-EMF exposure to be used as positive controls (1.5 Gy $\gamma$-irradiation). CBMN Assay: The human blood samples were diluted 1:9 with RPMI 1640 culture media (containing 10% FBS, 2mM l-glutamine), stimulated with 1% phytohemagglutinin and then cultured for 44 hours. Cytochalasin-B (4 $\mu$g/mL) was then added to halt cytokinesis and the lymphocytes were cultured an additional 28 hours prior to fixation and slide preparation. Slides were stained with Acridine Orange, followed by manual analysis of blinded samples.
The incidence of micronuclei (MN) were then evaluated in 1000 binucleated (BN) lymphocytes. From each culture, a total of 500 cells were examined to determine the proliferation index of each culture. Alkaline Comet Assay: The comet assay was conducted according to a modified method of Singh et al. (Singh et al. 1994) using Trevigen Cometslides®. The slides were stained with SYBR Gold prior to analysis on an Olympus BX-60 fluorescence microscope using ‘NB’ filter cube, a Hitachi KP-D8 digital camera and the Alkomet v3.1 image analysis system (McNamee et al. 2002). From each culture, a total of 50 cells were analyzed to determine DNA damage.

**Results.** A total of 21 male subjects and 22 female subjects participated in this study. The blood of 3 male and 3 female subjects were used for the dose-response curves. The dose-response curve, figure 1 and figure 2, currently includes data from 5 subjects (n=3 males and n=2 females). From the remaining 18 male and 19 female subjects, 11 exposure condition samples (n=6 males and n=5 females) and 6 sham condition samples (n=3 males and n=3 females) have been analyzed using the CBMN assay and the comet assay. To date, 2 male and 3 female samples have been excluded from the study (prior to unblinding of samples), due to poor sample quality at the time of analysis.

**Conclusions.** Human testing was completed at the beginning of December 2007. The remaining samples are currently being analyzed to obtain a total of 1000 BNC for the micronucleus assay and 50 cells for the alkaline comet assay. Statistical analysis is to commence in mid-February. Final conclusions and findings of this research will be disseminated at the BEMS conference in June 2008.

**References**
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**Figure 1.** Gamma irradiation dose-response and the cytokinesis-block micronucleus assay. Radiation dose in Gy produced by a Cobalt-60 source, at 0, 0.1, 0.3, 0.5, 1.0 and 1.5. Each bar represents the mean and standard deviation n=5 (n=3 males and n=2 females) blood samples. Mean Total Micronuclei per 500 binucleated lymphocytes.

**Figure 2.** Gamma irradiation dose-response and the alkaline comet assay. Radiation dose in Gy produced by a Cobalt-60 source, at 0, 0.1, 0.3, 0.5, 1.0 and 1.5. Each bar represents the mean and standard deviation of n=5 (n=3 males and n=2 females) blood samples. The alkaline comet assay contains 5 parameters.
**P-66** NON-CONTACT BROADBAND FREE SPACE MEASUREMENTS OF THE COMPLEX PERMITTIVITY OF BIOLOGICAL TISSUES

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**Summary of Abstract.** The measurement of the complex permittivity of beef fat tissue is reported from 8 to 18 GHz using a unique focused beam free space measurement system. The system consists of horn/lens antennas with double plano-convex lenses for obtaining a focused beam with a constant phase front. A picture frame sample holder can hold slices of biological tissues. Full TRL calibration is implemented at the input plane of the tissue sample. The sample is somewhat heterogeneous, but the focused beam system can be used to illuminate different spots on the sample and an effective complex permittivity can be obtained by averaging. This is a non-contact method and the tissue sample can be characterized over different frequency bands. This is a decided advantage of this measurement method relative to contact probe methods.

**Objectives.** In order to understand the interaction of electromagnetic waves with biological tissues, it is important to know accurately its complex dielectric permittivity. In this study, we use a unique focused beam free space method to measure the complex dielectric property of a fatty tissue, which plays an important rule in the microstructure of human breast. Other methods are suited only for a certain range of frequency, while the free-space method can be used for a very wide range of frequencies without change of sample.

**Methods.** Dielectric permittivity measurements were performed using free-space method. The measurements were done over a wide range of frequency with the help of a HP Network Analyzer 8510B. The effective complex permittivity is extracted by inversion of the S-parameters.

**Results.** Very good agreement is obtained with previous reported measurements for bovine fat samples.

**Conclusions.** Our studies have been indicated that there is a local variation in the dielectric properties of biological tissues which require more careful study in the future. The obtained dielectric values for beef fat were compared with the experimental data that based on relaxations models where a reasonable agreement is obtained.

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P-67 INTERMEDIATE FREQUENCY MAGNETIC FIELDS DID NOT HAVE MICRONUCLEUS FORMATION POTENTIAL IN IN VITRO TESTS

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Summary of Abstract. In this study, we investigated the effects of the intermediate frequency (IF) magnetic fields (MFs) on micronucleus formation in a mammalian cell line. The Chinese hamster V79 cell was chosen to estimate the effects of the MF exposure on micronucleus formation and DNA damage repair caused by mitomycin C (MMC). The V79 cells were exposed to MFs of 0.91mTrms at 2kHz, 1.1mTrms at 20kHz or 0.11mTrms at 60kHz, for 24h at 37°C in 5% CO2. The ratios of micronucleus formation rates between MF exposed and unexposed control groups were mostly in the range from 0.8 to 1.2. In statistical analysis, neither significant nor reproducible difference was found between the micronucleus formation rates for all MF exposure conditions. To examine the effect on DNA damage, V79 cells were exposed to MMC with/without above three MF conditions, which potentiate micronucleus formation. Some statistically significant differences were found between the rates for all MF exposure conditions, however, no reproducible difference was found. These results suggested that the strong IF MFs used in this study did not induce micronucleus formation and did not affect DNA damage by MMC or DNA damage repair system in mammalian cells.

Objectives. In this study, we have investigated the effects of the IF MFs on micronucleus (MN) formation in a mammalian cell line, V79.

Methods. (1)Exposure system
We constructed a Helmholtz type exposure system, which generates a vertical and sinusoidal IF MFs in the frequency range of 2-60 kHz. The incubator was located in the center of the system. The incubation temperature was controlled at 37 ± 0.4°C.
(2)Test strains
The Chinese hamster V79 cell was chosen to investigate the effects of the MF exposure on micronucleus formation and DNA damage repair caused by mitomycin C (MMC). The V79 cells were exposed to MFs of 0.91mTrms at 2kHz, 1.1mTrms at 20kHz or 0.11mTrms at 60kHz, for 24h under a humidified atmosphere of 5% CO2 /95% air at 37°C.
(3)MN tests
The V79 cells (1×10⁴ cells/ml, 35ml) were inoculated into twelve T-175 flasks, and the flasks were randomly divided into two groups. One group (six flasks) was used for investigating the effect of the IF MFs on a micronucleus formation. Three of six flasks were placed into the unenergized control incubator, and another three flasks were placed into the incubator for the MF exposure. Another six flasks were putted mitomycin C (MMC) at a final concentration of 5ng/ml to investigate the effect of the IF MFs on DNA damage by MMC or DNA damage repair system in mammalian cells. Then, three of six flasks were placed into the unenergized control incubator, and another three flasks were placed into the incubator for the MF exposure. After the MF exposure for 24h, the cells were collected and inoculated into a chamber slide (Lab-TekII, 4well, Nalge-Nunc) at 1x10⁴ cells/500µl/well.
After 4h incubation, cytochalasin B was added at a final concentration of 4µg/ml. After 24h incubation, micronucleus (MN) formation rate was measured as following criteria; (1) nucleus should be in cytosol, (2) MN should be below 1/3 of diameter of nucleus, (3) the color of MN should be same as nucleus. The MN formation rate was calculated by following formula;

\[
\text{MN formation rate (\%) } = 100 \times \frac{\text{Number of cells with MN in binucleus cell}}{\text{Number of binucleus cells}}.
\]

We used the Student’s t-test (paired, two-tailed) to determine the statistical significance between unenergized control and IF MF exposure groups.

**Results.** The ratio of micronucleus formation rates between MF exposed and unenergized control groups were mostly in the range from 0.8 to 1.2. In statistical analysis, neither significant nor reproducible difference was found between the micronucleus formation rates for all MF exposure conditions. To examine the effect on DNA damage, V79 cells have been exposed to each MF with MMC which potentiates micronucleus formation. In statistical analysis, two cases of 2kHz MF exposure and one cases of 20kHz MF exposure with MMC showed significant differences. In the case of 2kHz MF exposure, the differences were very small and opposite directions each other. In the case of 20kHz MF exposure, the differences were very small and not reproduced. Neither significant nor reproducible difference was found between the rates for all MF exposure conditions.

**Conclusions.** We conclude that the strong IF MFs used in this study did not induce micronucleus formation and did not affect DNA damage by MMC or DNA damage repair system in mammalian cells.
P-68 ROOT GROWTH OF SUBMERGED THYME SEEDS IN A GRADIENT MAGNETIC FIELD

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Summary of Abstract. We have presumed that physiological activities of aerobic organisms in a hypoxic environment can be improved by supplying oxygen to that environment using strong gradient magnetic fields. Submerged thyme seeds, positioned near a magnet for 24 h, were used to investigate that hypothesis. The seeds were classified into three groups according to their magnetic flux exposures. Some seeds were exposed to magnetic flux density of 0.6 T: the gradient magnetic field would attract oxygen to the seeds. The other two groups' exposures were much weaker; oxygen would not be affected by those magnetic fields. No significant differences were found among growth parameters of three submergence treatments with different magnetic flux densities. We therefore reject the hypothesis that magnetically induced oxygen supply reinforces the growth of submerged thyme seeds.

Objectives. Considering a biological importance and magnetic properties of oxygen, we have assumed that physiological activities of aerobic organisms that exist in a hypoxic environment can be improved by supplying oxygen to the hypoxic environment using strong gradient magnetic fields. In this study, the early root growth of thyme seeds under a submerged condition was used as a biological indicator to investigate that hypothesis. The submerged seeds were positioned 24 h in a strong gradient magnetic field that was comparable to that used previously for a chemical reaction study in which the magnetically accelerated oxygen supply was observed [1]. The objective of this study is to test the hypothesis that magnetically induced oxygen supply reinforces the early root growth of submerged thyme seeds.

Methods. The seeds of thyme *Thymus vulgaris* were submerged in deionized water for 24 h for imbibition. After 24 h imbibition, four seeds with breaks on their seed coats were selected; three of them were put in respective holes (one seed per hole) of a PCR plate (Fig. 1a). The thickness of the bottom wall of the PCR plate was 0.5 mm. Ten microliters of deionized water, which corresponds to 2.5 mm water depth, was pipetted into each hole. The other seed was put on bibulous paper containing 20 microliters of deionized water. Both sufficient water and air were available for the seed on the bibulous paper, which was treated as a positive control. The planted PCR plate was put on a NdFeB magnet (98 mm × 98 mm × 35 mm) in a plastic box in a wooden dark room: the temperature and the humidity were respectively maintained at 22 ± 3°C and at 75 ± 5%. A rectangular coordinate system (x, y, z) was defined as shown in Fig. 1a: one seed was located on the magnet at x = −9 mm and y = 20 mm (treatment A); another seed was located on the edge of the magnet at x = 0 mm and y = 20 mm (treatment B); another seed was located outside the magnet at x = 9 mm and y = 20 mm (treatment C); the other seed was put on the bibulous paper located at x = 18 mm and y = 20 mm (treatment D). Distributions of the magnetic flux densities...
near the magnet are shown in Fig. 1b. The maximum magnetic flux density was 0.6 T. The magnetic force acting on an oxygen molecule was calculated [1, 2]. The magnetic force in the z direction acting on an oxygen molecule was stronger than that of the gravitational force at x = 0 mm and z ≤ 4 mm. The seeds of treatments A, B, and C absorb dissolved oxygen from the surrounding water; thereby, the oxygen concentration decreases near the seeds. Oxygen dissolves from the air into water, but only the oxygen near treatment B would be significantly accelerated by the strong gradient magnetic field [1, 3-6]. Therefore, it is inferred that the seeds of treatment D grew fastest among all treatments and that the seeds of treatment B grow faster than those of treatments A and C. After 24 h, the length and diameter of radicles, the length of root hairs, and the projected root area consisting of radicle and root hairs were determined. The series of experiments was replicated nine times.

**Results.** Radicle diameter, root hair length, and the projected root area of seeds were significantly different among treatments (P < 0.001, ANOVA). The Tukey test revealed that the radicle diameter, root hair length and projected root area of the seeds of treatments A, B, and C were significantly less than those of the seeds of treatment D (P < 0.005). Consequently, we concluded that the submergence inhibited the root growth of thyme seeds. No statistically significant differences in any root parameters were found among the seeds of three submergence treatments, which differed only by their magnetic fields.

**Conclusions.** No root parameter among the submerged seeds of treatments A, B, and C, where only magnetic fields were different, exhibited a significant difference. Therefore, the hypothesis that magnetically induced oxygen supply reinforces the root growth of submerged thyme seeds was rejected.

References
Figure 1. Definition of the coordinate and seed (●) locations near the magnet (a) and magnetic flux densities near the magnet (b). The center of one side of the magnet was defined as the origin of the coordinate. The south pole was the top face (x-y plane). All data (b) were derived at y = 20 mm where seeds were located: ●, z = 2 mm; ○, z = 4 mm; △, z = 6 mm.

P-69 EFFECTS OF MOBILE TELEPHONY SIGNALS EXPOSURE ON RADICAL STRESS IN THE RAT BRAIN

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Summary of Abstract. Radical stress was investigated in the brains of rats exposed to GSM-1800 or UMTS (2.6 W/kg brain averaged SAR - BASAR), after single or repeated exposures. Oxidative damage was evaluated at the level of DNA, proteins, and lipids using immunohistochemistry on coded brain slices. Lipid peroxidation was found unaffected except for a significant decrease after repeated exposure to UMTS. Other markers are currently being investigated and only the full set of data will allow to conclude on the effects of GSM-1800 and UMTS on radical stress in rat brains.

Objectives. Radical stress is involved in neurodegenerative diseases, such as Alzheimer disease or amyotrophic lateral sclerosis. In the last few years, it was suggested that radiofrequency radiation (RFR) could play a role in the generation of radical stress in cells or animals, but this phenomenon was not investigated in the brain.

The objective of this work was to investigate radical stress in the brains of rats exposed to GSM-1800 or UMTS (2.6 W/kg brain averaged SAR - BASAR), after a single or repeated exposure. Oxidative damage was evaluated at the level of DNA, proteins, and lipids using specific immunological markers.
Methods. We used 8 male Wistar-Han rats of 10 weeks or 17 months of age for each condition: sham exposures, RFR exposures, cage and positive controls. Exposure duration was 2 hours (single exposure) or 2 hours/day, 5 days/week, for 4 weeks (repeated exposure) in a head-only configuration using a loop antenna. Rats were progressively habituated to the exposure setup (rockets) over one week to avoid restraining stress. At the end of exposure, rats were immediately sacrificed under anesthesia (isoflurane 5%) and paraformaldehyde-fixed brains were removed and coded. They were then cryopreserved with sucrose (20% in PBS), frozen in isopentane and stored at $-80^\circ$C. Cryosections (10 $\mu$m) were prepared on Superfrost gold-plus® slides. Three zones were chosen based on both distance to the antenna and brain structure: post bregma: $-0.8$ mm for the motor cortex, $-3.8$ mm for the cortex and hippocampus, and $-8.0$ mm including the visual cortex. Three markers were used to investigate radical stress in rat brain using immunohistochemistry. Lipid peroxidation was detected using anti 4-hydroxynonenol, 4-HNE (HNEJ-2, 1/100°, overnight, 4°C, GENTAUR®) FITC-labelled second antibodies (FITC-antimouse 1/250°, 1 hour, room temperature, SIGMA®). Protein nitration was detected using anti 3-Nitrotyrosine antibodies (1/500°, overnight, 4°C, GemacBio®) and avidin-biotin-peroxidase antirabbit second antibodies (ABC kit, 1 hour, room temperature, VECTASTAIN®). The presence of 3NT was revealed using DAB and Nickel (peroxidase substrate kit, VECTOR®). DNA oxidation was detected using mouse anti-8-oxo-dG antibodies (1/25°, overnight, 4°C, GENTAUR® and a secondary antibody. Positive control rats were submitted to intraventricular injection of LPS or quinoloinic acid for the identification of the presence of 3-Nitrotyrosine and 4-HNE, and 8-oxo-dG, respectively. Rats were kept for 24 hours before sacrifice, and their brains handled as previously described. Coverslips were mounted on slides before microscopy observation. In each brain region of interest, one X400 representative microscopic photograph was taken using a camera on a microscope. From these photographs, analysis was performed on the brain regions selected using either visual scoring (score ranging from 0 to 6) or Aphelion image-analysis software based on fluorescence intensity and area. Values were averages of two slices per sample. Then, the analysis was performed, in each group, in each sub-region and on the total score for the cortex, the hippocampus and the brain. Statistics were performed using the Statview software (SAS Institute Inc., Cary, NC, USA). Statistical comparison between sham and exposed groups used the Kruskal-Wallis test. Statistical comparison between cage and positive controls used the Mann and Whitney test. $p < 0.05$ was considered as significant.

Results. Significant lipid peroxidation was observed in the whole-brain of positive-control rats (score 42.4) as compared to cage-control animals (score 31.8; $p<0.05$). The maximum score was obtained in some regions only. The 4-HNE score was found comparable in sham-exposed (score 36.7) versus cage control rats ($p=0.43$). In the young-adult rats, a single exposure to either signal did not influence background lipid peroxidation (medium level) in the brains as compared to sham-exposure. After repeated
exposure to GSM-1800, no effect was observed on lipid peroxidation, while repeated exposures to UMTS were found to significantly induce a decrease in lipid peroxidation in the rat brains (score 23.9, \( p < 0.001 \) UMTS vs. sham). The decrease was seen in every single brain region of UMTS-exposed rats.

In elderly rats, no significant difference could be seen in the brains after either a single or a repeated exposure to GSM-1800 and UMTS as compared to sham-exposed rats. Analysis of protein nitration and DNA oxidation is in progress.

**Conclusions.** 4-hydroxynonenal (4-HNE) is a neurotoxic byproduct of lipid peroxidation of arachidonic acid. It was recently shown that 4-HNE covalently modifies amyloid b peptide, triggering its aggregation, which may be important in the pathogenesis of Alzheimer’s disease. Therefore, the decrease in 4-HNE staining observed after repeated exposure to UMTS in the brains of young rats is suggestive of no effect or at best a “beneficial” one.

Radical stress will be further investigated at the DNA and protein levels before drawing definitive conclusions. All data will be available at the meeting.

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**P-70 OXYGEN RADICAL RELEASE IN HUMAN LEUKEMIA CELL LINES AFTER ELF MAGNETIC FIELD EXPOSURE.**

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**Summary of Abstract.** Exposure of human leukaemia cell lines to 50 Hz MF for different times and at various flux densities showed that even short term exposure increases levels of the superoxide radical.

**Objectives.** The aim of this study was to investigate whether human leukaemia cells respond with changed oxygen radical levels after exposure to extremely low frequency magnetic fields (ELF-MF).

**Methods.** Several human leukaemia cell lines were used in this study and cultured according to standard procedures. Exposure to 50 Hz sinusoidal MF (various flux densities, horizontal or vertical polarization) was performed in cell culture incubators equipped with Helmholtz coils for different times (ranging from 5 min – 1 h) after which the superoxide radical was analyzed using nitroblue tetrazolium chloride. Cells were exposed to the ELF MF alone and in combination with the tumour promoting phorbole ester phorbol
12-myristate-13-acetate (PMA) to reveal any additional or cooperative effect of MF. All experiments were performed in the presence of the local geomagnetic field and under controlled temperature conditions.

Results. Our results show a significant increase of superoxide radical production in the K562 cell line, whereas only a slight, although significant, increase could be detected in Mono-Mac-6 cells after 30 min 0.10 mT exposure. In K562 cells a 1.3-fold increase was observed after 1 h exposure (0.10 mT) compared to sham conditions. Moreover, a 30 min exposure gave rise to a 1.7-fold increase in superoxide production. Additional experiments revealed a 4.4-fold, 2.7-fold and 3.5-fold increase after 5 min, 10 min and 15 min respectively. Further on, co-exposure to PMA (0.1 µM) and 0.10 mT MF revealed a highly significant additive/co-operative effect in both cell lines after 1 h exposure. Interestingly, a 30 min co-exposure in K562 cells revealed a highly significant decrease in superoxide production. After 5, 10 15 min exposure at different flux density levels (0.025, 0.05 and 0.10 mT), 0.10 mT showed the highest production of superoxide radicals in K562.

Conclusions. Short exposures to ELF MF can cause significant increases in superoxide radical levels in human leukaemia cells, in a flux-density dependent manner. However, responses to field exposure seems to be cell-type specific. On-going work aims at elucidating the actual mechanism behind the observed effects.

P-71 IN VITRO CO-GENOTOXIC EFFECTS OF 2.45 GHZ ELECTROMAGNETIC FIELDS ON HUMAN CELLS CLOSE TO THE THERMAL THRESHOLD

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Summary of Abstract. The aim of the study was to investigate the co-genotoxic effects of 2.45 GHz electromagnetic field in vitro and to determine whether or not the biological effects observable near the thermal threshold are purely thermal. The effect of 2.45 GHz microwaves combined to a know mutagen agent was examined at several SAR values (4, 8 and 16 W/kg) and compared to the effect of different incubations of the cells in the same temperature range. DNA damage was quantified with the comet assay. Complementary experiments were carried out. The results suggest a gap between classical thermal effects (conduction) and non ionizing radiation thermal effects at the threshold of thermal effects.

Objectives. The aim of the study was to investigate the co-genotoxic effects of 2.45 GHz microwaves in vitro and to determine whether or not the biological effects observable above a certain electromagnetic field intensity are purely thermal. An indirect influence of microwaves during an intermediary step of mutagenesis cannot yet be excluded. We hope to
obtain information on the mechanism involved at the threshold of the thermal effects, when the energy source is an electromagnetic wave or exogenous heat.

The comet assay was used to assess DNA damage with the monocyte human cell line THP1. The cells were treated by the mutagenic agent 4-nitroquinoline-N-oxide (4-NQO) and simultaneously exposed to microwave at several SAR levels. At the higher SAR level, an influence of the electromagnetic field on induced DNA damage was observed. Further investigations were carried out to determine if the emergence of this combined effect was due to a temperature rise in the sample: 1/measurement of the temperature in the culture medium under experimental conditions; 2/ evaluation of the effect of temperature on DNA damage induced by 4-NQO. A simple cell survival assay sensitive to temperature and additional numerical simulations were used to validate of the temperature measurements.

**Methods.** The carrier frequency was 2.45 GHz CW and PW (radar type, 1 kHz repetition time, 10 % duty cycle) with the same average power density. The experiments were carried out at different SAR values: 4 W/kg, 8 W/kg and 16 W/kg. Especially Plexiglas designed incubators were integrated in three identical anechoic chambers equipped with horn antennas. In each experiment, non-exposed (sham) and exposed (PW and CW) cell culture plates (3 petri dishes by condition, 2 slides per dish) were incubated simultaneously in the presence of 4-NQO, for 2h, at 37°C under gentle shaking. The electromagnetic field was applied alternatively in the three anechoic chambers in order to avoid cage effects. Each experiment was reproducibly repeated 8 times. Care was taken to increase the reproducibility of the experiments and to avoid false positive or misinterpretation of the results. The presence or the absence of the electromagnetic field was the only difference between the sham and exposed assays. The alkaline comet assay was performed according to the method originally described by Singh & al (1988, Exp. Cell Res., 175, 184-91). The images were analyzed with the Komet 5.0 image analysis system. Images of 200 randomly selected cells were analyzed from each sample. Fragmentation was expressed in Tail Extent Moment (TEM) taking into account tail length and the percentage of DNA in the comet tail.

In a second step, the temperature inside the Petri dishes was monitored in the different exposure conditions and further experiments were realized. The temperature of the culture medium was measured inside the cell plates with a microprocessor-controlled thermometer using fluoro-optic fiber temperature probes (Luxtron). Numerical dosimetry was calculated using the Finite Difference Time Domain method. A time-scaled form of the heat transfer equation allowed calculating the temperature inside the petri dishes. The DNA damage was quantified for non-exposed cells incubated in the anechoic chamber at different temperature simulating the heating curve observed under microwave exposure.

For cell survival test, the cells were incubated, under gentle stirring, for 2 h at a temperature range (37 to 43 °C) or under microwave exposure (2.45 GHz, PW and CW). Then, the cell suspension was counted and diluted. After a 72h growing phase, cell survival was determined with a classical colorimetric method.

**Results.** 2.45 GHz CW and PW microwave exposure with SAR values 4 and 8 W/kg doesn’t modify the level of DNA damage induced by a known mutagen. At 16 W/kg, there is a significant increase in DNA strand breaks (+40%). At the SAR 16W/kg, there is an increase of temperature compared to sham, the temperature do not exceed 39 °C in
the sample at the end of the exposure time (+2°C compared to sham). Incubation of the cell cultures at different temperature (same conditions except microwave exposure) showed that a 6°C rise is necessary to modify DNA damage level induced by the mutagen agent. Surprisingly, the temperature rise resulting from electromagnetic field exposure is too low to induce such DNA damage.

**Conclusions.** Those data suggest a gap between classical thermal effects (conduction) and non ionizing radiation thermal effects at the threshold of thermal effects. Compared with exogenous heat, microwave exposure enhances the action of the mutagenic agent. It could provide new insights into the interactions between biological systems and electromagnetic fields at a critical intensity level. Further experiments are currently in progress to go into the subject in greater depth and will be discussed at the time of the meeting.

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**P-72 EFFECTS OF RADIO FREQUENCY RADIATION ON INTRACELLULAR LEVELS OF REACTIVE OXYGEN SPECIES AND ANTIOXIDANT ENZYMES, AND SENESCENCE-ASSOCIATED BETA-GALACTOSIDASE ACTIVITY**

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**Summary of Abstract.** Effects of single or combined radio frequency (RF) radiation exposure on intracellular levels of reactive oxygen species and antioxidant enzymes, and senescence-associated b-galactosidase activity were examined.

**Objectives.** The aim of this study was to investigate whether single or combined radio frequency (RF) radiation exposure had effects on intracellular levels of reactive oxygen species and antioxidant enzymes, and senescence-associated b-galactosidase activity.

**Methods.** MCF7 human breast cancer cells were exposed to RF radiation at SAR values of 2 W/kg for 1 h. RF exposure were conducted with four separate groups; sham-exposed, CDMA RF (835 MHz)-exposed, WCDMA RF (1980 MHz)-exposed, and combined RF-exposed (CDMA plus WCDMA) groups. During exposure, the temperature in the chamber was maintained isothermally by circulating water within the cavity. After RF exposure, intracellular levels of reactive oxygen species and antioxidant enzymes were assessed by
 floroscence-activated cell sorting (FACS) analysis using dichlorofluorescein diacetate (DCF-DA) and Western blot, respectively. Morphological changes of RF-exposed cells were examined microscopically, and senescence-associated b-galactosidase activities were observed with senescence-associated b-galactosidase staining method.

**Results.** Intracellular levels of ROS were not affected by either single or combined RF radiation exposure. Intracellular levels of antioxidant enzymes, catalase, Mn superoxide dismutase (SOD), Cu/Zn SOD, peroxiredoxin were not altered by either single or combined RF exposure. It was statistically assessed with ANOVA (p > 0.05). In contrast, ionizing radiation-exposed group which was used as positive control group showed dramatic changes of intracellular ROS and antioxidant enzyme levels. When changes of cellular morphology and senescence-associated b-galactosidase activity were observed after either single or combined RF exposure, there was no significant alteration. Whereas, ionizing radiation-exposed group showed evident alterations in cellular morphology and senescence-associated b-galactosidase activity.

**Conclusions.** Either single (CDMA only or WCDMA only) or combined (CDMA plus WCDMA) RF radiation exposure did not affect intracellular levels of ROS and antioxidant enzyme, and senescence-associated b-galactosidase activity.

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**P-73 EFFECTS OF 365NM UVA-LED ON BACTERIA**

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**Summary of Abstract.** The effects of 365 nm UVA-LED on bacteria are examined here especially from a view point of sterilization. There are several methods used for sterilization. In those methods chlorine, heat and UV rays are traditionally used. In recent years, the UV sterilization is taken notice as a sterilization method that the sterilized object does not change in quality and is environment-friendly. In this paper, an UV-LED is focused because it does not contain harmful substance and has longer operating life. The results have showed that complete germicidal effects for E. coli and Vibrio parahaemolyticus by UV-LED exposure of 30 minutes and 10 minutes, respectively. These results suggest that the UV-LED has sterilization effects. Therefore, UV-LED can be used as a sterilization device.
Objectives. Sterilization is a technology necessary for our daily life. For example, it is used for water and sewerage disposal, medicine, foods and etc. Methods used widely for sterilization are those using chemical drugs, heating, ultraviolet (UV) radiation and ozone. Sterilization by UV is friendly for environment. In addition, it does not produce drug-resistance of bacteria. Thus sterilization by UV which performs effective disinfection without addition of chemical substances into object has attracted attention recently as a substitute for chlorination. Conventional UV sterilization uses UV lamps such as the low-pressure mercury lamps. The low-pressure mercury lamps emit UV of 254 nm in wavelength. UV of 254 nm wavelength is known that it has the highest sterilization effect. However, UV of 254 nm is classified as UVC. UV-LED has 365 nm wavelength and it is not very hazardous for human eyes and skin than mercury lamp. Furthermore, mercury is not included in UV-LED and it does not have harmful effects on ether a human body or environment. UV-LED is a smaller device and has longer operating life as compared with those of the low-pressure mercury lamps. It will be a low power consumptive and environment-friendly sterilizer. Therefore, our project aims at development of a new sterilization device using 365nm UVA-LED that is moderate to a person and environment.

Methods. Our project uses a High-Power UV-LED (NCCU033 (T); Nichia Corporation, Japan, wavelength 365 nm) to make sterilization device, connect the eight UV-LEDs in series, and apply DC power. The current is set 500 mA constantly. We perform 30 minutes preliminary operation to stabilize the wavelength and power of UV. Irradiation distance from the UV-LED to bacteria is set to 20 mm.

Results. It is proved that it could sterilize nonpathogenic and pathogenic bacteria almost completely by irradiating UVA-LED of 27 J/cm2.

Conclusions. The purpose of this research was to investigate whether it being able to sterilize by UV-LED and to make researches of the possibility to apply UV-LED to the sterilization device. From the results, it is found that it can sterilize nonpathogenic and pathogenic bacteria almost completely by irradiating UV-LED for 27 J/cm2. It is difficult to sterilize instantly as UV lamps, however it is useful as the UV-LED sterilizer for sterilization for certain time.

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P-74 EFFECT OF LOW-POWER MILLIMETER WAVES ON ENDOPLASMIC RETICULUM STRESS

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Summary of Abstract. This paper reports experimental results on the effect of low-power millimeter-wave (MMW) radiations on human brain cells. We investigated potential effects of the radiations in 59-61GHz frequency range on the endoplasmic reticulum (ER) stress. This cellular organelle is extremely sensitive to environmental insults and perturbation of its homeostasis is involved in various pathologies such as cancers, diabetes or neurodegenerative diseases. The selection of the exposure frequencies was essentially determined by their near-future applications in new local high-data-rate wireless communication systems.

Objectives. The main aim of this study was to extend current knowledge on the potential biological impact of low-power MMW radiations on the human health investigating potential effects of these radiations on ER functions.

Methods. As ER stress is a complex and multi-step phenomenon, we used several assay systems to assess the ER stress. By quantitative RT-PCR, we analysed the level of expression of the endogenous ER-biomarker BiP/GRP78. We completed our analysis using other endogenous indicators including the ER-chaperon ORP150/GRP170. We also used alternative systems, namely the ER-stress sensitive enzyme secreted alkaline phosphatase or the luciferase reporter enzyme under control of promoter containing ER stress response element.

An exposure system operating in 50-75GHz frequency range was specifically developed for exposure of the cell culture in vitro.

Results. The human glial cells U-251 MG were exposed or sham-exposed at a few discrete frequencies within 59-61GHz frequency range at a superficial power density of 0.14mW/cm$^2$. We used a microwave spectroscopy approach to select a group of frequencies corresponding to the spectral lines of the molecules and molecular groups.

Our results showed that low-power MMWs do not alter ER protein folding and secretion and do not induce ER stress-related transcription factors maturation. Furthermore, expression of ER stress sensors, namely the ER chaperone BiP/GRP78 or ORP150/GRP170, were analyzed by real time PCR. Our data demonstrated the absence of any significant changes in mRNA levels for the considered stress-sensitive genes.

Conclusions. The results of this study suggest that ER homeostasis does not undergo any detectable modification at sub-cellular or molecular level due to the exposure to low-power MMW radiations at frequencies around 60GHz.
**Acknowledgements.** This study was supported by National Research Agency (ANR), France, under Grant No. 2006 SEST 19 02 (HIMWR project) and by Health and Radiofrequency Foundation, France, under project "StressOM".

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**P-75 BIOLOGICAL EFFECTS OF 1,763 MHZ RF RADIATION IN AUDITORY HAIR CELLS**

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**Summary of Abstract.** In the present study, we used HEI-OC1 auditory cells derived from long-term cultures of “Immortomouse” cochleas. The cells express several molecular markers characteristic of organ of Corti sensory cells. To examine the biological effect of 1,763 MHz RF radiation from mobile phone, we checked several parameters like cell cycle, DNA damage, and stress response in RF-exposed HEI-OC1 cells. We also compared the gene expression patterns of RF-exposed cells against sham-exposed cells using microarray to monitor any alteration in transcription level.

**Objectives.** Radiofrequency radiation at the frequency of mobile phone has been reported to induce no cellular damage in in vitro and in vivo models. We chose HEI-OC1 immortalized auditory hair cells to characterize cellular responses upon 1,763MHz RF radiation because auditory cells could be exposed closely to mobile phone.

**Methods.** HEI-OC1 mouse auditory hair cells were irradiated with 1,763MHz RF radiation at 20 W/kg specific absorption rate in code domain multiple access exposure chamber for 24 hours and 48 hours to check the changes in cell cycle, DNA damage, stress responses and gene expressions.

**Results.** None of cell cycle phases and DNA damage were detected in RF-exposed cells. The expression of heat shock proteins and the phosphorylation of mitogen-activated protein kinases were not changed, either. We tried to identify any alteration in gene expressions using microarray. Using Applied Biosystems 1700 full genome expression mouse microarray, we found that only 29 genes (0.09% of total genes examined) were changed more than 1.5 fold upon RF radiation.

**Conclusions.** We could not find any evidence for the induction of cellular responses including cell cycle distribution, DNA damage, stress responses and gene expressions upon 20W/Kg SAR 1,763MHz RF radiation in HEI-OC1 auditory hair cells.
Acknowledgements. This work was supported by the IT R&D program of MIC/IITA (2007-F-043-01, Study on Diagnosis and Protection Technology based on EM) and BK21 program of the Korea Ministry of Education and Human Resources Development.

P-76 EXPOSURE OF HEPG2 CELL CULTURES TO LF ELECTROMAGNETIC FIELDS. EVALUATION OF ALKALINE PHOSPHATASE

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Summary of Abstract. The research aims to recognize the effects of low frequency electromagnetic field (LF) exposures on the bone reconstruction process. Experimental investigations are carried out on cell cultures of human liver (HepG2). Such cultures are exposed to amplitude modulated (12.5 Hz) LF electric fields (60 kHz). Analyses currently considered as reference of cell proliferation and differentiation are performed on the exposed cultures.

Objectives. Electromagnetics fields can interact with biological materials. Thermal effects and non-thermal biological effects following exposure to electromagnetic fields are reported in many scientific papers. While the consequences of environmental exposure to electric, magnetic and electromagnetic fields have been extensively investigated, the effects of electromagnetic fields used for clinical diagnosis and therapy are not, though various applications are established in the clinical practice. CCEF (Capacitive Coupled Electric Fields) used to enhance healing bone have been successfully used in patients and no side effects have been reported. Biophysical bone growth stimulation treatments are particularly suitable when there is a delayed bone healing and conventional therapies failed. Among the available equipments, those employing CCEF are widely accepted for their simplicity of use. Generally such systems operate with low intensity signals, amplitude modulated at extremely low frequency (about 10 Hz). Values for both frequency and intensity of the electric signals have been selected on the bases of preclinical data. In vitro studies, analyzing the biological response to the CCEF exposure, appear to be the most effective approach for understanding the effect of LF electromagnetic fields on biological systems. The employment of cell cultures enables to operate experimentally with high repeatability both from the biological point of view, and from the electromagnetic one (accurate definition of the applied solicitation, dosimetry). Moreover, a suitable choice of the biological parameters to analyze can provide an appraisal of the effects of the field exposure on the relevant cell processes (for example, proliferation and differentiation). To this end, the expression of alkaline posphatase is generally considered a typical enzymatic activity associated with bone tissue regeneration and mineralization of the matrix. For this reason, an experimental study on the effects of LF electric fields on the expression of
alkaline phosphatase should be helpful for identifying the molecular mechanisms involved in the treatment of bone tissue.

**Methods.** Cell cultures of human liver *HepG2* were used in this study. These cells represent a widely accepted experimental model, being derived from a liver neoplasia and presenting most of the original metabolic features of liver cells. Confluent cells, grown in Eagle Minimum Essential Medium (*EMEM*), supplemented with 10% fetal bovine serum (*FBS*) and 2 mM L-glutamin, were washed twice with phosphate buffer saline solution (*PBS*) and then exposed to *CCEF* for one hour in a culture flask filled with serum free culture medium. Cells were then put back in complete medium and incubated at 37 °C for either 3 or 23 hours. Cells were then detached and lysed to assess the cytosol *ALP* enzymatic activity, which was determined spectrophotometrically at 405 nm following the development of absorbance from the 4nitrophenilphosphate (*4DNPP*) substrate.

The cultures were exposed to the signal whose characteristics are shown in table. Planar electrodes are placed on of the largest bottle walls (dimensions 4.7 x 5.4 cm, thickness 1 mm) as shown in figure. An elementary electric model of the system can be represented by a parallel plate capacitor. Consequently, the electrical current circulating in the sample can be easily calculated in terms of known quantities (the voltage *V*, the angular frequency *ω*, the permittivity *ε*, the surface *A* and the thickness *d* of the walls). Assuming for the polystyrene a permittivity $\varepsilon \approx 3\varepsilon_0$ (*$\varepsilon_0$* vacuum permittivity), the calculation gives a current density in the sample of about 6 µA/cm². A density current of the same order of magnitudes (5 µA/cm²) was calculated by measuring the impedance of the sample by means of an impedance meter *QuadTech 7600*. The measured impedance was $670-i110\times10^3$ Ω.

**Results.** In some preliminary repeated experiments, *ALP* values increase in *HepG2* cells by 60% after 3 hours exposure to *CCEF* compared to sham exposed cells. On the contrary not significant difference was observed after 23 hours of exposure.

**Conclusions.** The expression of the Alkaline Phosphatase in human liver *HepG2* cells is influenced by exposure to electric, amplitude modulated, *CCEF* (frequency 60 kHz, frequency of the modulating signal 12.5 Hz, peak-to-peak voltage 26 V) when evaluated 3 h after exposure. The absence of differences when analyzing cells after 23 h might be explained considering that the initial variation is then compensated by cellular mechanisms.

**Acknowledgements.** Thanks to Mr Raffaele Raimo for the accuracy in performing preliminary measurements. Thanks to Dr Willer Righi for the suitable support for set up of exposure system.
Figure 1.
P-77 REAL-TIME MEASUREMENT OF CYTOSOLIC FREE CALCIUM CONCENTRATIONS IN DEM-TREATED HL-60 CELLS DURING STATIC MAGNETIC FIELD EXPOSURE AND ACTIVATION BY ATP

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Summary of Abstract. The purpose of this study was to examine if free radicals influence cytosolic free calcium concentration during static magnetic field exposure. Cytosolic free calcium concentration was monitored using ratiometric fluorescence spectroscopy in HL-60 cells under conditions of reduced endogenous free radical scavengers and 100 mT static magnetic field exposure. No effect of a 100 mT static magnetic field was observed on cytosolic free calcium concentration in HL-60 cells.

Objectives. Studies have shown that static magnetic fields (SMF) can exert effects on biological systems [1]. One proposed method of SMF coupling with biological systems is through an action on free radical reaction kinetics [2]. Elevated intracellular free radical concentration can lead to oxidative stress, which can result in a variety of biological effects including DNA damage[3], cell dysfunction, and accelerated cell aging [4]. To blunt the impact of free radicals, cells have evolved buffering mechanisms, the most important of which is the glutathione disulfide-glutathione (GSSH/2GSH) couple[5]. Perturbation of this buffering mechanism results in altered intracellular free radical concentration, and so may affect the cellular response to a SMF. Cytosolic free calcium concentration ([Ca\textsuperscript{2+}]\textsubscript{c}) is a potentially sensitive measure of cellular responses to external stimuli since it is involved in many biological functions including differentiation and proliferation[6]. Using [Ca\textsuperscript{2+}]\textsubscript{c} as a readout, this study investigated whether manipulation of radical buffering through depletion of GSH affected the sensitivity of HL-60 human leukemia cells to SMF exposure.

Methods. Cytosolic free calcium concentration was measured in real-time using a ratiometric fluorescence spectroscopy system. Human leukemia HL-60 cells were loaded with fura-2AM, placed in a disposable cuvette, and then incubated in a circulating water bath at 37 °C. Cells were acclimated for 1200 s, at which time 8 mM of diethyl-maleate (DEM) was added to cells to deplete GSH. At 2700 s, cells were exposed to a SMF of 0 mT (sham) or 100 mT. Cells were then activated with 1 µM ATP at 3000 s. The field was return to sham levels at 3480 s and a fluorescence calibration was performed to facilitate calculation of [Ca\textsuperscript{2+}]\textsubscript{c}. The potential systematic error related to sample order and simulated turn-on of the magnetic field was also investigated. Five [Ca\textsuperscript{2+}]\textsubscript{c} related measurements were obtained for each experiment: Pre-DEM exposure, Post-DEM/Pre-Field exposure, Post-DEM/Field exposure, peak [Ca\textsuperscript{2+}]\textsubscript{c} following ATP activation, and the full width at half maximum (FWHM) of the peak [Ca\textsuperscript{2+}]\textsubscript{c} response. Statistical analysis of data included a paired t-test and 2-way ANOVA.

Results. A systematic error was observed for the Peak-ATP metric, where the peak [Ca\textsuperscript{2+}]\textsubscript{c} depended on consecutive cell sample removal from one flask (P<0.05). Comparison of calcium related metrics between sham and 100 mT experiments revealed the following results: post-DEM/Field [Ca\textsuperscript{2+}]\textsubscript{c} was 53±2 nM and 58±2 nM for sham and 100 mT groups. Peak
[Ca\textsuperscript{2+}]_c was 189±10 nM and 185±9 nM for sham and 100 mT groups. FWHM was 51±3 s and 54±3 s for sham and 100 mT groups. There was no statistically significant difference between sham and 100 mT groups for any of the five calcium related metrics.

**Conclusions.** Based on the results from this study, it was observed that [Ca\textsuperscript{2+}]_c did not change during SMF exposure in DEM-treated HL-60 cells either at rest or after activation with ATP. The finding supported the hypothesis that a 100 mT SMF had no effect on resting or activated [Ca\textsuperscript{2+}]_c in HL-60 cells even when the intracellular free radical concentration was manipulated. There are other possibilities however. For example, (1) an effect of SMF might have been present but not measurable with the [Ca\textsuperscript{2+}]_c-dependent metrics measured in the study, and (2) potential effects of SMF on HL-60 cells may not be influenced by the presence or absence of DEM. Two streams for future work can be suggested from these possibilities. The experiments could be repeated over a greater range of magnetic field strengths above and below 100 mT. Also, repetition of the experiments at a variety of doses of DEM and with GSH potentiators such as L-NAC and glutathione diesters would allow for a greater range of GSH levels to be tested. This last possibility is driven by the hypothesis that a threshold free radical concentration exists where the action of SMF becomes apparent.

**References:**

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P-78 MORPHOLOGICAL TRANSFORMATION OF THE PROTOZOA 
BLEPHARISMA BY FREQUENCY SPECIFIC AMPLITUDE MODULATED RF 
PULSED PLASMAS

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Summary of Abstract. The protozoa Blepharisma can undergo dramatic and disruptive morphological transformations caused by frequency specific, low power, pulsed, amplitude modulated radio frequency (RF) fields utilizing an enclosed gas plasma antenna.

Objectives. Proof-of-concept experiments demonstrating that frequency specific, low power, pulsed, amplitude modulated (AM) radio frequency (RF) fields utilizing an enclosed gas plasma antenna, can have dramatic disruptive effects on some biological organisms. Specific harmonic and dissonant tonal relationships between input frequencies in AM RF pulses are explored and correlations are drawn between these relationships and the level of biological effects. The biological effects are photographed and video taped.

Methods. Two types of plasma bulbs were tested: 1) an 8 inch diameter round ‘phanotron’ glass bulb filled with 100% helium and having two internal electrodes and 2) an 18 inch long, 1 inch diameter argon/neon mixture tube with an internal ‘getter’. A custom designed digital sound synthesis program was developed for a laptop computer, capable of generating sine or square waves with selectable duty cycles in the audio range (20Hz-20KHz). These audio-range waveforms were used as input to control the amplitude modulation (AM) of a 27 MHz carrier signal of an RF transmitter (OM1 from Plasmasonics Ltd.) where the index of modulation was higher than 1. This ‘over-modulation’ of the RF carrier results in a pulsed RF output from the transmitter. These pulses are then used to stimulate the noble gasses of helium, or argon, or a combination of argon and neon into a plasma state. The plasma bulb is located between 5 and 6 inches from the stage of an Olympus BX60 research microscope with a high-resolution video camera. Slides of living microorganisms are set on the microscope stage, exposed to the RF pulsed plasma field and the results are photographed and videotaped in real time. Waveform and spectrum output of the plasma device are analyzed and correlations are made between waveform pulse shapes, spectral content, and biological effects. Various types and combinations of waveforms and frequencies were tested as input for controlling the AM pulsed RF signal.

Results. The primary organism utilized in these experiments was the single celled protozoa Blepharisma. The experiments have resulted in microphotographic and videotape evidence of morphological transformations in hundreds of Blepharisma caused by frequency specific amplitude modulated, pulsed RF fields utilizing an enclosed gas plasma antenna. Five primary effects have been documented: 1) complete disintegration of an organism [see Figure 1 below], the remnants of which often assemble spontaneously into numerous round membraneous structures (spheroids); 2) post-disintegration fusion of these negatively charged membraneous spheroids, overcoming any natural repelling of like charges; 3) partial disintegration of an organism during which a remnant of the organism seals itself off, retaining motive cilia, and survives autonomously following the experiment (birth of a new organism?); 4) partial disintegration of an organism forming some membraneous spheroids but leaving some of the organism intact but apparently nonfunctional; 5) general size expansion...
and distortion of the organism’s shape accompanied by dissolution of internal structures (vacuoles etc.) and general loss of motility, often ending in elimination of all cilia action. Initial results indicated that *Blepharisma* were sensitive to an amplitude modulation control input signal of 924Hz., causing effects described in point 5 above. Subsequent experiments showed that a combination of two square waves (50% duty cycle) was extremely effective in producing disruptive biological effects when the lower square wave’s frequency was between 924Hz-933Hz and when the higher frequency was tuned to the 11th harmonic of the lower square wave, a dissonant musical interval relationship known as a compound tritone. Waveform and spectrum analysis indicated that square waves generated in the audio band (20Hz-20Khz), and used to control the amplitude modulation of the transmitter’s RF carrier, generated many hundreds (possibly thousands) of sideband frequencies ranging from the audio region to over 150Mhz. Subsequent experiments with real time spectrum analysis indicated that changing the mathematical relationships between the two square wave inputs could result in the intentional ‘steering’ of many sideband locations well up into the Mhz range, allowing one to increase or decrease the spectral density at chosen locations in the frequency domain.

**Conclusions.** The protozoa *Blepharisma* can undergo dramatic and disruptive morphological transformations caused by frequency specific, low power, pulsed, amplitude modulated radio frequency (RF) fields utilizing an enclosed gas plasma antenna. Five different types of changes in organisms have been documented. Biological effects seem to be most pronounced when two or three simultaneous and harmonically related square wave frequencies are used as input controls for the AM with the index of modulation exceeding 1 within the RF transmitter, resulting in a pulsed RF output which contains a wideband spectrum reaching as high as 150Mhz. Spectrum analysis shows that harmonically related audio range square waves can create a greater spectral energy density at specific locations in the frequency domain, serving to group sidebands into focused areas of greater spectral intensity and this correlates with the biological effects documented. Waveform analysis reveals that a correlation may exist between the biological effects, the number of RF pulses per second and the shape of pulse amplitude envelopes.

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**FIGURE 1.** FIGURE 1: Disintegration in progress of the protozoa *Blepharisma* caused by a frequency specific amplitude modulated RF pulsed plasma. Photo taken through an Olympus BX60 research microscope

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**P-79 EFFECT OF EDGE AND UMTS SIGNALS ON THE VIABILITY OF RAT PRIMARY NEURONAL CELLS**

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**Summary of Abstract.** The effect of EDGE and UMTS signals are explored on viability in rat primary neuronal cell cultures. Under the tested exposure conditions, there is no evidence of effects of these signals on the viability and death of neuronal cells in rat primary cultures.

**Objectives.** To date, some research groups have explored the effects of mobile telephony signals on the apoptotic process in neuronal cells (Merola et al. 2006; Joubert et al. 2007; Gurisik et al. 2006; Joubert et al. 2006). But, to our knowledge, we report for the first time the effect of EDGE and UMTS signals on viability in rat primary neuronal cell cultures.

**Methods.** Neuronal primary cultures were prepared from four-postnatal-day Wistar Han rat cerebella. Cells were cultured in 35-mm diameter polylsine-coated dishes. Cells were plated in HMEM culture medium supplemented with antibiotics (1%) and horse serum (10%). They were maintained in vitro in a culture incubator with 5% CO2 in air at 37°C
for 3 days. Medium was changed before RFR exposure. In vitro exposure to RFR was performed using SXC-1800 waveguides (IT’IS-Foundation, Zürich, Switzerland) modified to allow exposure to the EDGE signal or using the UMTS system (waveguides), which was generously lent by Prof. Rita Massa (Naples, Italy). Six and Four Petri dishes can be exposed simultaneously in the EDGE and UMTS systems, respectively. Two waveguides (exposed, sham) are placed inside a commercial incubator to ensure constant environmental conditions (37°C, 5% CO2, 95% humidity). For the EDGE signal, two exposure conditions were tested: 2 W/kg for 24 h and 10 W/kg for 1 h. Cell viability parameters were evaluated 24 h after the one-hour exposure or at the end of the 24-h exposure. For the UMTS signal, 2 and 4 W/kg were applied for 1 or 24 h. During exposure, temperature was 37±0.5°C (Sannino et al. 2006) Neuronal viability criteria were assessed as described for the EDGE signal. All samples were coded prior to exposure and codes were revealed only when all parameters investigated in a given experiment had been analyzed. Apoptosis, viability, necrosis, and post-apoptotic necrosis were assessed by flow cytometry (Facscan®, Becton Dickinson) using Annexin V and Propidium Iodide staining. The CellQuest® software was used for data analysis. In situ detection of apoptosis was visualized on cells cultured on glass slides using the NeuroTACS II kit (Gentaur, Belgium). Positive controls were generated with TACS-Nuclease that allows DNA breaks in every cell and provides an appropriate positive labelling control. Apoptotic neurons were counted under the microscope. The Kruskal-Wallis test was used for statistical analysis.

Results. After exposure of neuronal cell cultures to the EDGE signal at the two tested SAR levels, no significant differences were measured on apoptosis, viability, necrosis, and post-apoptotic necrosis (n=6 at 2 W/kg and n=9 at 10 W/kg). No significant difference in the in situ detection of apoptosis was observed (n=5 for both SARs). UMTS exposure (at 2 and 4W/kg) did not induce significant changes in the percentage of apoptotic, viable, necrotic, and post-apoptosis necrotic neuronal cells (n=6). The number of apoptotic neurons counted using the in situ detection kit was not altered by UMTS exposure at either SAR tested (n=6).

Conclusions. Under the tested exposure conditions, there is no evidence of effects of the EDGE and the UMTS signals up to 10 and 4 W/kg respectively, on the viability and death of neuronal cells in rat primary cultures.

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P-80 EFFECT OF 100 MT STATIC MAGNETIC FIELD ON HSP70 mRNA IN HL-60 CELLS

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Summary of Abstract. Heat shock proteins are involved in stress related cellular responses involving protein folding. The stressors that trigger this response vary widely and include both chemical and physical agents (e.g. heat and magnetic fields). The effect of magnetic fields on the expression of heat shock genes has been an issue of debate since the discovery that weak electromagnetic fields increased the amount of hsp70 transcript in human cell lines and yeast [Goodman R 1994]. Although follow-up reports from a variety of groups are not directly comparable due to differences in experimental variables including strength of the magnetic field, length of exposure, and organism, there has been consistent use of relatively weak magnetic fields (40-600 µT), which correspond to occupational and residential situations.

Since the observable effect of magnetic field exposure may be small under normal cellular conditions, manipulation of the cellular environment to amplify potential effects may allow for measurable and reproducible findings. Diethylmaleate (DEM) changes the cellular environment by decreasing the amount of reduced glutathione (GSH) in the cell. The decreased concentration of this free radical scavenger will theoretically increase the level of damaging radicals in the cell. This in turn may amplify the cell’s response to magnetic field exposure.

Objectives. The objective of this study was to examine the effect of higher (100 mT) static magnetic fields (SMF) after treatment with DEM on the amount of Hsp70 mRNA in HL-60 cells.

Methods. Undifferentiated HL-60 cells were centrifuged, resuspended in a balanced saline solution, and placed in a disposable cuvette. The cuvette was placed between the poles of a toroidal magnet held within a circulating water bath. Cells were acclimated within the apparatus at 37°C and 0 mT with constant stirring for 20 min. Sham-exposed cells remained under these conditions for an additional 30 min then immediately removed from the apparatus. Cells used for the positive control (heat) were exposed to 42°C for 20 min. Experimental cells were exposed to A) 9 mM DEM at 20 min and 100 mT SMF at 25 min; B) 9mM DEM at 20 min, or C) 100 mT SMF at 25 min. All experimental cells were removed from the apparatus at 50 min. Immediately following exposure, RNA was isolated from the cells to be used in reverse transcription-PCR. The PCR was done using multiplexed primers for Hsp70 and the internal control GAPDH. The average integrated density value (AVG) of the band for each individual PCR product was determined using AlphaImager 2200 v5.5 gel doc software. To determine the size of any effect the AVG value of each Hsp70 specific PCR band was divided by the AVG value of its corresponding GAPDH specific band to obtain a normalized Hsp70 value. The normalized values of field exposed, DEM exposed and field plus DEM exposed were divided by the control value to obtain a ratio of effect size.
Results. Analyses of the normalized AVG ratios of 11 to 12 replicates of each condition showed that there was an average of a 1.5X increase in the level of Hsp70 mRNA in DEM-exposed cells as compared to control, a 1.6X increase in the field-exposed cells, a 1.8X increase in the field- and DEM-exposed cells, and a 4.9X increase in heat-exposed cells. The observed differences in the DEM-, field-, and (field plus DEM)-exposed cells were not statistically significant as determined by a one-way ANOVA. The heat-exposed cells did show a statistically significant difference in mRNA levels compared to control cells.

Conclusions. We found that there was no significant effect on the amount of Hsp70 mRNA when HL-60 cells were exposed to DEM, to a 100 mT SMF, or to a combination of DEM and SMF. In contrast, exposure to 42°C (i.e. positive control) did lead to a statistically significant increase in the amount of Hsp70 mRNA. Heat shock proteins are the hallmark of cellular stress; however, they also play an important role in the unstressed cell by assisting with the folding of newly synthesized proteins. Since most stressors act as protein denaturants it follows that such stress would induce the increased production of heat shock proteins. Exposure to a 100 mT SMF for 30 min may not be a severe enough condition to affect protein stability within the cell, which could explain why levels of Hsp70 were not increased. Surprisingly, treatment of the cells with 9 mM DEM, which has been shown in our lab to significantly increase cytosolic free Ca\(^{2+}\) concentration, did not increase Hsp70 mRNA levels, nor did the combination of DEM and SMF. Thus, despite the fact that DEM exposure depleted GSH levels enough to alter intracellular calcium homeostasis and presumably increased the levels of protein damaging radicals, the cells did not respond through increased levels of Hsp70. Future work could increase the concentration of DEM until a measurable change in the cellular expression of Hsp70 is observed followed by exposure to a SMF.

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P-81 EVALUATION OF MUTAGENIC POTENTIAL OF COMPLEX MAGNETIC FIELDS WITH STATIC AND TIME-VARYING COMPONENTS

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Summary of Abstract. The purpose of our study is to evaluate biological effects by complex EMFs and mutagenic potential of complex EMFs, especially with static and power frequency components were examined by bacterial mutation assay. Three exposure conditions were selected; a. 20 mT static magnetic field and 1 mT 50Hz magnetic field, b. 1 mT static magnetic field and 0.5 mT 50Hz magnetic field, c. 1 mT static magnetic field and 0.1 mT 50Hz magnetic field. In all exposure conditions, no difference in the number of mutant colony was observed. Therefore, these complex magnetic fields have no mutagenic potential in bacterial mutation assay.

Objectives. Biological effects and health risk/benefit of electric and magnetic fields (EMFs) are still unclear in intensive studies over 25 years. Since 1996, the World Health Organization conducted “International EMF project” and recently published Environmental Health Criteria monographs (No. 232 for static fields and No. 238 for extremely low frequency fields). In these monographs, single component (e.g. single frequency) field were considered mainly. However, in our environment, various types (e.g. frequency, field strength) of EMFs exist and their distributions are complex. Moreover, there are few reports on biological effects of such complex EMFs exposure to date. In this point, the purpose of our study is to evaluate biological effects by complex EMFs and mutagenic potential of complex EMFs, especially with static and power frequency components were examined by bacterial mutation assay.

Methods. For complex EMFs exposure, two exposure devices were used. One device constructed with a Helmholtz coil and a superconducting magnet (JS-500, Toshiba, Japan). The Helmholtz coil that was able to generate 50Hz, 1 mT time-varying EMF was located at the center of the bore of superconducting magnet that could generate static magnetic field up to 5 T. This exposure system was located in a constant temperature room and maintained exposure space at 37±1°C. The other exposure device constructed with two merit coils combined orthogonally. This device is able to generate static magnetic field and/or 50Hz magnetic field up to 1 mT in this study. Induced current in the test plate which contains agar and nutrient compounds for complex exposure condition was estimated using impedance method.

Three exposure conditions were selected; a. 20 mT static magnetic field and 1 mT 50Hz magnetic field, b. 1 mT static magnetic field and 0.5 mT 50Hz magnetic field, c. 1 mT static magnetic field and 0.1 mT 50Hz magnetic field. Mutagenic potential of complex EMFs was estimated by bacterial mutation assay (Ames test). This assay was performed using Salmonella typhimurium TA98, TA100 by standard method. 0.1 ml of pre-cultured cell suspension (containing 1-3×10⁸ cells in nutrient broth) was plated onto minimal glucose agar with 0.5ml of the phosphate buffer and 2 ml of 0.05...
mM histidine and 0.05 mM biotin containing molten agar. At least six plates were made for each point and three independent tests were performed. The plates were randomly divided into two groups; plates of exposure group were incubated in a magnetic field while the others in a conventional incubator at 37±1°C. Except these plates, additional 3 plates were made with an chemical mutagen 2-(2-furyl)-3-(5-nitro-2-furyl) acrylamide (AF-2) as positive control. After 48 hours incubation, number of histidine prototroph mutant colony appearing on each plate was scored and mutagenic activities of complex magnetic fields were evaluated by comparing the number of the mutant colonies. Student’s t-test was used for statistical analysis.

**Results.** Number of reverse mutant colony was almost same both in exposure and control in the condition of complex magnetic field with 20 mT static and 1 mT 50Hz magnetic field in both tester strains. It indicates lack of mutagenic potential by exposure to the complex magnetic field. Moreover, no difference in the number of mutant colony was also observed in all of other exposure conditions (1 mT static, 0.5 mT 50Hz and 0.5 mT static, 0.1 mT 50Hz). Therefore, it was concluded that these complex magnetic fields have no mutagenic potential in bacterial mutation assay.

We have already reported a lack of mutagenic potential by exposure to a complex magnetic field with 5 T static and 1 mT 50Hz in Ames test. On the other hand, this complex field showed very weak mutagenic potential on chromosomal recombination in yeast cells [Ikehata et al., 28th BEMS meeting, Cancun, 2006]. However, we found that the effect of exposure to strong static magnetic field was the dominant effect in the induction of mutation by the complex field. This suggests combination of 50Hz magnetic field did not affect the mutagenic potential of strong static magnetic field, thus combination with static and 50Hz magnetic field may have no synergetic effect. In addition, these results also suggest that environmental weak complex magnetic fields would have no potential to cause mutation.

In future studies, different combination of frequency of complex EMFs will be investigated for achieving basic knowledge of biological effects of EMFs. These efforts may contribute for evaluation of health risk by exposure to EMFs in our environment.

**Conclusions.** This study showed various complex magnetic fields with static and 50Hz components such as 20 mT static and 1mT 50Hz, 1 mT static and 0.5 mT 50Hz, and 1 mT static and 0.1 mT 50Hz did not have any mutagenic potential in bacterial mutation assay.
**P-82** EFFECTS OF MICRO WAVE ELECTROMAGNETIC FIELDS (438.5MHZ) ON TRANSIENT INCREASE IN INTRACELLULAR CA2+ IN BOVINE ADRENAL CHROMAFFIN CELLS

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**Summary of Abstract.** We tested the effects of 438.5MHz frequency electromagnetic field on bovine adrenal chromaffin cells. After the cells were exposed to the electromagnetic field for varied time, the intracellular Ca2+ concentration ([Ca2+]c) was measured after addition of acetylcholine (Ach). In control cells, addition of ACh and replacing to the high K+ medium transiently increased [Ca2+ ]c and then decreased with time. In all experiments, significant difference was not seen between exposed and control cells. These results are suggested that 438.5 MHz high frequency electromagnetic fields does not affect Ach-induced transient increase in [Ca2+]c of chromaffin cells.

**Objectives.** Recently, the rapid spreading of communication devices using electromagnetic energy has been increasing public concern about health effects of radio frequency. The purpose of this study is to examine the effects of 438.5MHz high frequency electromagnetic field on an increase in [Ca2+ ]c evoked by some neurotransmitters using nerve-like adrenal chromaffin cells derived from bovine adrenal medulla.

**Methods.** Bovine adrenal chromaffin cells were dispersed enzymatically, and cells were plated on cover glasses (13 mm diameter) placed in 35-mm culture dishes. After the cells were attached to cover glasses, they were cultivated for 2-6 days in monolayer. We used normal balanced salt solution for incubating these cells during the exposure to the electromagnetic field. Electromagnetic field produced by micro wave generator was used.(Fig.1) This generator produces a sinusoidal wave with a frequency 438.5 MHz. The value of electric power and reflection in the exposure device was measured by using two wattmeter. Cells were exposed to the electromagnetic field for 0.5, 1 and 2 hr and the electric field strength was 26.6 V/m and 54.6 V/m. After the exposure, [Ca2+ ]c was measured at two different conditions, one was addition of 10-4M acetylcholine (Ach) and another was replacing to the high K+ medium. [Ca2+]i was determined with a permeable fluorescent probe, Fura2-AM by ARGUS-50/CA (Hamamatsu Photonics Co. Ltd.,Japan).

**Results.** We tried to test effects of the high frequency electromagnetic field on increases in [Ca2+]i stimulated by both ACh and high K+. Electric field strength was changed from 26.6 to 54.6 V/m. In all experiments, exposure to the electromagnetic field did not significantly influenced the peak value, increasing and decreasing rate of the transient increase in [Ca2+]i.
**Conclusions.** These results are suggested that 438.5 MHz high frequency electromagnetic fields does not affect Ca2+ release from endoplasmic reticulum and Ca2+ influx through Ca2+ channel of plasma membrane in chromaffin cells. Further studies are needed to confirm these results.

**P-83 EFFECTS OF TIME-VARYING MAGNETIC FIELD ON REGULATORY VOLUME DECREASE IN BOVINE ADRENAL CHROMAFFIN CELLS**

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**Summary of Abstract.** Exposure to the time-varying magnetic field affects distribution and content of F-actin fiber in cytoplasm of chromaffin cells. When the cells were incubated in hyposmotic medium, the cell volume was sharply increased and then decreased with time. Exposure to the magnetic field increased the initial peak value and but delayed the recovery to the normal value. Replacing with hyposmotic medium caused transient decrease in cellular F-actin and then the content was increased to the normal value in control cells. In exposed cells recovery to the normal level of F-actin was delayed. These data are suggested that exposure to the time-varying magnetic field influence the volume regulation by affecting actin protein.

**Objectives.** We have recently found that a switched 1.5 tesla magnetic field affected intracellular transient Ca²⁺ increase induced by acetylcholine and actin filaments of adrenal chromaffin cells. In this study, to investigated how the magnetic field affects on the Ca²⁺ increase and we aimed at morphology and functions of actin protein. Actin filaments have a many functions, it is reported that this filaments change markedly and control cell volume during cell volume regulation. To accomplish this objective, confirm functions of and investigated the effects of the magnetic field on actin protein during volume regulation in hyposmotic medium in chromaffin cells.

**Methods.** Bovine adrenal chromaffin cells were plated on 35-mm culture dishes or cover glasses placed in the same culture dishes. After the cells were attached to the dishes or cover glasses, maintained for 2-5 days in CO₂ incubator. After the cells were exposed to a time-varying magnetic field (varied intermittently from 0.07 to 1.5 T at an interval of 3 sec) for 2 hr, the culture medium were replaced with hyposmotic media. Fura 2 and calcein were used for measurements of the concentration of intracellular Ca²⁺([Ca²⁺]i) and cell volume,
respectively. Morphology of cellular F-actin was observed by actin phalloidin staining and contents of actin was measured by western blots.

**Results.** When the cells were incubated in hyposmotic medium, the cell volume was sharply increased and then decreased with time. Exposure to the magnetic field increased the initial peak value and but delayed the recovery to the normal value. Preincubation of cytochalasin D and latrunculin B indicated the same volume changes as 2 hr-exposed cells, specially latruncrin B perfectly inhibited the recovery to the resting value. The exposure or addition of cytochalasin D increased the contents of intracellular G-actin, and this data suggests an increase in the F-actin content. Replacing with hyposmotic medium caused transient decrease in cellular F-actin and then the content was increased instantly to the normal value within 30 sec in control cells. In exposed cells recovery to the normal level of F-actin was delayed. This volume regulation was closely related to the intracellular Ca\(^{2+}\) because addition of BaCl\(_2\) or DIDS (4,4’-diisothiocyanatostilben-2,2’-disulfonic acid) inhibited the recovery to the normal value. But changes in \([\text{Ca}^{2+}]_c\) during the regulation was not influenced by the exposure.

**Conclusions.** Exposure to the time-varying magnetic field affects distribution and content of F-actin fiber in cytoplasma of chromaffin cells. These data are suggested that exposure to the time-varying magnetic field influence the volume regulation by affecting actin polymerization or depolymerization.

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**P-84 FUNCTIONAL INVESTIGATIONS OF THE GSM-DTX MODULATION OF 1.8 GHZ RF EXPOSURE IN IMMUNE RELEVANT CELLS.**

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**Objectives.** and Introduction: We demonstrated in earlier studies statistically significant free radical release using exposure to 1.8 GHz modulated by GSM-DTX signal at 2 W/kg for 45 min in immune relevant cells. This change could only be detected in primary human monocytes and Mono Mac 6 cells, but not in primary lymphocytes and K562 cells, if data were compared to sham but not to incubator control (Lantow et al. 2006 a,b,c).

**Methods.** In the present study we explored the reason for the activation capacity of the GSM-DTX signal modulated 1.8 GHz RF to induce free radicals (reactive oxygen species) and HSP70 using immune relevant cells by flow cytometric analysis. Different SAR values of the GSM-DTX signal (2,0; 5,0 und 10 W/kg) and frequency modulations of the 1.8 GHz fields at 2 W/kg were used to analyse functional changes on cellular level. The GSM-DTX signal is used during the hearing modus by mobile phones. The signal is modulated with 2, 8 and 217 Hz with a highest pulse of 140 W/kg at an average SAR of 2 W/kg. Therefore we
used 2, 8 and 217 Hz modulated 1.8 GHz RF, with an average SAR of 2 W/kg (max. fixed pulse: 500 W/kg) for 45 min. Additionally we investigated the effects of 50 Hz modulation as well.

**Results and Conclusions.** Statistically significant differences were detected for ROS production after using the frequency modulation of the DTX signal, whereas only small but statistically significant changes on HSP70 level at 5 and 10 W/kg could be detected. We think the reason for our findings is based on the very high peak SAR in the used signal, causing the activation and the regulation of certain proteins, and the increased ROS release. The applied positive controls (PMA, LPS, heat (40°C) induced a statistically significant higher level of free radical release via different mechanisms suggesting differences between the involved signal transduction pathways. No additive effects of RF and PMA could be detected.

**References.**

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**P-85 EFFECT OF 50HZ, 2MT AC ELECTROMAGNETIC FIELD ON PROLIFERATION, MORPHOLOGY AND CBFA1 PROTEIN EXPRESSION IN PRE-OSTEOBLASTS**

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**Summary of Abstract.** Many studies have demonstrated an effect of electromagnetic fields (EMF) on bone formation, often seeing changes in proliferation, differentiation and morphology. These effects have long been harnessed for therapeutic use in the clinic and also show potential as tools for bone tissue engineering. With this in mind we investigated the effect of an AC EMF on proliferation, morphology and expression of the differentiation marker protein, CBFa1, in mouse pre-osteoblasts. The cells were exposed to a homogenous 50Hz, 2mT AC electromagnetic field for 1 or 4 days. Measurements were carried out using the GE Incell 1000 and Cellomics KineticScan high content screening systems. No
significant changes in proliferation, morphology, or expression of CBFα1 were seen compared with sham-exposed / no exposure cells, thus suggesting that these EMF conditions would not be useful for tissue engineering or therapeutic applications.

**Objectives.** To investigate the Effect of 50 Hz, 2mT AC electromagnetic fields on proliferation, morphology and expression of the differentiation marker protein, CBFα1, in pre-osteoblast cells in order to assess their potential for therapeutic and tissue engineering applications.

**Methods.** MC3T3 mouse pre-osteoblasts (ATCC, USA) were seeded on 96 well plates and after 5 hours they were incubated in a temperature controlled (37°C) solenoid (20cm L x 12cm d, 2000 turns/m) producing a well characterised homogenous 50Hz, 2mT electromagnetic field. Exposure times were 24 hr for proliferation and morphology measurements and 4 days for CBFα1 expression. For each experiment there were 3 plates, exposed (Exp), sham and control (Ctrl). The sham and exposed plates were placed in bifilar solenoids where the active exposure coil was connected in series to produce a 2.00 mT field and the sham coil was connected in anti-series so that the electromagnetic fields cancel. The same current passed through both coils, but the sham did not generate a detectable magnetic field (0.00mT). The control plate was placed in the same incubator away from the solenoids and experienced no magnetic field (0.00mT). All fields were measured using a gaussmeter (Lakeshore, USA). After exposure, cells were fixed with 4% formaldehyde and their actin cytoskeletons and nuclei were stained with the fluorescent markers, phalacidin-BODIPY and hoechst 33342 (Invitrogen, USA). 4 day exposed cells were stained for CBFα1 using fluorescent antibodies (R&D systems, USA and Invitrogen, USA). Measurements were carried out using the GE Incell 1000 and the Cellomics (Thermo Fischer) KineticScan automated fluorescent microscope systems and their accompanying analysis software. To obtain the proliferation data (cells per well) entire wells were imaged, followed by counting of the stained nuclei by the software. For other measurements 12 random images (600 – 7000 cells) were taken per well. From these, again using the analysis software, the anti-CBFα1 fluorescence intensity was isolated and quantified in the 4 day cells and morphological parameters were measured in the 1 day cells.

**Results.** After analysis of the large number of acquired images, exposed cells were compared to sham-exposed and control cells. No significant differences (ANOVA-1; significant if p < 0.05) were seen for proliferation (Fig. 2), CBFα1 protein expression (Fig. 3), cell size, nuclear size and number or length of processes extending from the cells (Fig. 1). Average anti-CBFα1 fluorescence intensity was greater in exposed and sham cells compared with controls but these increases were not significant due to high variability in the measured intensities. Also, the increase was approximately equal for sham and exposed indicating that the effect was not due to the magnetic field.

**Conclusions.** Although previous studies have demonstrated electromagnetically induced effects on bone cells, our results suggest that 2mT, 50 Hz AC fields do not affect pre-osteoblast proliferation, differentiation or morphology significantly. Thus, it would seem unlikely that these fields would be of use in a therapeutic or tissue engineering context.
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**Figure 1.** Effect of 24 hr exposure to 50Hz, 2mT AC electromagnetic field on pre-osteoblast morphology. No significant (ANOVA-1; significant if $p < 0.05$) changes were seen. $n = 3$ for process length and $n = 5$ for all others.

**Figure 2.** Effect of 24 hr exposure to 50Hz, 2mT AC electromagnetic field on pre-osteoblast proliferation. No significant (ANOVA-1; significant if $p < 0.05$) changes were seen. $n = 4$. 
Figure 3. : Effect of 4 day exposure to 50Hz, 2mT AC electromagnetic field on pre-osteoblast CBFa1 protein expression. Increases in anti-CBFa1 fluorescence intensity were seen, but exposed (Exp) and sham did not differ indicating that the effect was not due to the magnetic field. Also these increases were not significant (ANOVA-1; significant if p < 0.05) due to high variability in the measured intensities. n = 3.

**P-86 ELF UTILIZED IN CELL PHONE CAUSES DESTRUCTION SINGLE NEURON HABITUATION TO STIMULUS**

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**Summary of Abstract.** Exposure of the neuron to the low frequency electromagnetic fields utilized in the cell phone (8.34Hz and 217Hz) causes destruction of habituation to intracellular stimulus and increase of neuron excitability. Effect is proportional to the magnetic induction peak value. The observed destruction of habituation is degradation of the signal to noise ratio and destruction of neuron normal functioning.

**Objectives.** The aim of present work was to investigate the influence of extremely low frequency electromagnetic fields (8.3 Hz and 217 Hz), utilized in cell phones, on habituation of the mollusk single neuron to intracellular stimuli.

**Methods.** Isolated nervous system of the mollusk Helix Pomatia was used in the study. To apply sinusoidal magnetic fields the brain ganglia were placed between a pair of Helmholtz coils of 11 cm diameter, separated by 5.5 cm, to get a homogeneous MF in the coils centre. Peak MF induction was always calibrated previously in the centre of the
coils and monitored during the experiment with a Hall-effect probe. Current feeding the coils was supplied by amplifier, which in turn was controlled by a commercially available low frequency waveform generator. Peak value of the magnetic induction was 1-6 mT in the coils centre.

Identified giant neurons were selected for investigations. The neuron was impaled with two glass microelectrodes filled with 2, 5 mol KCl. One microelectrode served for registration and the other for intracellular stimulation. The intracellular stimulus consisted of a train of depolarizing current impulses of 4ms duration. The frequency of these impulses was 0.9 Hz. Neuronal activities were recorded using a “PowerLab ML866” data acquisition unit.

Results. Neuron reacts to the stimulant intracellular impulses with Action Potentials (AP) and then habituation arises. Habituation is expressed as a decline of the stimulus-induced APs. At the beginning of recordings we determined the threshold of AP triggering. The threshold of the stimulant impulses for AP triggering varied in amplitude between 0.1 -0.5 nA. The time necessary for habituation varied from several seconds to 1-2 minutes when stimulant intracellular impulses were close to the threshold. The number of APs triggered as the reaction varied, on average, between 50-60 AP per stimulation series, after which complete habituation was reached. The time interval during which habituation is saved depends on duration of stimulation.

If intracellular stimulation goes on after establishing of habituation and at the same time neuron is exposed to the ELF MF, neuron begins triggering of the action potentials i.e. habituation is destroyed. Usually frequency of triggered APs is less than frequency of stimulant intracellular impulses. A sample recording of the habituation dynamics of a sham-irradiated neuron and its destruction during neuron exposure to the ELF MF is shown in the Figure 1.

Destruction of habituation depends on the frequency of ELF MF. Maximal effect causes 8.3 Hz. Efficiency of destruction of the habituation proportionally depends on peak value of the ELF MF. This is illustrated in the Figure 2.

A study of the latency during exposure to ELF MF revealed significant decrease in its average value in comparison with the sham case; however the mode of irregular oscillations, characteristic of the sham case, was retained- Figure 3.

Conclusions. The destruction of habituation caused by neuron exposure to the ELF MFs utilized in the cell phone is degradation of the signal to noise ratio and destruction of neuron normal functioning.

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Figure 1.
a- Neuron reaction on stimulation with intracellular current impulses. The amplitude of stimulant impulses was 0.4 nA, frequency-0.9Hz.
b- AP triggering and habituation destruction caused by exposure of the neuron to the ELF MF with 8.3 Hz frequency and 6 mT peak value. Cut off the ELF MF was accompanied with AP triggering cut off.
c- Habituation destruction caused by exposure of the neuron to the ELF MF with 217 Hz frequency and 6 mT peak value. Momentum of beginning and cut off of neuron exposure to the ELF MF are shown with arrows. Vertical bar represents 25mV, horizontal bar 5s.
Figure 2.
Dot lines under recordings correspond to the time interval during which neuron was exposed to the MF (8.3 Hz) with peak value 1 mT. Solid line under recordings corresponds to peak value 6 mT. Vertical bar represents 25mV, horizontal bar 5s.

Figure 3.
Latencies for sham case -series 1 and for exposure to 8.3 Hz ELF MF (peak value 6 mT) -series 2. Dot line represents the trend for sham case (series1). Solid line represents the trend for exposure to the ELF MF with the frequency of 8.3 Hz (series 2). On the X axis is plotted the number of action potentials. On the Y axis is plotted latency in milli seconds. Measurement error =10%
P-87 USE OF STATIC MAGNETIC STIMULATION TO PROMOTE ENDOTHELium RECOVERY AND FUNCTION

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Summary of Abstract. Pulsed electromagnetic fields (PEMFs) have been used extensively in bone fracture repairs and wound healing. It is accepted that the induced electric field is the dose metric. The mechanisms of interaction between weak magnetic fields and biological systems present more ambiguity than that of PEMFs since weak electric currents induced by PEMFs are believed to mediate the healing process, which are absent for the former. The present study examines the response of human umbilical vein endothelial cells to weak static magnetic fields. Applications of weak magnetic fields in tissue engineering are also discussed. Static magnetic fields may open new venues of research in the field of vascular therapies by promoting endothelial cell growth and by enhancing the healing response of the endothelium.

Objectives. In this work, the response of endothelial cells to weak magnetic fields will be assessed. The aim of this study is to develop a magnetic treatment for use in vascular therapies to enhance the response of the endothelium.

Methods. To assess the effects of the magnetic treatment, we measure changes in cellular proliferation, eNOS, VEGF expressions, Nitric Oxide activity, and investigate the response of endothelial cells to changes in magnetic field intensity.

Results. Weak magnetic fields of 120μT increased cellular proliferation by 40% after 2 days of treatment. The field effects were determined to be a function of initial cell density. Wound healing was promoted significantly for injured monolayers exposed to weak fields. Immunohistochemistry by using von Willebrand factor confirmed endothelial phenotype after magnetic stimulation process. Magnetic treatment also increased the number of endothelial cells positive for eNOS. Nitric Oxide activity and VEGF expressions are also investigated.

Conclusions. The preliminary effects observed regarding increase in proliferation may indicate enhanced endothelium recovery under magnetic field treatment and could have a great impact in endothelial regeneration after injury or denudation as in endoluminal surgical procedures, including balloon angioplasty and stent implantation.
**P-88 MAGNETITE NANOPARTICLES IN THE CYTOSKELETON INFLUENCE CELLULAR PHENOTYPIC ALTERATIONS IN THE PRESENCE OF MAGNETIC FIELDS**

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**Summary of Abstract.** Weak magnetic fields have been shown to increase cellular proliferation in endothelial cells. Magnetite nanoparticles embedded in the cytoskeleton may enhance the response of cells exposed to such weak external fields via a localized mechanical deformation in the membrane. Cell proliferation and protein secretion may thus be increased after magnetic treatment. However, effects of magnetic treatment on cellular integrity are not understood.

**Objectives.** In this work, the response of endothelial cells labeled with clinically approved superparamagnetic nanoparticles in the presence of weak magnetic fields will be assessed. The aim of this study is to develop a magnetic treatment for use in vascular therapies to enhance the response of the endothelium.

**Methods.** The response of endothelial cells labeled with clinically approved superparamagnetic nanoparticles in the presence of weak magnetic fields are assessed via changes in cellular proliferation and expression of genes and proteins that are critical for normal cell metabolic function (e.g., eNOS and VEGF). The response of labeled endothelial cells to changes in magnetic field intensity is also investigated. Specifically, we: 1) measure changes in cellular proliferation and activities. These include: a) measure changes in eNOS, VEGF at the gene level (qRT-PCR) and protein level; b) measure Nitric Oxide activity; 2) measure metabolic changes of HUVECs after magnetic treatment; 3) investigate response of labeled endothelial cells to changes in magnetic field intensity and inclination.

**Results.** So far, we have shown an increase in eNOS positive endothelial cells labeled with nanoparticles after magnetic treatment. Investigation of changes in proliferation, VEGF expression, and magnetic intensity are ongoing.

**Conclusions.** The use of magnetic fields in combination with nanoparticles may open new venues of research in the field of vascular therapies by promoting endothelial cell growth and enhancing the healing process of the endothelium. The results will help to elucidate the interactions of magnetic nanoparticles with normal cellular function and may prove to be a useful tool in tissue engineering applications.
P-89 INDUCTION OF HEAT SHOCK PROTEINS USING STATIC MAGNETIC FIELDS - POTENTIAL FOR TARGETED GENE THERAPY

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Summary of Abstract. We examined the response from exposing transfected Rat-1 cells to static magnetic fields of varying strengths (1, 10, 100, 1000, and 4900 Gauss) and exposure durations (8-72 hours) using Affymetrix RAT 230 genomic microarrays and luciferase reporter gene expression. Results indicate a small but consistent heat shock response as well as changes in the expression of several other genes.

Objectives. Approximately half of all men and one-third of all women in the US will develop cancer during their lifetimes and one in six will die from the disease. It is projected that in 2005 and 2006 there will be >1,300,000 new cancer cases diagnosed and >570,000 cancer deaths annually overall, 32% from lung cancer; 11% from cancers of the colon/rectum; 8% from female breast cancer; and 6% from prostate cancer with the remaining 43% distributed among all other adult and childhood cancers. Traditional therapies and treatments focus on an integrated approach of surgery, chemotherapy, and radiation therapy. However, surgery and radiation treatment, represent a localized treatment, affecting the cancer cells only in a specific area of the body. Chemotherapy provides a systemic treatment approach utilizing chemical agents “anticancer drugs” to disrupt the cell cycle to destroy the cancer cells. The side effects caused by damage to normal cells by chemotherapy and radiation introduce dose limitations which directly impacts the effectiveness and potential success of the treatment. These limitations have driven scientists and engineers to investigate new technologies, such as gene therapy, the significant advances in the knowledge of gene function and techniques necessary to manipulate and alter genetic material.

Research performed at Memorial Sloan-Kettering Cancer Center (Li (2003)), has indicated that increased radiation sensitivity and enhanced radiation-induced apoptosis can be achieved by its limiting cellular DNA repair mechanism following ionizing radiation. This work has demonstrated the potential of a gene therapy approach where antisense Ku70 can be placed under the control of a heat shock responsive hsp70 promoter, and the heat activated antisense Ku70 expression results in significant reduction of Ku70 protein. This reduced level of the Ku70 proteins then limits repair of radiation induced DNA damages producing hypersensitivity to radiation. This known and predictable response of the heat shock gene enables the use of hsp70 promoter for the controlled expression of selective therapeutic gene fragments.

Application of heat to tumors to induce a heat shock response presents significant limitations within the actual clinical treatment scenario. The development of localized hyperthermia for tumor treatment has been hindered by a number of physical and biological factors, including heterogeneous temperature distribution and the inability of current techniques to selectively heat many smaller visceral masses.

The potential for inducing the stress response using alternative techniques, ideally non-invasive techniques, such as magnetic fields has been hypothesized. The use of magnetic
fields could provide a innovative and non-invasive method of consistently and uniformly inducing the cellular stress response, enabling the expression of selective genes as therapeutic agents.

**Methods.** Rat-1 cells were transfected (calcium phosphate method) with a plasmid containing a HSP70 promoter driven luciferase reporter gene and exposed to static magnetic fields of varying strengths (1, 10, 100, 1000, and 4900 Gauss) and exposure durations (8-72 hours). Exposure response was determined using luciferase reporter gene expression normalized to cells transfected but without exposure to a magnetic field and cells transfected and heat shocked at 45°C for 10 minutes. Affymetrix RAT-230 genomic microarrays were also used to evaluate genome wide changes in gene expression due to field exposure.

**Results.** Luciferase response to 100 and 1000 Gauss exposure, normalized for protein content and to sham-treated transfected controls, showed increases in hsp70 response on the order of 1.4–1.7 for exposures of 24 hours and 2-3 for exposures of 48 hours. These responses, though small compared to thermally induced heat shock response, indicate a consistent and predictable response. Results of RNA transcription analysis using Affymetrix RAT 230 microarrays show an increase in hsp 90 as well as increases in expression of several additional genes including signaling molecules (e.g. cysteine rich protein - Cyr61) and transformation and proliferation factors (e.g. avian myelocytomatosis viral oncogene homolog - v-myc).

**Conclusions.** We have shown that exposure to static magnetic fields can induce a low level heat shock response as well as increase the expression of additional genes. Further studies on the optimization of this response may be sufficient to provide a exploitable promoter or delivery agent of gene therapy.

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**Methods.** Whereas previous RFR studies tend to have used whole blood preparations or peripheral blood mononuclear cells rather than specific cell subsets, this study used a purified white blood cell type in order to focus on potential RF-induced alterations in gene expression in a relevant cell system. In order to reduce extrapolation issues and to reduce the risk of inappropriate gene transcript regulation in defective genes, normal human cells were selected over a transformed (cancer) cell line. Human T lymphocyte cells are involved with disease states including cancer and inflammation. In addition, to put any findings in context, a known mutagenic, carcinogenic and teratogenic positive control, sulphur mustard (HD), has been included in the study. The T lymphocytes were purified from peripheral blood mononuclear cells using a magnetic cell separation/CD3+ capture technique. A propidium iodide/annexin V flow cytometer based cell viability assay was used to characterise T lymphocytes responses to HD exposure. The RF exposure was a 1.6 GHz pulsed signal from a horn antenna generating 200 V/m in the sample area, with 550 ns pulse duration at a pulse repetition frequency of 300 Hz. The microarray system selected was the Operon Human V4 OpArray.

**Results.** T lymphocyte preparations were found to have a purity of 99.4% (±0.4) and could be maintained for a minimum of 48 h in culture. The propidium iodide/annexin V assay was used to obtain dose-response curves for sulphur mustard (HD) in order to identify a suitable positive control dose of this agent (3 µM HD) for the microarray study. Cells have been exposed to a positive control with this agent and an RF test set has been completed; despite the measured 200 V/m peak field strength, the pulsing gives a low calculated time-averaged power density of 0.0175W/m². The microarray results have been processed by Agilent. Initial analysis of the data indicates that, while altered regulation of some 96 gene transcript changes were associated with HD exposure, RF exposure did not induce any significant changes in transcript expression.

**Conclusions.** The use of human volunteer T lymphocytes offers a model free from extrapolation issues which would occur if either an animal or a transformed cell line had been employed and offers the potential to increase confidence in in vitro to in vivo extrapolation issues. Individual variation is greater than would be encountered with a transformed cell line but can be minimised in effect by using a number of volunteers and averaging the data. The HD positive control data have demonstrated a number of significant findings. In comparison, the first of the RF exposures at a low average power has not provided similar changes. The results to date therefore indicate that the model will demonstrate potentially harmful changes and that, at the low average exposure employed to date, which is well below the ICNIRP power density limit for public exposures, no changes have been demonstrated with RFR. Use of a variety of pulses would demonstrate an effect or no effect which would be useful data for formulating pulsed RF safety guidelines.

Higher average power exposures will be required to determine whether RFR affects this model.

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P-91 PHYSIOLOGICAL EFFECTS OF MILLISECOND DURATION HEATING IN BRAIN SLICES

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Summary of Abstract. This work examines the effects of short pulses of localised heating on evoked potentials in brain slices.

Objectives. Previous studies have suggested that in vitro exposure to 700MHz radiofrequency (RF) fields at SARs less than 5mW.kg$^{-1}$ can affect both evoked and spontaneous electrical activity in rat hippocampal slices (Tattersall et al, 2001). More recent experiments in our laboratory have demonstrated that these effects may be explained by localised heating produced by interaction of the RF fields with the recording and stimulating electrodes (Mifsud et al., 2007). We are now exploiting this electrode-mediated heating artefact to explore the effects of short pulses of localised heating on neurotransmission in the brain tissue. The results of this work will help to inform thermally-based standards for limiting exposures to pulsed RF fields.

Methods. Extracellular field potential responses were recorded in hippocampal slices prepared from adult rats and exposed to 380 MHz RF fields in a parallel plate transmission line (Tattersall et al., 2001). Pulses of RF energy were used to heat the electrodes to induce rapid local heating in the tissue around the electrode tip. An infrared camera (Cedip Infrared Systems Jade) was used to image the brain slice and the electrodes in order to measure the heating produced during RF exposure. This camera has a theoretical thermal resolution of 0.025$^\circ$C and each pixel on the sensor corresponded to approximately 200$\mu$m at the brain slice target. The acquisition rate was 50 frames.s$^{-1}$.

Results. Initial experiments investigated the relationship between heating duration and the temperature rise required to abolish the evoked field potential recorded in CA1. For RF pulses at an input power of 100W into the transmission line, the field potential was abolished at a pulse duration of 20ms. For a lower input power of 10W, a longer duration of exposure of 2s was required to abolish the evoked field potential response. The pulse duration of 20ms at 100W produced a peak temperature increase to 58$^\circ$C from the perfusion temperature of 33$^\circ$C, a rise of 25$^\circ$C. A plot of temperature increase against exposure duration showed an initial rate of temperature rise of 1438$^\circ$C.s$^{-1}$ (Figure 1). Assuming a specific heat capacity for brain tissue of 3850J.kg$^{-1}.^\circ$C$^{-1}$ (Mall & Eisenmenger, 2005), this represents a specific absorption rate of RF energy of 5.54MW.kg$^{-1}$, which is far higher than could be achieved without exploiting the electrode heating artefact.
Conclusions. These results demonstrate that the RF-induced electrode artefact can be exploited to study the effects of millisecond periods of heating on neurotransmission in brain tissue, enabling the relationship between thermal threshold and heating duration to be determined. Future experiments will determine the threshold temperature rise for changes in the evoked field potential for a range of durations of RF exposure. The minimum heating duration that can be accurately measured is limited by the frame capture rate of the infrared camera.

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Figure 1. Temperature rise in brain slice tissue near the stimulating electrode plotted against duration of RF exposure for a 100W input power into the exposure system. The solid line is a linear regression of the points up to 20ms duration, the dashed lines show the 95% confidence intervals of the fit.
P-92 EFFECTS OF STRONG STATIC MAGNETIC FIELD UP TO 13 T ON MUTAGENISITY IN SOD-DEFICIENT E. COLI CELLS

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Summary of Abstract. In this study, the effects of strong static magnetic fields (SMFs) on mutagenesis related to reactive oxygen species (ROS) behaviour were investigated. To estimate mutagenicity of SMFs, superoxide dismutase (SOD)-deficient *Escherichia coli* QC774 that is defective of *sodA* and *sodB* was employed. QC774 cells were exposed to 5, 10 and 13 T SMFs for 24 hr at 37°C in LB medium. After exposure, the frequency of thymine synthesis deficiency (Thy−) mutant was determined for evaluation of mutagenicity. In the result, no statistically significant difference in Thy− mutant frequency was observed between SMF-exposed cells and unexposed cells in all of magnetic flux densities. It suggests that SMF did not have mutagenicity in SOD-deficient *E. coli* under the condition in this study.

Objectives. Technological innovations in the fields of transportation, telecommunication and medical devices give the opportunity for exposure to electric and magnetic fields to both the general public and occupational environments, encouraging public’s vague concern about electric and magnetic fields. To respond such social needs around the world, the World Health Organization (WHO) has conducted the international EMF project to summarize the health risks by exposure to electric, magnetic and electromagnetic fields which frequency ranged from 0 to 300 GHz. Recently, this project has published the Environmental Health Criteria of static (2006) and extremely low frequency (2007) fields. However, experimental evidences related to evaluation of biological effects of strong SMFs are not enough to date although there are some opportunities that people are exposed to strong SMFs such as MRI and so on. Therefore, accumulation of basic knowledge would be the key efforts to elucidate the mechanism of magnetic field effects and also solve the public anxiety.

Among the studies regarding SMFs exposure, several reports suggested that SMFs caused oxidative stress and effects on life time of radicals, such as ROS. In this study, we focused on effects of SMFs on mutagenesis by ROS. The aim of this study was to estimate mutagenicity of SMFs using SOD-deficient *E. coli*.

Methods. Superconducting magnet JMTD-10C13E-NC (JASTEC), which generates up to 13 T of vertical magnetic flux density with magnetic gradient, was used for SMFs exposure. Temperature in the bore was kept to be 37°C by running heated water (37°C) in silicon tube covered inside wall of the bore. In this study, *E. coli* QC774, which is defective in SOD gene, sodA and sodB (Φ(sodA-lacZ)49 Φ(sodB-kan)1-Δ2 Cm Km) and its wild-type were used. It is known that SOD catalyzes the dismutation of superoxide radicals and this process is the one of primary defence mechanisms against oxygen toxicity. These strains were pre-incubated for 4 hr at 37°C in LB medium and then exposed to 5, 10 and 13 T SMFs for 24 hr at 37°C in LB medium. Sham exposure experiment was conducted using same magnet without magnetic fields. After 24 hr exposure, each culture was poured onto glucose minimum medium plates containing trimethoprim and thymine to select Thy−
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(thymine synthesis deficient) mutant. These plates were incubated 37°C and colony number was counted after sufficient incubation period. Then, the concentration of survival cell and the mutation frequency from Thy+ to Thy− (mutant number per 10⁷ of live cells) was determined from colony number on LB plates and glucose minimum medium plates containing trimethoprim and thymine, respectively.

**Results.** In this study, SMFs exposure could not be done together with sham exposure because only one magnet system was available for the experiment. Therefore, we prepared control, which E. coli cells were incubated in 37°C incubator, to compare with SMFs exposure or sham exposure, respectively. Firstly, we examined sham exposure and found no significant differences in average value of each experimental data in both survival cell concentration and mutation frequency in both QC774 cells and wild-type cells. Difference in temperature between sham exposure and control was within ±0.5°C. Therefore, we concluded incubation condition between control and sham exposure is identical. Then, we examine strong SMFs. In SMFs exposure, no statistically significant difference in mutation frequency was observed between SMF-exposed cells and control cells in 5, 10 and 13 T, respectively. Before SMFs exposure, it has been confirmed that mutation frequency of QC774 cells increase in dose response relationship with concentration of the chemical agent that generates superoxide, while that of wild-type did not change. Consequently, it was confirmed that QC774 cells are sensitive to the superoxide, but not SMFs exposure, suggesting that SMFs may not affect superoxide-related effect. So far, several studies about biological effects of SMFs, which focused oxidative stress, have been reported. Zhan et al. (Int. J. Radiat. Biol., 2003) reported that mutation frequency increased with dose response relationship depend on magnetic flux density in E. coli defective in soxR or both sodA and sodB (QC774). In their study, mutation frequency was determined by rifampicin-containing LB plate, which inhibits RNA polymerase. Because results of this study did not find any effect of SMFs, it was suggested that difference in detecting system led to different results in this study.

**Conclusions.** E. coli QC774 defective in SOD was used to investigate biological effect of static magnetic field up to 13 T. No significant difference was observed in mutation frequency in both 5, 10 and 13 T SMFs exposure, respectively. These results suggested that SMF up to 13 T did not have mutagenicity in SOD-deficient E. coli under the experimental condition in this study.
P-93 EFFECTS OF MAGNETIC FIELDS GENERATED BY INDUCTION HEATING (IH) COOK TOPS ON GENOTOXICITY AND HSP EXPRESSION IN CULTURED CELLS

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Summary of Abstract. We evaluate the effect of an intermediate frequency (IF) magnetic field at 6 mT$_{rms}$ for 2 hours on cell growth, micronucleus formation, DNA strand breaks, HPRT gene mutation and expression of heat shock proteins. As a result, there was no significant difference between exposure group and sham-exposure group in the experiments of each cellular criterion.

Objectives. Replacement of gas and electric cook tops with induction heater (IH) cook tops has become popular in Japan and Europe. IH cook tops generate intermediate frequency (IF) magnetic fields of 20 to 90 kHz from heating coils, with induction of currents in metal pans that results in heating of the pans. Evaluation of potential carcinogenesis at the cellular level requires assessment of cellular genotoxicity associated with IF magnetic fields. We had already reported that the short exposure (2 hours) to an IF magnetic field at 532 $\mu$T$_{rms}$ (85-fold of ICNIRP guideline) did not cause cellular genotoxic damage (Miyakoshi et al., 2007). In the present study, we evaluate the effect of an IF field with higher magnetic density at 6 mT$_{rms}$ (960-fold of ICNIRP guideline) on cell growth, micronucleus formation, DNA strand breaks, HPRT gene mutation and expression of heat shock proteins (HSPs).

Methods. The experimental system for IF magnetic field exposure supplies ELF electric power (100V, 50 Hz) to an IH cook top and supplies IF electric power (23 kHz) to a magnetic field-generating coil in an incubator via an electronic circuit inside the IH cook top. The level of magnetic field generated by the system was set to 6 mTrms with spatial field uniformity of less than 4.8%. The temperature of the medium in the dishes was monitored at all times during the experiment and was maintained at 37.0±0.5 °C.

For micronucleus (MN) formation and the Comet assay, Chinese hamster ovary (CHO)-K1 cells were used. These methods were conducted as described elsewhere (Koyama et al., 2004, Koyama et al., 2003, Miyakoshi et al., 2002, Miyakoshi et al., 2000). For the mutation analysis, the HPRT gene-mutation assay, which is a well-established method based on selection of clones that are resistant to purine analogs such as 6-thioguanine (6-TG), was performed. Details of the HPRT gene mutation assay have been described elsewhere (Ding et al., 2001, Ding et al., 2000).

For HSP expression, we analyzed HSP27 (monoclonal, Stressgen, 1:500), phosphorylated HSP27 (p-HSP27; polyclonal, Stressgen, 1:1000), and HSP70 (monoclonal, Stressgen, 1:200) using Western blotting and immunohistochemistry methods in human glioblastoma A172 cells.

Results. Exposure to the IF magnetic field at 6 mT$_{rms}$ for 2 hours did not affect the growth of CHO-K1 cells. Exposure to the IF magnetic field for 2 hours induced neither single nor double DNA strand breaks in the Comet assay, and caused no significant changes in the mutation frequency at the HPRT locus compared to sham exposure. For the expression of HSP27, p-HSP27, and HSP70, no significant changes were observed following
exposure to the IF magnetic field for 2 hours using Western blot analysis (Figure 1) and immunohistochemistry.

**Conclusions.** These results demonstrate that exposure to an IF magnetic field at a high magnetic density of 6 mT_{rms} (960-fold of ICNIRP guideline) for 2 hours did not cause cellular genotoxicity, i.e., MN formation, mutation and DNA strand breaks. The expression of the HSPs examined was also not affected by the IF magnetic field exposure. However, the possibility of effects on other cellular functions remains, and further studies on the cellular effects of IF magnetic fields are required.

![Figure 1](image)

**Figure 1.** Protein Expression of HSP70, p-HSP27, and HSP70 in A172 cells exposed to an IF magnetic field at 6 mT_{rms} for 2 hours, sham-exposure, or heat-treatment at 42.5°C and 43°C for 2 hours

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**P-94 EFFECTS OF EXPOSURE TO RADIOFREQUENCY FIELDS (UMTS/IMT-2000; 1950MHZ) ON MICRONUCLEUS FORMATION IN HL-60 CELLS**

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**Summary of Abstract.** We investigated the effects of exposure to RF fields (UMTS/IMT-2000; 1950MHz) on micronucleus (MN) formation in HL-60 cells. As a result, no significant differences in the frequencies of MN formation were observed in the RF exposure group compared with the sham-exposure and control groups.

**Objectives.** UMTS/IMT-2000 (universal mobile telecommunications system/International Mobile Telecommunication 2000) at 1950 MHz is one of the third-generation (3G) cell phone technologies that have recently been used in Europe. There are many reports on cellular genotoxicity concerning radiofrequency fields (RFs), including GSM (Global System for Mobile Communication). REFLEX study reported some positive effects by RF(GSM) exposure on cellular genotoxicity. Other many negative results
concerning cellular genotoxicity had also been reported. However, the cellular genotoxic effects of UMTS/IMT-2000 have not been adequately examined. In the present study, we investigated the effects of exposure to RF fields (UMTS/IMT-2000; 1950MHz) on micronucleus (MN) formation in HL-60 cells.

**Methods.** HL-60 cells derived from human promyelocytic leukemia were exposed to RF fields (UMTS/IMT-2000; 1950 MHz). RF fields were generated by the REFLEX 1950 exposure apparatus provided by the Foundation for Research on Information Technologies in Society, Zurich, Switzerland which was connected to the exposure incubator. This generator has two exposure units inside the exposure incubator. One of the units is exposed and the other units allows for the sham-exposure. A random function determined which unit would be exposed prior to the experiment.

For the MN formation assay, HL-60 cells were cultured in RPMI1640 medium supplemented with 10% fetal bovine serum, 1% HEPES buffer and 2% penicillin/streptomycin. Cells were grown in an incubator (37°C in 5% CO₂). The initial cell number was 7.5×10⁵ cells in the 35mm petri dish. Six 35mm petri dishes were placed in each of two exposure units inside the incubator.

The experiments were performed, as follows:
1) RF exposure,
2) Sham-exposure,
3) Control groups that were incubated in a conventional incubator, and
4) Positive control groups that were irradiated by X-rays with 1 and 3Gy.

The exposure conditions for the RF field were as follows:
1) SAR; 0.2, 1.0, 1.3, 1.6, 2.0 and 3.0 W/kg for 24 hours, and
2) SAR; 1.3 W/kg for 6, 24 and 72 hours.

Cytochalasin B (final concentration 3.0 µg/mL) was added to the growth medium after exposure and washing. The cells were fixed after 24 hours. For fixation, the cells were washed and treated with cold hypertonic KCl solution (5.6 g/L). Then the cells were fixed 3 times with a solution of acetic acid/methanol (1:3) and subsequently air dried preparations were made. For the detection of MN in binucleated cells (BNC) the slides were stained with 2.0% Giemsa solution.

To determine the frequency of MN of the RF exposure groups, sham-exposure groups, control groups and positive groups, the number of MN in 1000 BNC cells were scored microscopically for each experiment.

**Results.** 1) SAR; 0.2, 1.0, 1.3, 1.6, 2.0 and 3.0 W/kg for 24 hours:
HL-60 cells were exposed to the RF fields (UMTS/IMT-2000; 1950 MHz) with a range of SAR values between 0.2 and 3.0W/kg for 24 hours. Results were obtained in three independent experiments. No significant differences in the frequencies of MN formation were observed in the RF exposure group compared with the sham-exposure and control groups.

The MN formation for the positive control was increasing in dose-dependent manner at the X-ray dose of 1 and 3 Gy.
2) SAR; 1.3 W/kg for 6 and 24 hours:
HL-60 cells were exposed to the RF fields with a SAR of 1.3W/kg for 6 and 24 hours.
Results were obtained in three independent experiments. No significant differences in the frequencies of MN formation were observed between the RF exposure and the sham-exposure and control groups.

Conclusions. In the present study, we did not observed any increase in MN formation by exposure to UMTS/IMT-2000 (1950MHz) RF field. In the future, we would like to examine the effect of UMTS/IMT-2000 (1950MHz) RF field on the other indices of cellular genotoxicity, such as DNA strand breaks using the Comet assay.

Acknowledgements. This study was partly supported by the Association of Radio Industries and Businesses Japan (ARIB).
Methods. It was believed that experimental paradigms employed in studies of human cells were easily affected by factors such as the condition of the temperatures, a slight oscillation during the experiment and so forth, therefore affecting the outcomes. Hence, as large as 600 cell samples were tested in the present experiment. The obtained data was statistically analyzed to see if there was a significant difference in the radical production rates of the cells between the microwave exposure and thermal exposure conditions.

I. Exposure Setup: The exposure conditions are shown in Table 1. An open exposure setup was employed for the 2.45 GHz microwave exposures [1]. Further, a temperature control unit was added to the system to adjust the cell temperature during the exposures. A rigid waveguide exposure setup was employed for the 900 MHz exposures [2]. Under the 2.45 GHz condition, exposures were conducted using a range of SAR levels from average SARs of 2 W/kg to a maximum of 700 W/kg for each sample. Under the 900 MHz condition, exposures were conducted using a range of SAR levels from average SARs of 2 W/kg to a maximum of 150 W/kg for each sample. Note that the ambient temperature in both conditions was set to below 39°C.

II. Radical detection: A fluorescent observation in which cells labeled with DCFH-DA (2',7'-dichlorodihydrofluorescein diacetate) was used to observe fluorescent cells. The fibroblasts and leukocyte cells were assessed by comparing radical production rates in cells under non-microwave exposure (control), ultraviolet ray (UV) and microwave conditions to examine microwave induced radical production. By comparing a radical production process of cells with altered temperature in a thermostatic chamber (non-irradiation control condition) and a radical production process of cells with altered temperature by microwave irradiation, whether or not radical production specific to microwave irradiation would be observed was examined.

Results. Data on the fluorescent intensities observed in the samples exposed to microwaves of 2.45 GHz and 900 MHz and the control samples (UV and sham exposure) were obtained (figure 1 and figure 2). No significant difference was found in the rates of radical production detected in the samples exposed to microwaves and control cells (non-microwave irradiation) in the same temperature.

Conclusions. The experiments described that the radical production in the cells was primarily induced by the temperature increase, and irrespective of the waveforms (modulated or not modulated), the nonthermal effects of microwaves found in the radical production possibly damaging DNA were undetected by the latest technology available.


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Figure 1. Fluorescence intensities of fibroblast after 2.45 GHz & 900 MHz microwave exposure

Figure 2. Fluorescence Intensities of leukocyte after 2.45 GHz & 900 MHz microwave exposure
**P-96 MORPHOLOGICAL AND FUNCTIONAL ANALYSIS OF RADIOFREQUENCY FIELD-EXPOSED MICROGLIAL CELLS IN VITRO.**

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**Summary of Abstract.** To examine the biological effects on the central nervous system (CNS) exposed to radiofrequency (RF) field, we plan to investigate effects of RF-EMF on microglial cells in the brain. Our experimental model was sensitive to the stimuli enough for the purpose of the RF exposure studies. Following the preliminary studies, we will perform the RF exposure experiments.

**Objectives.** It is very important to examine whether the RF electromagnetic fields has some biological effects today when the cellular phone is used widely. Especially, many researchers have studied RF effects on brain functions. To examine the biological effects on the CNS elicited by 1950 MHz modulation signals controlled with the International Mobile Telecommunication 2000 (IMT-2000) cellular system, we plan to investigate effects of RF-EMF on microglial cells in the brain.

**Methods.** Microglial cells play immunological roles in the CNS and are activated during pathological events. The microglial cells are activated in response to CNS injury: morphological changes, antigen presentation, release of various cytokines, and phagocytic capacity [1, 2]. We will study morphological changes in microglial cells to access their functional changes after RF exposure.

(1) Exposure System: The large-scale in vitro exposure systems [3], which were used in previous studies [4], will be used in this study.

(2) Microglial cells: Rat newborn primary-cultured microglial cells (Sumitomo Bakelite, Tokyo) were used and were pre-cultured for three days at 37°C in a humidified atmosphere of 5% CO2.

Morphological Analysis; After the sham or RF field exposure, cells were fixed with 3.7% formaldehyde in PBS for 10 minutes at a room temperature. Histostain SP kits (Zymed, Carlsbad, CA) were used according to the manufacturer’s instruction. The cells were incubated with anti-Iba1 or anti-CD11b antibody and then incubated with biotinylated second antibody. The cells were incubated with enzyme conjugate and then incubated with DAB chromogen.

Cytokine Assay; After the sham or RF field exposure, the culture supernatant was collected for the determination of TNF-alpha, IL-1beta, and IL-6. Human 9-plex Antibody Bead Kits (BioSource, Camarillo, CA) were used. The specific proteins were detected using the bead-based multiplex assay, which is similar to a capture sandwich immunoassay.

**Results.** We evaluated the variation of microglial cells treated with lipopolysaccharide (LPS), instead of RF field exposure, as preliminary studies. Microglial morphology was studied after 24 and 72 hours incubation with or without 100 ng/mL LPS. The non-treated cell population was highly heterogeneous and extending small processes. On the other hand, LPS-treated cells adapted to macrophage-like morphology with flat cell bodies without
any extending processes. Treatment of microglia cells with 100 ng/mL LPS resulted in a significant increase in TNF-alpha, IL-1beta, and IL-6 of each sample, compared to untreated samples (Figures). Thus, our experimental model was sensitive to the stimuli enough for the purpose of the RF exposure studies. Following the preliminary studies, we will perform the RF exposure experiments.

References:

Acknowledgements. This work was supported by Association of Radio Industries and Businesses (ARIB), Japan.

Figure 1.
P-97 THE INFLUENCE OF EXTREMELY LOW FREQUENCY MAGNETIC FIELD ON DEGRANULATION RATE OF MAST CELLS

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Summary of Abstract. In in-vitro studies, mast cells alter their habitual degranulation following their exposure to extra-low frequency magnetic field. These changes are magnetic field frequency dependent.

Objectives. The search of cellular targets of magnetic field influence in multi-cellular organisms is one of the important questions of magnetobiology. We directed our attention to mast cells, which are the cells of the APUD-system. These cells are located in different tissues and secrete a wide spectrum of biologically active substances that exert powerful modulatory effects at local and systemic levels. However, the details of in vivo and in vitro responses of these cells to ELF MF are not yet clear. Our previous work has demonstrated that exposure to multi-spectral magnetic field activated mast cells in vivo in rats. The purpose of this project was to find out whether activation of mast cells following exposure to magnetic field was mediated through systematic changes or through direct cellular mechanisms.

Methods. Suspensions of mast cells were obtained from white rats by washing off cells from the peritoneal cavity by 15 ml of warm (37 degrees Celcius) physiological solution (0.9% NaCl) supplemented by 1 millimolar calcium chloride. Cell suspensions incubated at 37 degrees Celcius without or with an activator (morphine) and an inhibitor (sodium cromoglicate) of degranulation of mast cells with different concentration (from 10 millimolar to 1 nanomolar). The activity of mast cells was estimated by the level of their degranulation that was revealed by treating cells in 0.3% solution of neutral red followed by a microscopic analysis. Magnetic field in frequency diapason 0-100 Hz and induction 0.020 − 0.200 µT was created by Helmgolts coils. Induction vector was parallel to geomagnetic. Control samples were placed in laboratory with usual electromagnetic background 0.020 µT. The results of sham exposure were used as an independent double control.

Results. Mast cells spontaneously degranulate in physiological solution in vitro. The response of mast cells depends on frequency, amplitudes of ELF MF and also exposure. Magnetic field 25 µT with frequency 2; 8-10; 50; 72-74 Hz activates, yet a field with the frequency of 32-34 Hz decreases spontaneous degranulation of mast cells in vitro. Response of mast cells increases with increasing of induction of ELF MF. The minimal induction of MF for minimal statistically significant changes of degranulation rate is in the diapason of 0.020 - 0.200 µT. Exposure to 8 Hz, 25 µT magnetic field reduces the inhibitory effect of sodium chromoglicate on the functional activity of mast cells. Such exposure also modulates the response of mast cells to the activating influence of calcium ions and morphine, which,
in turn, speaks to the fact that intracellular signaling pathways are involved in modulation of an in-vitro response to ELF MF.

**Conclusions.** Mast cells, which are the cells of the APUD-system of organism, respond to ELF MF in vitro by altering their spontaneous degranulation. Possible ways of such direct influence can be revealed at the molecular and physical-chemical levels. It is possible that mast cells act as cellular magnetic field sensors in humans and animals.

**P-98 WHAT ARE YOU EXPOSING YOUR CONTROLS CELLS TO?**
**A STUDY OF BACKGROUND MAGNETIC FIELDS IN INCUBATORS**

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**Summary of Abstract.** Commercial cell incubators are not always fit to be used for low level electromagnetic field experiments. The background magnetic field in incubators can be high, we have seen levels up to tens of \(\mu\)T, and normal values are typically a few \(\mu\)T. There is also a spatial gradient in the incubator – usually from top to bottom - depending on where the electronics are located and how the heating wires are drawn.

**Objectives.** Measure magnetic fields in incubators.

**Results.** Biological effects after exposure to low frequency magnetic fields have been reported in several publications at field levels from a few tenths to tens of \(\mu\)T (Berman et al, 1990, Blackman et al, 2001, Girgert et al, 2007). From epidemiological studies increased odds ratios for cancer in connection with exposure to magnetic fields are seen from 0.4 \(\mu\)T (IARC, 2001).

In view of this it is therefore very urgent that the experiments are done under as control conditions as possible, and that means that the control cells should be kept at as low background magnetic field level as possible. Now it could happen that the background field is even higher than the field you actually want to expose to.

It is necessary to control measure the incubator on all shelves, and if the values are too high one may need to rewire the heating system or relocate the electronic control equipment. It is also necessary to control for other environmental sources in the lab; for instance if you place an apparatus on top of the incubator it may have a transmorer inside giving a high leakage field into your incubator. Example of this is when a sterile bench is placed close to the incubator.

**References**
Blackman CF et al. The influence of 1.2 microT, 60 Hz magnetic fields on melatonin- and

**Conclusions.** It is necessary to carefully check the incubator for stray fields when doing low level magnetic field experiment.
P-99 IN VITRO EXPERIMENTAL DETERMINATION OF THERMOPHYSICAL PROPERTIES OF BIOLOGICAL TISSUES

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Summary of Abstract. This paper presents methods and protocols measurements for the determination of thermophysical tissues properties. Several in vitro experimental characterizations are realized on animal tissues.

Objectives. A 3D numerical model was developed to predict temperature distribution in human body submit to radiofrequency fields (1MHz - 3GHz) [N. Siauve et al. "Optimization of the sources in local hyperthermia using a combined finite element-genetic algorithm method", International Journal of Hyperthermia, vol. 20, no. 8, pp. 815-833, December 2004]. The temperature distribution was numerically calculated using the finite element method to solve the Pennes bioheat equation and the electromagnetic source term of this equation is obtained by solving Maxwell equations with finite element method, with incomplete first order edge elements discretization. The 3D numerical model requisite the knowledge of physical and thermal tissues properties, in this aims different experimental devices had been developed to determine thermal conductivity, specific heat and mass density of biological tissues.

The aim of this study is therefore to determine, each parameter value, the uncertainties associated to parameters and parameters variability’s with temperature.

Methods. The influence of temperature on thermal tissues characteristic is need for a temperature range of 31 °C (human body surface temperature) to 45 °C (maximal temperature reach in tumour tissues) due to the applications fixed : hyperthermia treatment planning, mobil phone and wireless applications dosimetroies.

Both mass density and specific heat measurements have been performed on standard devices. A pycnometer suitable for high viscous liquids and solids for the first one and a differential calorimeter for the second one. Thermal conductivity is identified using a flash method and by solving an inverse problem. Flash method is usually applied on solid materials. A brief excitation is applied on one sample face and the response in term of temperature is observed on the other side. The thermogram obtained during the excitation and temperature increase contains informations on sample thermal properties. The experimental thermogram is compared to a thermogram calculated with a program describing the sample behaviour on the experimental configuration. By minimizing a function representing the sum of the quadratic discrepancy between the experimental and theoretical thermogram, the investigated parameters : in our case the sample thermal diffusivity \( \alpha = \lambda / \rho c \) (m\(^2\).s\(^{-1}\)) can be identified. The minimization is performed by using an algorithm of identification based on a least square fit method which
used the Gauss linearization procedure. While the flash method is usually employed on solid material the experimental device have been adapted for measurements on liquids and soft materials [R. Coquard and B. Panel, "Adaptation of the flash method to the measurement of the thermal conductivity of liquids or pasty materials", International Journal of Thermal Sciences, Submit October 2007]. The sample under testint is situated in a cylindrical cell. By taking into account the experimental errors and models simplifications, uncertainties on thermal diffusivity have been found to be fewer than 4 %. Therefore, uncertainties on thermal conductivity which is linked to those on mass density and specific heat, are fewer than 9 %. Measurements on the flash method device have been supply with measurements on the Hot Wire (HW) method, which gives directly the thermal conductivity values.

Results. The campaign of test runs has been done on pig samples of muscle and fat kept in sealed packages at -20 °C. Mass densities measurements have been performed on samples of different pig at ambient temperature 25 °C. The average density of pig muscle is about 1073 kg.m$^{-3}$ and the average value of pig fat is about 951.3 kg.m$^{-3}$. The standard deviation for the measurements is 3 kg.m$^{-3}$.

Specific heat measurements at different temperatures had pointed out the dependency on temperature of specific heat. On pig muscles from 31 °C to 37 °C an increase of 16 J.kg$^{-1}$.K$^{-1}$ per K is observed on initial value of 3482 J.kg$^{-1}$.K$^{-1}$ and on fat vary from 37 °C to 45 °C an increase of 28 J.kg$^{-1}$.K$^{-1}$ per K is observed with a start value of 2763 J.kg$^{-1}$.K$^{-1}$.

Thermal diffusivity $\alpha$ measured and resulting calculated thermal conductivity $\lambda$ are summarized in Table 1. The experiments presented have been performed on muscle and fat seven day after the pig sacrifice.

HW method has been used to study the influence of fiber direction of tissues on thermal conductivity values. The experiences have been realized only on pig muscle tissues, the results highlight the thermal isotropic nature of muscle tissues.

Conclusions. Three experimental plateforms have been developed to determine thermal tissues properties. The uncertainties due to each method used have been quantifies and also the influence of temperature on thermal tissues properties. The next steps are oriented to the determination of thermal characteristics of several other tissues such as bone, liver and blood. The influence of the time between the sacrifice and the realization of the measure will be analysed. The verification of bone isotropy may be also studied.
P-100 DEVELOPMENT OF HIGH-OUTPUT 6.25 MT INTERMEDIATE-FREQUENCY MAGNETIC FIELD EXPOSURE SYSTEM FOR STUDIES OF IN VITRO BIOLOGICAL EFFECTS

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Summary of Abstract. We have developed a high-output (6.25 mT_{rms}) intermediate-frequency magnetic field exposure system for in vitro studies, and report the results of experiments using our system.

Objectives. Recently, the use of induction heating (IH) cook tops, which can replace gas or electric cook tops, has been rapidly becoming widespread in Japan and Europe. The IH cook tops can generate a magnetic field with a frequency of 20-90 kHz, by which a pan on the appliance surface is heated by induction.

In June 2007, Fact Sheet 322 regarding electric and magnetic fields (EMF) of up to 100 kHz was published by WHO, which promoted research programs to further reduce the uncertainty of scientific evidence on the health effects of extremely low frequency (ELF) EMF exposure. In Environmental Health Criteria (EHC) 238, it was reported that further research on intermediate-frequency (IF) magnetic fields, the range of which is considered to be 300 Hz - 100 kHz, was necessary. The heating frequency of IH cook tops is within this frequency band.

In this study, a magnetic field exposure system that can be used for in vitro studies is developed with the aim of reducing the uncertainty of the above-mentioned scientific evidence. The results of experiments using our system are reported here.

Methods. We previously developed a system for exposing cultured cells to a magnetic field of 532 µT_{rms} (approximately 85 times the value in the ICNIRP guidelines) and reported the results of experiments using the system (Fujita et al., 2007). In this study, the generated magnetic field was further increased to verify the threshold of the cytological effect; namely, a system that can generate a magnetic field of 6.25 mT_{rms} (10³ times the value in the ICNIRP guidelines) was developed (Fig. 1).

Because the exposure system has a structure in which a solenoid coil is built in a CO₂-based incubator, heat generation from the coil is a problem. In the previous study, only approximately 7 W of heat was generated because the generated magnetic field was relatively low, which enabled the temperature inside the incubator to be maintained at a level that produced no cytological effect by natural cooling.

Results. An increase in the coil current or the number of coil turns is required to strengthen the magnetic field generated. However, a greater coil current increases the coil loss and an increased number of coil turns requires a higher coil voltage, causing a problem related to insulation design. In this study, the number of coil turns was set to be 96, which was considered appropriate in the context of the above tendencies, and the coil was cooled by circulating water (Fig. 2) because approximately 400 W of heat was generated from the coil, which was too large to be effectively dissipated by the natural cooling adopted in our
previous study (Fujita et al., 2007).
Regarding the uniformity of the magnetic field inside the incubator, the magnetic field was
distributed spatially within 4.8% of the value at the center of the exposed space, where
the output was 6.05 mT$_{rms}$. Moreover, the stability of the magnetic field was obtained by
checking the measured value every 5 min; the data temporal dispersion remained within
±0.4% at the output of 6.05 mT$_{rms}$.
In addition, a separate circulator was installed to improve the temperature adjustability of
the incubator, and the temperature near the petri dish in the incubator was controlled to
within 37±0.5°C. A measurement system using an optical fiber that was not affected by
EMF was used to measure the temperature.
The system developed in this study is composed of two units, i.e., a magnetic field exposure
setup and a sham setup. The effect of the exposure setup on the sham setup was 0.59 µT$_{rms}$
for a frequency of 50 Hz and 0.37 µT$_{rms}$ for 23 kHz, which was negligible compared with
the generated magnetic field.

**Conclusions.** It was demonstrated that the uniformity of the magnetic field in the exposed
space was within ±5% of the value measured at the center of the space exposed to the mag-
netic field, which is of sufficient uniformity for the study of in vitro biological effects.
The temperature near the petri dish in the incubator was successfully maintained at
37±0.5°C. Furthermore, the level of the magnetic field that leaked from the exposure setup
was very small.
Therefore, it is concluded that the magnetic field exposure system outlined in this report
has sufficient accuracy to be used for in vitro studies using a magnetic field in the IF band.
Figure 1. Spectrum of magnetic field generated using experimental setup. This is the frequency spectrum obtained by synthesizing the magnetic field using an ELT-400 3-axis probe. The spectrum was measured at the magnetic field output of approximately 1 mT in consideration of the device limit (maximum: approximately 1.5 mT).
Figure 2. Coil used to generate strong magnetic field inside incubator. A pipe for circulating water to cool the coil is wound around the inner and outer circumferences of the coil. Magnetic shielding rings and ferrite are arranged between the pipes for circulating the cooling water and the coil, and aluminum plates are placed inside the incubator case at the top and bottom.
P-101 CHARACTERIZATION OF A PERSONAL RF EXPOSIMETER FOR AN OCCUPATIONAL EXPOSURE ASSESSMENT STUDY

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Summary of Abstract. We tempted to evaluate for frequencies beyond 900MHz total uncertainty of measurement when the personal RF exposimeter Antennessa DSP120 is placed within a tissue carry bag carried against a standing human body. Our results tend to reveal a slight under estimation.

Objectives. Personal RF exposimeter [1] [2] [3] are now available to perform pilot exposimetric studies [4] [5] that aim to characterize the exposure of individuals to radiofrequency fields. The selective personal exposimeter Antennessa DSP 90/120 has been technically tested among others to evaluate the measurement capabilities of equipment positioned on phantom or on belt on human body [6], to evaluate the linearity and the isotropy of equipment without human body [7], and to compare the equipment with spectrum analyzer measurement or with Mashek exposimeter [6] [7] [8]. In our research, we tempted to evaluate total uncertainty of measurement when the personal RF exposimeter Antennessa DSP120 is placed within a tissue carry bag carried against a standing human body.

Methods. A radiofrequency source (Kathrein antenna K80010248 and CW generator) is localized inside an anechoic chamber producing reference electric field of 3V/m from 2 meters distance. At this distance, the exposimeter is carried in a tissue carry bag against stomach (case A) or back (case B) of a human adult (1m75, 80Kg). For each localization (case A and case B) 8 orientations are tested with 4 different frequencies: 947MHz (GSM900 downlink), 1842MHz (GSM1800 downlink), 2140MHz (UMTS downlink) and 2450MHz (WiFi). Total uncertainty is obtained comparing reference field with measured field by exposimeter.

Results. What ever it could be case A or case B and with the 4 analyzed frequencies (947MHz, 1842MHz, 2140MHz, 2450MHz), the exposimeter Antennessa DSP120 mounted in a carry bag seems to slightly under estimate the present electric field. For a 3V/m reference field, the noticed average fields are respectively of 1,28V/m ± 0,96V/m, 1,92V/m ± 1,69V/m, 1,77V/m ± 1,21V/m and 1,75V/m ± 1,25V/m. At 940MHz and 2140MHz, we find under estimation of 58% and 36% comparing to the reference value due to carry bag and to presence of body. From his part, H Lehmann [6] find respectively decrease of about 30% and 40% due to cylindrical phantom presence, and a decrease of 30% at 900MHz for a exposimeter carried by a man in reflecting situation at 940MHz. Compared to a measure taken with an isolated exposimeter, presence of carry bag and body decrease of about 44%.
Conclusions. Our results tend to reveal a slight under estimation of electric field value measured with Antennessa personal exposimeter DSP120 when carried in a tissue carry bag close to the body. For frequencies beyond 900MHz, under estimation is about 44%. These results seem to correspond to H.Lehmann results [6] and uncertainties given by manufacturer (3.2dB).

References
[1] Antennessa DSP120
[3] Narda RadMan

P-102 UNIFORM EXPOSURE OF NON-RESTRAINED RODENTS TO GSM900 SIGNALS FOR INVESTIGATING POSSIBLE EFFECTS ON THE METABOLIC RATE

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Summary of Abstract. The development of exposure devices for investigating possible effects of mobile communication systems to non-restrained animals aims at a homogenous field distribution in the area the animals occupy. In the presented 900 MHz exposure device a quite good field homogeneity is reached in the cage region mainly by flattening the transverse field. The desired maximal whole body specific absorption rate (SAR) of 4 W/kg in the Djungarian hamster model is achieved at an input power of approx. 4 W.

Objectives. Some published results might support the hypothesis that rf signals in the non-thermal range can influence the metabolic rate of rodents. Therefore, an experiment was set up within the framework of the “Deutsches Mobilfunk Forschungsprogramm” to confirm or disapprove this thesis. The poster presents the exposure set-up and the numerical dosimetry for this project.
Four plastic cages (dimensions (wxhxl) in mm: 147x117x355), each housing one hamster, are exposed to a GSM test signal at 900 MHz. In consecutive experiments whole body specific absorption rates (SAR) of 0 (sham), 0.08, 0.4, and 4 W/kg are applied. During the tests air of a defined speed (30 – 40 l/h) flows through the cage, while the temperature and the concentration of oxygen and carbon dioxide is measured.

Methods. In a rectangular waveguide with standard dimensions for the carrier frequency of 900 MHz only the fundamental H\textsubscript{10}-wave can propagate. However, it has a sinusoidal inhomogeneous transverse field. In order to flatten the field, two dielectric sheets of thickness d, distance D and height H are positioned symmetrically to the waveguide axis. The waveguide is of type WR1150 with internal dimensions W = 292.1 mm and H = 146.05 mm (fig. 1).

Material characteristics, thickness and position of the sheets are optimized to achieve a good field homogeneity between the sheets.

In principal, by use of matters in waveguides, the next higher-order wave type is able to propagate in addition to the fundamental mode because the dielectric material reduces its cutoff frequency. To overcome this drawback in our case, the fundamental mode is excited selectively by using a transition from the empty metallic standard waveguide to the optimized structure with dielectric sheets.

Results. From various optimization steps, the best dimensions of the sheets are found as D = 155 mm; d = 30 mm, and \( \epsilon_r = 2.9 \). A good field homogeneity of 5 % (including the standing wave contribution due to internal reflections) is reached in the cage region mainly by flattening the transverse field. For the standard waveguide (WR1150) without dielectric sheets this value reads 14 %. Figure 2 shows the transverse electrical field distribution for an input power of 1 W and for the best dimensions with the permittivity \( \epsilon_r \) as parameter. Field measurements and calculations of the total configuration including the rf feeds confirm that selective excitation is a good solution to maintain only the desired wave.

SAR computations on the basis of a dielectric hamster model derived from MRI scans yield a fairly low input power of approx. 4 W per waveguide for the achievement of the maximum desired whole body SAR of 4 W/kg.

Figure 3 shows the entire exposure system installed at the Jacobs University Bremen. It consists of four rectangular waveguides each housing one cage, of a signal generator/modulator/amplifier-combination and of a 1:4-power splitter in order to distribute the output power to the four waveguides. 50 W -terminations are mounted to the output connectors of the waveguides. The computer is used to select the power level (and thereby the applied SAR) and to record a control signal from an rf detector-diode. This signal is permanently analysed with the view to check the functionality of the equipment.
**Figure 1.** Cross section of waveguide WR1150 with inserted dielectric sheets.

**Figure 2.** Field distribution in transverse direction for $d = 30$ mm, $v = 38.5$ mm, and variable permittivity $\varepsilon_r$ ($P = 1$ W).
**Figure 3.** Photograph of the entire installed rf exposure set-up.
P-103 MW TREATMENT OF WOODEN HANDICRAFTS. THE RESTORATION OF SAN LEONE MAGNO STATUE

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Summary of Abstract. MW treatments can be applied for the preservation of works of art. The disinfestation of an ancient wooden statue is performed by MW using the MiSyA (Microwave System for Art) treatment. A description of the intervention is presented outlining its peculiarities. The results deriving from applications of non-invasive methods presented hereby show that these methods preserve handworks, without any risk for operators and for the environment. It is possible to affirm that the system can be applied to works of art if it permits the monitoring of the objects’ temperature and if it is possible to identify the conditions of the treatment in advance in order to avoid any dangerous effect.

Objectives. The statue of Saint Leone Magno is kept in the cathedral of the dioceses of Alife-Caiazzo, district of Caserta in the South of Italy. The cathedral “Santa Maria Assunta” of Alife was built by the Lord Rinulfo III (1106 - 1139) for keeping the relics of St. Sisto 1st, Pope and Martyr, according to the canon of Romanesque-Lombard architecture. The carved and polychrome wood sculpture, of exquisite workmanship, is attributable to the Parthenopean art of the end of the XVIII century. (Fig. 1). The half bust represents the Saint, elegantly wrapped in the soft pleats of his richly decorated cope. He is wearing a golden mitre set with gems. The left hand holds a liturgical book. And his finely shaped face has a delicate complexion. The preliminary exam confirms that the sculpture is in a very bad repair. (Fig. 2). The disinfestation against the numerous infesting agents, is performed by means of a MW treatment into a reverberation chamber.

Methods. In the initial phase materials to be used are tested according to any problem that could arise. Before the treatment the statue is subject to an X-ray examination in order to notice the presence of any nail or other metallic object in the inner part of the sculpture. All precautions are taken to prevent any damage to the handicraft during the MW exposure. The MW exposure is realized into a reverberation cavity (projected and manufactured by Emitech) that ensures a uniform irradiation of the object under treatment into a volume with controlled conditions. (See table) MiSyA. (Microwave System for Art), is a device working at microwave frequencies that neutralizes deteriorating agents. Microwaves interact with the biological forms making...
increase their inner temperature up to their lethal temperature, which ranges from 53°C to 
55°C for xylophagous insects and from 65°C to 70°C for fungi and mouldings.

Results. In previous tests the mortality of larvae, at the end of the experimentations, was 
of 100%.
There were not any rapid or excessive humidity losses in the object, whose moisture content 
was always < 1%.
Microscopic analysis, before and after the treatment, showed very good results because no 
chinks, detachments nor deterioration of the pictorial layer were found.
The parts corresponding to metals were covered with a metallic film (the common tin foil) 
that adhered perfectly on the surfaces to be safeguarded.
Samples, that presented the gilding technique, were heated up to 56°C (lethal temperature 
for the insects) and no alteration was provoked.

Conclusions. The disinfesting system was successfully applied in several laboratory ex-
periments.
The exposure of samples is important in order to establish schedules that ensure the total 
disinfection of the statue in a very short time (a few minutes) with efficacy and without 
any impact on the environment.

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Figure 1.
Figure 2.
**P-104 GIS APPLICATION TO ESTIMATE POPULATION EXPOSED TO MAGNETIC FIELD AROUND HIGH VOLTAGE TRANSMISSION LINE (2ND STAGE)**

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**Summary of Abstract.**

**Objectives.** This study proposed the application of geographical information system (GIS) to estimate the population size of people exposed to magnetic field around 154kV high voltage transmission lines (HVTL) in the south metropolitan area of Korea.

**Methods.** We selected of target area that expected magnetic field exposure emitted from involuntary MF sources (power transmission lines, substations, etc.). MF exposure sources and their emission levels were confirmed. To estimate the exposure population, we made use of results from simulation models using annual maximum current load. We were approached to calculate exposure population to overlay land use classification map and Jipgyegu (means basic census block) to avoid estimation error due to the statistical data from an administrative section.

**Results.** The first step of the estimation of exposure population was carried out. The number of exposed buildings was multiplied by the number of members per household, and the result is 3.3 in Buk-gu residential districts. According to this step, there were 7,504 people in Buk-gu considered as exposure population. The second step of estimation results was performed by exposure building area (m²), which is that land use that takes advantage of a buffer zone assumed that the number of residents living in mountainous regions and green tracts of land is zero and applied to actual exposure building area (m²) ratio. From this step, 2,701 people were identified. In the final step of the estimation procedure, we carried out the multiplication of population density in the buffer zone of the exposure building area (m²) by Buk-gu population density. In the final results we obtained, 2,503 people were identified as belonging to the exposure population.

**Conclusions.** Our estimation results of exposure population according to building area ratio and population density showed an 85% level of accuracy in the actual exposure population.
Figure 1.
P-105 MANAGEMENT OF THE ELECTROMAGNETIC FIELDS IN THE ENVIRONMENT

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Summary of Abstract. This paper presents a method of creating cartographies of the electromagnetic environment from time measurements on fixed points.

Objectives. Exposure to electromagnetic fields raises questions not only from the point of view of compliance with existing limits, but also from an environmental point of view. The trends on personal communication systems without license, which contribute to the electromagnetic environment with mobile transmitters or broadcasting, raise questions about the exposure of individuals.

In this paper, a method to interpolate of the exposure from isolated measurements of electromagnetic field is presented. Temporal frequency selective measurements were carried out over an area of interest. The interpolation of the whole set allows mapping the electromagnetic environment of this area of interest. Also, the temporal aspect of the measure and its interpolation allows the determination of the variation of the environment over the period measured.

Some measurement protocols to determine human exposure to electromagnetic fields exist. However, the determination of the site where the measurements are done is given only by the demand of the measurement itself or by visual inspection of the emitters. The interpolation of a sufficient number of consecutive measurements over a site avoids the prior investigation of the site and its emitters.

Measurements are made on frequency selective. A broadband probe 80 MHz to 3 GHz is used and each band is filtered. The objective is to determine the contribution to the exposure of each radio service separately.

For all the measurements done, a geostatistical interpolation method is applied. This approach aims to minimize the error committed in the estimation of the electric field as a function of its variation. Finally, the estimation of the field is represented on a map on the area of interest.

Methods. Two measurement devices [1] are used for the experimentation. Four personal dosimeters EME Spy 120 were used to assess exposure on four different points simultaneously over a period of one day. For the measurement of fixed points and to record statistics of exposure, the frequency selective fixed station INSITE Box was used. The choice of the measuring device is based on the sensitivity and location for the measurement.

Measurements are performed in indoor environment, the goal is to establish the quality of the interpolation in a complex propagation environment. The devices have made continuous measurements from 9 am to 18 pm every day, depending on the use and occupancy of the buildings covered by the study. Each measure was sampled every 4 seconds in order to reduce the total burden of data. At the end of the measurement period, the data package has been identified and located geographically.

Kriging is a spatial interpolation method, which allows the estimation based on the linear mathematical expected value and the variance of the measurements. This method differs
from other methods of interpolation by the fact that it is the only one to take account of the spatial variation of the data. Thus, it does not only generate spatial estimations, but the estimation of errors it produces is more reliable than those produced by conventional regression. The reason is that the assumptions of Kriging are closer to reality for spatial reference data [2]. In order to study the correlation of measurements as a function of distance, geostatistics use a function $\gamma$ called variogram. The variogram is a function that quantifies the correlation between measurements separated by a distance $h$ [2].

E is the mathematical expected value.

The process of the analysis of the correlation is:

Calculate an experimental variogram with the measured data.

Adjust the experimental variogram by a theoretical model.

The experimental variogram is deducted from the variographic cloud which represents the variance between each pair of points [2].

Once the experimental variogram has been built, the theoretical model of the variogram points, obtained by optimizing the model by counter-verification, is adapted [2]. The variogram is investigated by means of theoretical models using a known function of the variographic cloud. The objective is to find the theoretical curve that best fits the experimental curve. In the case of our study, we adjusted it by the Cauchy model [5].

Kriging method was developed by [3]. In this method, the average is unknown but it is supposed invariant in the surroundings of the estimation. This method does not require that the hypothesis of intrinsic stationarity. With this assumption, the ordinary kriging technique has become the most used one according to [4].

The aim is to minimize the estimation of the variance under some constraints. This stage will be carried out using the Lagrange function.

**Results.** Results are presented as the final map of interpolation issued from measured electromagnetic fields, all frequency bands combined.

**Conclusions.** A method to interpolate of the exposure from isolated measurements of electromagnetic field has been presented. Temporal frequency selective measurements were carried out over an area of interest and then, interpolated in order to represent the electromagnetic environment. Issued from measurements, the interpolation by Kriging offers a step forward from a compliance problem to an environmental consideration of the exposure. Adjusting Kriging by a Cauchy function has been found to be the closest interpolation for spatial reference data.
**Figure 1.** Interpolation of the electromagnetic field measurements in an indoor environment.

**P-106 NOISE MF INHIBITED EGF RECEPTOR CLUSTERING AND PHOSPHORYLATION INDUCED BY 50 HZ MF IN FL CELLS**

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**Summary of Abstract.** On the present study, we found that exposure to 50 Hz MF could induce EGFR clustering and phosphorylation, and the noise MF could inhibit it according to intensity ratio.

**Objectives.** These are many evidences that ELF-MF exposure may activate signal transduction pathways. Our previous study also showed that 0.4 mT 50 Hz MF could phosphorylate and activate the stress-activated protein kinase and P38 mitogen-activated protein kinase. However, the mechanism is still unclear. In the present study, we explored the effects of exposure cell to 50Hz MF on clustering of EGF receptors (EGFR) and phosphorylation, and investigated whether noise MF could interfere the effects caused by 50 Hz MF.

**Methods.** 1.Exposure System:FL cells were exposed to a very uniform 50Hz sinusoidal MF in the center of the Helmholtz coils, located in the CO2 incubator. The combined exposure system of 50 Hz and noise MF connects with different MF signals, one for 50 Hz MF and the other for noise signal. The noise signal was supplied by Litovitz Lab. The MF signal
was monitored with oscilloscope.

2. Cell Treatment: FL cells were cultured in MEM medium for two days. Then cells were divided into five groups for the following treatments: a). positive control, treated with EGF for 15 min, b). sham exposure, c). 50 Hz MF exposure, exposed to 0.05, 0.1, 0.2, 0.4 mT 50 Hz MF respectively, d). noise MF exposure, exposed to 0.2 mT noise MF, and e). the combined MF exposure, exposed to combined MF which 0.2 mT noise MF superimposed on 50 Hz MF with different intensities. The MF was perpendicular to the dishes.

3. Confocal Microscope Analysis: Following treatment, cells were rinsed, fixed, sealed, incubated with antibodies of EGFR, dyed with propidium iodide. Finally, the clustering of EGFR was analyzed with confocal microscope. Experiments were repeated more than three times.

4. Phosphorylation Measurement of EGFR: Following treatment, cells were lysed in RIPA buffer. The cellular protein was extracted and the concentration was determined with the Lowry’s assay. The protein samples were separated on a 12% SDS-polyacrylamide gel and subsequently transferred to nitrocellulose membrane by Western blotting. The EGFR and phosphorylated of Tyr-1173 on EGFR was detected using the corresponding antibody. The blot was developed with ECL.

**Results.** The results of confocal microscope showed that, like the EGF, except for 0.05 mT, exposure to 50 Hz MF at 0.1, 0.2 and 0.4 mT for 15 min could induced EGFR clustering, while exposure to noise MF at 0.2 mT for the same time didn’t induce receptors clustering. When superposed of noise MF, the receptors clustering induced by 50 Hz MF at 0.1 and 0.2 mT was inhibited completely (Fig.1). However, the receptors clustering induced by 50 Hz MF at 0.4 mT was inhibited partly (data not shown). Similar to the results of EGFR clustering, exposure to 50 Hz MF at 0.1, 0.2, 0.4 mT for 15 min phosphorylated the EGFR on Tyr-1173 (Fig.2), and it also was inhibited completely or partly by noise MF with 0.2 mT (Fig.3).

**Conclusions.** The receptor on the membrane is one of important elements that receives the extracellular signals and transduces them into cells. Some ligands binding to receptors can induce receptors clustering, then activate the cellular signal transduction pathway. The results of the present study showed exposure to 50 Hz MF could induce the clustering of EGFR. It indicates that 50 Hz MF may interact with signal pathways normally used by growth factors. The carboxy terminal tyrosine-1173 residue on EGFR is a major site of autophosphorylation, which occurs as a result of EGF binding. In order to investigate whether EGFR clustering induced by 50 Hz MF can be activated at the same time, the phosphorylation of tyrosine-1173 residue on EGFR was serviced as biomarker. The result showed that 50 Hz MF with 0.1, 0.2 and 0.4 mT also could induced EGFR phosphorylation following the clustering. It suggests that the cellular membrane may be the initial target sites for ELF-MF, which may transfer and traduce its signal into cell via cell membrane receptor. However, the noise MF with the same intensity didn’t induce the receptors clustering and phosphorylation, and could inhibit the biological effects induced by sinusoidal MF while combined with sinusoidal MF. Based on the present study, we concluded that the receptors on cell surface are the possible target sites that EMF acts on organism. We also confirmed the noise MF could interfere the biological effects of ELF-MF.
Acknowledgements. The work was supported by grants from the NSFC (No. 30100036, 50137030, 30570448).

Figure 1. Noise MF inhibited the EGF receptors clustering induced by 50 Hz MF.
1 sham exposure, 2 positive control, 3 exposure to 50 Hz MF at 0.05 mT for 15min, 4 exposure to 50 Hz MF at 0.1 mT for 15min, 5 exposure to 50 Hz MF at 0.2 mT for 15min, 6 exposure to 50 Hz MF at 0.4 mT for 15min, 7 exposure to noise MF at 0.2 mT for 15min, 8 exposure to combined MF for 15min, which 0.2 mT noise MF superimposed on 0.1 mT 50 Hz MF, 9 exposure to combined MF for 15min, which 0.2 mT noise MF superimposed on 0.2 mT 50 Hz MF, ×1000.
Figure 2. 50 Hz MF induced the phosphorylation of tyrosine residue on EGF receptor in FL cells.

Figure 3. Noise MF inhibited the phosphorylation of tyrosine residue on EGF receptor induced by 50 Hz MF in FL cells.
P-107 NEUROPHYSIOLOGICAL EFFECTS OF ELF FIELDS PRODUCED BY MOBILE PHONE ON SNAIL NEURONS

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Summary of Abstract. This work considers waveform parameters and flux magnetic field intensities of ELF field from GSM900 near to real condition to study the effects of these fields on the bioelectrical activity of snail neurons.

Objectives. Over the last 10 years the exponential increase in mobile phone use has raised questions about possible bioeffects on users. Although the major focus is on RF radiation, some scientists are concerned about exposure to extremely low frequency (ELF) fields, since mobile phones not only expose the user to RF EMF but also to ELF EMF. The ELF fields are caused by high supply currents inside the phone (1-4). There are evidences that extremely low frequency magnetic fields can interact with targets (e.g., receptor and voltage gated ion channels) that could potentially affect the neuronal firing by modulating the membrane ionic channel currents (5-7). The site of interaction in the cell is unknown but the cell membrane and DNA have been suggested (9).

This work considers waveform parameters and flux magnetic field intensities of ELF field from GSM900 near to real one condition to study the effects of these fields on the bioelectrical activity of snail neurons.

Methods. Experiments was performed on the central neurons in the sub-oesophageal ganglia of land snail Helix aspersa. The circum-oesophageal ganglia was dissected out and were fixed on recording chamber in normal snail Ringer. To elicit \( \text{Ca}^{2+} \) spikes the extracellular medium was changed by TEA, and to which 4-aminopyridine (4-AP, 5 mM) was added (Ca\(^{2+}\) Ringer). Intracellular recordings were obtained in current clamp mode using an Axoclamp 2B. The ectrophysiological recordings were saved on computer for offline analysis. The parameters of spontaneously recorded action potentials were measured using Chart5 software.

The exposure system consisted of a pair of coaxial circular Helmholtz coils. They each had the same diameter (20 cm) and were connected in series. The distance between the two coils was 10 cm. A 217 Hz pulsed with a pulse width of 0.577 ms. electrical current produced by a function generator (IC XR2206, Van Ooijen Technische Informatica) and amplifier circulated in the coils in order to produce a magnetic flux density up to 500\(\mu\)T rms value. The value of the magnetic field was measured by magnetometer TES-1394 (TES Electrical Electronic Corp). and the recording chamber was placed between magnetic coils.

Numerical results are given as mean\(\pm\) S.E.M. Statistical significance was calculated by a one-way ANOVA using the software SPSS and differences with P < 0.05 were considered statistically significant.
Results. The experiments performed in normal Ringer and Ca\textsuperscript{+2} Ringer.

**Action potential characteristics in normal Ringer**

In normal Ringer, neurons had a resting membrane potential of $-39.82 \pm 0.35$ mV and showed spontaneous action potential with a frequency of $2.83 \pm 0.11$ Hz and the mean peak of $29.69 \pm 0.73$ mV. Single action potentials were followed by peak of AHP with a mean amplitude of $-52.17 \pm 0.06$ mV (Fig. 1A).

Application of magnetic field with 217 Hz frequency and 21.9 \( \mu T \) intensity within 5min, induced 37.81\%(n=50, , P < 0.05) decrease in the frequency of spontaneous action potentials that reached to a maximum of 43.21\%(n=50, P < 0.05) in 229 \( \mu T \) after 5min exposure. The inhibitory effect of magnetic filed was accompanied by a slow membrane hyperpolarization and significant decreased in peak of action potential 13.26\% in 65.6 \( \mu T \) (n=48, P < 0.05) and 30.44\% in 229 \( \mu T \) (n=30, P < 0.05) intensity. The effect was intensity dependent with a maximum hyperpolarization occurred within 229 \( \mu T \) after 5 min (Fig. 1).

**Action potential characteristics in Ca\textsuperscript{+2} Ringer**

In order to record Ca\textsuperscript{2+} action potentials, normal snail Ringer was washed out with a Na\textsuperscript{+} free Ringer containing voltage dependent K\textsuperscript{+} channel blockers. Superfusion with this solution resulted in an increase in the frequency of action potentials, induced a transition from rhythmic, single spike activity to the burst—interburst firing pattern and finally broadened the action potentials to form Ca\textsuperscript{2+} spikes with long plateau (Fig. 2A). After exposing the cells to magnetic filed in 217 Hz with 229 \( \mu T \) the duration of Ca\textsuperscript{2+} spikes 46.87\% increased and resting membrane potential significantly increased(n=17, P < 0.05).

Conclusions. To test the hypothesis, that ELF component of magnetic fields from mobile phone can effect on ion channels, first we measured the flux intensity of magnetic fields in 217 Hz frequency from battery current of mobile phone and then according to the waveform and different intensities of ELF component of GSM900 we measured neuronal firing activity of cells under the current clamp condition.

Our results show that the cell membrane is the site of interaction for weak low frequency magnetic fields. The AHP is generated by activation of distinct types of outward K\textsuperscript{+} channels by calcium ions entering the neuron during an action potential (10). A decrease in the duration and an increase in the amplitude of AHP show inhibitory effect of magnetic field in intensity dependent manner on neurons of land snail and shows that the opening of channels is influenced by ELF magnetic fields.

In Ca\textsuperscript{2+} Ringer containing TEA and 4-AP in which voltage dependent K\textsuperscript{+} channels are mainly blocked, so that the slow conductance Ca\textsuperscript{2+} dependent K\textsuperscript{+} channels are probably the main mediators responsible for the outward K\textsuperscript{+} currents. The increasing in the duration of action potential shows more specially, Ca\textsuperscript{2+} influx through voltage dependent Ca\textsuperscript{2+} channels and consequent activation of Ca\textless sup\textgreater 2+\textless /sup\textless dependent potassium channels is influenced by ELF magnetic field.


Figure 1. Magnetic field considerably changed the firing pattern of the neurons. a: regular spike activity of a neuron in control condition before exposing magnetic field. b: Within exposure to magnetic field with 21.9 μT intensity in 5 min. c: after exposing to 44.1 μT intensity in 5 min. d: activity of the same neuron, after application of 65.6 μT intensity in 5 min. e: after 229 μT intensity in 5 min. 2a: before exposing magnetic field with 217 Hz in Ca2+ Ringer. b-d: increasing the duration of Ca2+ spikes after exposure time in different intensities.
**P-108 DIELECTRIC BEHAVIOUR OF AQUEOUS ENVIRONMENT NEAR MEMBRANES: A MOLECULAR SIMULATION STUDY.**

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**Summary of Abstract.** Molecular dynamics simulations have been performed on bulk water and on ions/water systems, in presence of high E-fields, with the purpose to characterize dielectric behaviour. This is a preliminary step in order to model the thin water layer near cell membranes where high gradients of E-field are present. A non-linear dependence between water permittivity and E-field intensity is observed and eventually a higher polarizability of the ion solution with respect to the water alone.

**Objectives.** One of the main hypothesis in the study of bioelectromagnetic interaction mechanisms is that the effects of the field action at macromolecular scale could be mostly connected to the ion-binding process, in which the binding of a ligand ion to a channel receptor site underlies channel gating, causing ionic transport across the cellular membrane [1]. Therefore, if one considers that water in close proximity of membranes behaves in a very different way compared to the characteristics of bulk water, the local environment where ions approach the membrane receptor site, becomes extremely interesting. Water molecules surrounding isolated charges become highly oriented by charge-dipole interaction, the H\(_2\)O tetrahedral bonding becomes partially broken [2], moreover high gradient electric fields are present in few nm [3] and E-field intensities comparable with atomic local field values are present. The purpose of this work is to analyse and focus on dielectric properties of such aqueous environment starting from molecular simulations.

**Methods.** Among different numerical methods of molecular simulations, the molecular dynamics (MD) technique has been developed over the last decades to study many different types of systems at atomic resolution. In a MD simulation all atoms in the system are treated classically. Interactions between atoms are divided in non-bonded interactions, between any pair of atoms within a given radius, and bonded ones among atoms connected by chemical bonds; both types of interaction are modeled by a potential function. GROMACS Molecular Dynamics package can efficiently manage such systems of N interacting atoms. As a first step MD simulations on a system containing an increasing number of water molecules have been carried out. Moreover, simulations involving small boxes (some nm) of water molecules in presence of a static electric field have been performed, with the purpose to obtain a simplified model of membrane environment characterized by the presence of intense electric fields. E-field intensities have been varied in the range between 10\(^7\) V/m and 10\(^10\) V/m, values comparable with the atomic local ones. A successive step was the simulation of the same system in presence of ions (i.e. Na\(^+\)) in order to characterize the dielectric properties of an ionic solution and to verify water response to charged elements.

**Results.** By using different sets of parameters for MD simulations, i.e varying box sizes, force-fields applied, cut-off methods, temperature coupling, values of water dielectric constant have been obtained. As observed in Table I dielectric constant values remain almost
the same varying the number of simulated molecules for a specific model of water molecules (SPC/E) while for the other one (SPC), less accurate, values are within a 10% of variability. The behaviour of the real part of water dielectric constant vs. frequency is well reproduced and a non-linear dependence between permittivity and E-field intensity is observed (Fig. 1). These last results are in optimal agreement with data coming from previous analytical and numerical studies [4], as already shown in [5]. Regarding simulations of the solution (water molecules with the inclusion of a Na\(^+\) ion) preliminary results show a higher polarizability of the solution with respect to the water alone.

**Conclusions.** MD simulations have been performed in order to characterize the dielectric behaviour both of water and of aqueous solutions (water with an ion embedded). A non-linear dependence of the dielectric constant with the E field applied has been obtained in accordance with previous data. This kind of simulation represents a necessary step before moving towards MD of real membranes.

**References**


**Acknowledgements.** -

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**Figure 1.** Tab. I. Example of data output from a MD simulation varying number of water molecules and model, and cut-off radius: the table shows values for dielectric constant, finite Kirkwood factor (G), infinite Kirkwood factor (g).
P-109 EFFECT OF MILLIMETER WAVES ON CYTOKINE PRODUCTION BY T-CELLS – ROLE OF ENDOGENOUS OPIOIDS

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Summary of Abstract. Millimeter wave therapy is used in the former Soviet Union countries to reduce the toxic side effects of chemotherapy on the immune system. In a previous study we have reported that millimeter waves modulate T cell and macrophage functions. The present study was undertaken to investigate the mechanisms, particularly the role of endogenous opioids in modulation of T cell functions by millimeter waves (MMWs). The effect of low power millimeter waves was studied on drug induced modulation of cytokine
formation by T cells in the presence or absence of selective opioid receptor antagonists. The animals (BALB/C male mice) were irradiated with 42.2 ± 0.2 GHz on the nasal area on days 1, 2, and 3 for 30 minutes each day at an incident power density of 38 mW/cm². To study the effect of selective opioid antagonists, the animals were injected intraperitoneally 24 h prior to first irradiation. Cyclophosphamide (CPA, 100 mg/kg), an anticancer drug, was administered on day 2. The animals were sacrificed 7 days following CPA administration and CD4 T cells were isolated from splenocytes. The CPA treatment caused a significant increase in Th2 (IL-4, IL-5) cytokines as compared to control animals. A further enhancement in production of Th2 cytokines was observed when CPA treated animals were also irradiated with MMWs. On the other hand, no significant change was observed in the level of Th1 (TNF-alpha, IFN-gamma, IL-2) cytokines with CPA treatment alone or in combination with MMWs. The kappa- opioid antagonist, nor-binaltorphimine, shifted the balance back toward Th1 cytokines indicating that kappa opioids are involved in the observation that millimeter waves shift the balance from Th1 to Th2 cytokines.

Objectives. To determine the role of endogenous opioids in modulation of T cell functions by millimeter waves.

Methods. Millimeter wave irradiation:
MMWs (42.2 ± 0.2 GHz) were produced with a Russian-made YAV-1 generator (Istok, Fryazino, Russia. The mice were irradiated on the nasal area for 30 minutes a day for 3 consecutive days. For irradiation the animals were restrained in plastic tubes (3.5 cm diameter) with a breathing hole in the front The central part of the antenna of the YAV machine was kept at a distance of 5 mm from the nose during irradiation. Six groups of animals were used. The first group (MW) was irradiated with MMWs on days 1-3 for 30 min each day. The second group (Sham) served as a sham control for the first group. The third group (CPA+MW) was treated on day 2, with 0.5 ml CPA solution in physiological saline (100 mg/kg, ip). The fourth group (CPA+Sham) served as a sham control for group 3 where the animals were treated with CPA and positioned in front of the YAV machines in a similar manner as the third group but the machines were not energized. The fifth (CPA+MW+ORA) and sixth groups (CPA+SHAM+ORA) were treated with selective opioid receptor antagonists 24 hours before first irradiation.

The spatial average incident power density (20.55 mW/cm²) was determined by measuring the total power output from the YAV-1 and dividing by the area of the output plane of the horn. The SAR was calculated from the initial rise of temperature as measured thermographically, using an infrared camera, on the surface of the murine nose. The initial rate of rise of temperature is determined by fitting the measured temperature values to the theoretical (bioheat equation) heating curve and deriving the limit as time approaches zero. The SAR is then calculated by:

\[ \text{SAR} = C \frac{dT}{dt} \]  

where \( C = \) heat capacity of skin (3720 J/kg/K)

The maximum temperature rise observed at the end of the MMW exposure was 1.55°C. The Peak SAR was 681 W/kg and the peak incident power density was 38 mW /cm².

Opioidreceptorantagonist(ORA) studies:
Beta-funaltrexamine (β-FNA, 20 mg /kg), naltrindole methane sulfonate (NTI, 1 mg/kg), and nor-binaltorphine hydrochloride (nor-BNI, 20 mg/kg) were used as selective antagonists
for $\mu$, $\delta$, and $\kappa$ opioid receptors, respectively. All antagonists were injected intraperitoneally 24 hours prior to day 1 of the MW or sham exposure.

**Preparation of Splenocytes:**
Mice were sacrificed 7 days after CPA administration and the spleen from each mouse was removed aseptically. Splenocyte suspensions were prepared by homogenization of the spleen in Hanks balanced saline solution (HBSS) medium supplemented with 1% fetal bovine serum (FBS) and 0.5 mM EDTA. For Isolation of CD4+ T cells, the splenocytes were labeled with Biotinylated Mouse CD4 T Lymphocyte Enrichment cocktail (BD Biosciences). The enrichment cocktail was used for the negative selection of CD4 lymphocytes from mouse spleen. It contains monoclonal antibodies that recognize antigens expressed on erythrocytes and leukocytes that are not CD4 T lymphocytes.

**Cytometric Bead array:**
Th1 and Th2 cytokines were measured using a BD$^{TM}$ cytometric Bead array Mouse Cytokine Th1/Th2 kit (BD Biosciences). The experimental conditions were followed according to the manufacturer’s protocol. The samples were analyzed by flow cytometry using BD FACS Calibur machine.

**Results.** The table shows the relative concentration of Th1 (TNF-alpha, IFN-gamma, IL-2) and Th2 (IL-4, IL-5) cytokines in different groups. It was interesting to observe that CPA treatment caused a significant increase in Th2 cytokines as compared to control animals. A further enhancement in production of Th2 cytokines was observed when CPA treated animals were also irradiated with MMWs. On the other hand, no significant change was observed in the level of Th1 cytokines with CPA treatment alone or in combination with MMWs.

In order to determine the role of endogenous opioids in modulation of Th1 and Th2 cytokines by MMWs, the animals were treated with different opioid receptor antagonists. It was interesting to observe that all three selective opioid antagonists used in our study, mu (beta-FNA), kappa (nor-BNI) and delta (NTI) further potentiated the effect of MMWs on release of Th1 and Th2 cytokines. As shown in the table, a combination of MMWs and opioid receptor antagonists modulated the formation of Th1 and Th2 type cytokines to varying degrees. It should be noted that the kappa antagonist shifted the balance back toward Th1 cytokines indicating that kappa opioids are involved in the observation that millimeter waves shift the balance from Th1 to Th2 cytokines.

**Conclusions.** Our results suggest that Millimeter waves modulate cytokine formation by T cells through release of endogenous opioids.

**Acknowledgements.** Grant sponsor: National Center for Complementary and Alternative Medicine. Grant # PO1 AT002025.
**P-110 ANOMALOUS ABSORPTION OF ELECTROMAGNETIC ENERGY IN LIVING CELL MEMBRANES DUE TO STRONG MEMBRANE CAPACITANCE DISPERSION**

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**Summary of Abstract.** The specific capacitance of living cell membranes may exhibit strong dispersion (frequency dependence). Partial but consistent experimental evidence has been reported of the possible sign-reversal (inductive behaviour) of the membrane (specific) electric capacitance in some spectral ranges [M.B. Partenskii, P.C. Jordan, Condens. Mat. Phys., vol.8, n.2 (42),(2005)]. Negative capacitance observed in negative-permittivity (plasmonic) materials is known to originate a variety of “exotic” behaviors, including superradiant scattering and absorption [A. Alu’, N.Engheta, J. Appl. Phys., n.97, (2005)] even in electrically small scatterers.

Under normal circumstances (frequency invariant membrane capacitance) most of the power absorbed by a living cell exposed to an electromagnetic field is dissipated in the cytoplasm, and only a relatively small fraction in the membrane. Strong membrane capacitance dispersion may significantly alter this picture. In the spectral intervals where the membrane specific capacitance becomes small (or even negative), most of the absorbed power is dissipated in the membrane. This is exemplified in Fig.1, which refers to the special dispersion curve shown in Fig.2. The absorption peaks in Fig. 1 appear in full evidence whenever the “anomalous” spectral behavior of the membrane capacitance occurs beyond the knee point in Fig.1, whose spectral position, for the special case of a homogeneous spherical cell, scales roughly as the inverse of the cell radius.

In this communication we investigate the above scenario for several plausible models of the cell membrane dispersion law.

**Objectives.** Obtaining qualitative understanding of the possible effect of a strongly dispersive membrane specific capacitance on the spatial localization of the power dissipated in a spherical cell exposed to an incident EM field.

**Methods.** We present numerical simulations based on an analytic solution for the transmembrane potential of a homogeneous spherical cell with strongly dispersive (possibly inductive) membrane admittance, embedded in a homogeneous lossy half-space, exposed to a plane monochromatic electromagnetic wave. The solution is obtained under a quasi-static approximation appropriate to the small values of the ratio (cell diameter)/(wavelength).

**Results.** Strong peaks in the membrane absorption (and corresponding dips in the cytoplasm absorption) are observed, near the edges of the spectral bands where strong dispersion in the membrane capacitance is observed. The possible biophysical relevance of such peaks may deserve deeper investigation.
Fig. 1: Power absorbed in the membrane (top) and cytoplasm (bottom).
Fig 2: Membrane specific capacitance dispersion curve

Figure 2.
P-111 NONLINEAR RESPONSE OF A HODGKIN-HUXLEY EXCITABLE CELL TO A WIDEBAND NOISY EM FIELD

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Summary of Abstract. Complex EM-polluted environments can be efficiently modeled as stochastic EM fields. In this connection, the possible relevance of the nonlinear response of cell membranes to EM noise has been suggested [M. Bier, Acta Phys. Pol. vol. B37, pp. 1409-1424, 2006].


The response exhibits an interesting structure in the ELF band, and a distinct spectral signature throughout several frequency decades.

Objectives. Obtaining a deeper understanding of the nonlinear response of an excitable cell membrane in a complex EM environment modeled as a wideband stochastic process.

Methods. The response to an applied stochastic electromagnetic field of a homogeneous spherical cell with nonlinear membrane embedded in a homogeneous medium is obtained in analytic form.

In view of the typical cell diameter (1µm to 1mm), a quasistatic field analysis is appropriate up to 10GHz and above; which allows to derive all quantities of interest from a scalar potential.

The Volterra series formalism is used to solve the related nonlinear boundary value problem up to 3rd order included in the incident field. The DC transmembrane potential shift, and the transmembrane voltage Power Spectral Density are computed to the same order for a linearly polarized zero average gaussian white noise. The non-obvious spectral features of the result are discussed.

Results. In the ELF and VLF ranges the ratio between the dominant — nonlinear and linear terms of the Power Spectral Density has a non-trivial behavior, as shown in Fig. 1. It is tempting to speculate that the peak in the inset of Fig. 2 may drive the mechanical membrane oscillations observed in [A.E. Pelling et al., J. Mol. Recognit. vol. 20, 2007] at comparable frequencies.

It is reasonable to expect that ambient EM fields may elicit significant biological responses if capable of altering the natural spectral distribution of the membrane electric noise in a significant fashion. On the other hand, one may speculate that the spectral distribution of
the natural membrane noise may be due in part to the spectral distribution of the natural EM noise background. The possible biophysical relevance of such results deserves deeper investigation.

**Figure 1.**

![Graph](image)
P-112 EFFECTS OF RADIO FREQUENCY MAGNETIC FIELDS ON THE IRON RELEASE FROM CAGE PROTEINS VIA 6-HYDROXYDOPAMINE

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Summary of Abstract. In this study we show how radio frequency magnetic fields of 200 kHz to 3 MHz and amplitudes from 10 to 100 microT alter the 6-hydroxidopamine entry time and reduction rates of iron ions from iron cage proteins (ferritins). We propose a mechanism for this effect based on changes in the internal energy of the inner ferrihydrate nanoparticle, which is verified by iron-release spectroscopy experiments.

Objectives. We propose a mechanism for the interaction between RF magnetic fields and iron-rich cage proteins as follows: when an alternating magnetic field of high enough frequency is applied, the magnetization of the nanoparticle (magnetic moment of about 0.1 Bohr magneton per iron atom) will lag the applied field, resulting in an increase of its internal energy. The nanoparticle may relax via either Néel or Brownian processes. The former will result in the irradiation of phonons from the nanoparticle (the magnetization rotates within the crystal). In a Brownian process, the nanoparticle will try to mechanically rotate and align itself with the magnetic field, colliding with the surrounding water molecules and the proteic cage that encloses it.

Methods. Ferritin [1] is a ubiquitous protein which role is to capture and store the harmful Fe2+ ions in the body. It is formed by a roughly spherical peptidic cage of 440 kDa in mass and 12 nm in diameter (apoferitin) and an inner ferrihydrate nanoparticle containing the stored iron. To be released, the iron has first to be reduced from Fe3+ to Fe2+. One of the molecules with this role is 6-hydroxydopamine, which goes into the ferritin cage and produces deprotonated quinone, H2O molecules and Fe2+ ions. This reaction is related to Parkinson’s disease via the catalyst role played by the Fe2+ ions in the oxidative stress. Iron release from the ferritin can be monitored by the addition of ferrozine, an iron chelator that acts as colorimetric probe.

Results. In our experiments we have worked with iron-saturated ferritins with nanoparticle diameters of 8 nm (about 4500 Fe ions). We observe that proteins exposed to the RF magnetic fields have a higher rate of iron release during the first 1-3 hours at neutral pH with differences of almost 50% at long exposure times. However, as the molecule reaches its release saturation level or as the pH is lowered, the iron released from proteins exposed to magnetic fields is drastically decreased in comparison to control samples. At a constant frequency-magnetic field (f x B) product, the biggest effect is obtained at frequencies of 1 MHz, suggesting a relaxation time of order 1 microsecond. The flow of iron ions released from control ferritin samples at low pHs is enough to block the hydrophilic terminals, and the molecules coagulate and precipitate. In contrast, in the case of ferritin molecules exposed to magnetic fields for several hours, the iron released by the 6-hydroxydopamine is almost quenched and the precipitation occurs more slowly or not at all.
Conclusions. Our study has given evidence that RF magnetic fields have the possibility to alter the iron release dynamics from iron cage proteins, with important changes in protein functioning and solubility. The good functioning of these proteins is essential to avoid oxidative stress and therefore this effect could have important physiological consequences. References:

Acknowledgements. This study is supported in part by the grants (S)17100006 and 19.07371 from the Japan Society for the Promotion of Science (JSPS).

P-113 CALCIUM EFFLUX OF PLASMA MEMBRANE VESICLES EXPOSED TO ELF MAGNETIC FIELDS – TESTS OF ION AND NUCLEAR MAGNETIC RESONANCE INTERACTION MODELS

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Summary of Abstract. The properties of different versions of the Ion Parametric Resonance interaction model are studied for calcium channel proteins in highly purified plasma membrane vesicles at the ELF magnetic field frequency tuned to the resonance frequency of the Hydrogen ion. In addition, the possibility, as suggested by Lednev, is investigated that polarization of the proton nuclear spin by combinations of DC and AC magnetic fields, can influence opening of the calcium channel.

Objectives. During the last two decades, a large amount of data has been accumulated demonstrating that electromagnetic fields influence biological systems. In spite of many negative and conflicting experimental researches, the result of a number of studies suggests that low-frequency electric and magnetic fields may influence physiological systems. But the mechanism by which a weak magnetic field is detected in a biological system remains obscure. There is no generally accepted theoretical model that can explain how an extremely low frequency electromagnetic field induces a biological effect. A number of experiments suggest the existence of resonance frequencies and dose-response relationships that exhibit amplitude windows. Moreover the observed resonance frequencies seemed to be related to the strength of the local geomagnetic field. On the basis of these observations, several interaction models were developed. These classical and quantum mechanical models [Edmonds 1993; Engstrom and Bowman 2004; Engström 1996; Lednev 1991; Lednev 1993; Lednev 1996] have in common that under certain conditions the orbit of an ion that is captured on the surface of a protein is polarized by the combined action of a static and dynamic
magnetic field which in turn influences the biological activity of the protein. Blackman et al. [Blackman and others 1995; Trillo and others 1996] performed experiments to test the Ion Parametric Resonance theory as proposed by Lednev and found discrepancies that could not be explained by theory.

Our group studied the efflux of calcium ions through channel proteins in isolated plasma membrane vesicles for different ions at different frequencies of the time-varying ELF magnetic field [Baureus Koch and others 2003]. A good agreement was found with the predictions of the IPR model, but the amplitude window was found to be a factor of two narrower than the one predicted by theory. The same factor of two difference was found by Blackman et al. [Blackman and others 1995].

In 2006 Belova and Lednev [Belova and others 2006] presented data consistent with a model in which the hydrogen nucleus is polarized. Already at field strengths in the order of 1 \( \mu T \), biological effects were observed, and the effect can be found at any frequency of the ELF magnetic field.

The aim of the present investigation is to study the prediction of the original proposal by Lednev [Lednev 1991; Lednev 1993], a newer, modified model [Lednev 1996] that might explain the factor of two controversy and to test the latest proposal by Lednev [Belova and others 2006] that polarization of hydrogen nuclei at non-resonant frequencies can elicit biological effect.

**Methods.** Our experimental system consists of highly purified isolated plasma membrane vesicles from spinach (Spinacia oleracea L.) and the flow of calcium ions across this membrane is followed. The plasma membranes are obtained from spinach using aqueous polymer two-phase partitioning. By subsequent treatment with Brij58, the plasma membrane vesicles oriented with the cytoplasmic surface facing the surrounding medium. Prior to exposure, the vesicles are loaded with \( \text{Ca}^{2+} \) with the help of the primary \( \text{Ca}^{2+} \)-pump (\( \text{Ca}^{2+} \)-ATP-ase, exposing its active site to the medium). The efflux of \( \text{Ca}^{2+} \) through the plasma membrane is studied at 32\(^\circ\)C using \( ^{45}\text{Ca} \) as a radioactive tracer. A static magnetic field of 2 \( \mu T \) and parallel to this field a time varying magnetic field tuned to the resonance frequency for \( \text{H}^+ \)-ions (30 Hz) were used. In each experiment 12 Eppendorff tubes with vesicles in 100 \( \mu l \) medium were exposed or sham exposed for 30 minutes in a Helmholtz coil arrangement. The amplitude of the time-varying magnetic fields was varied between 1 and 10 \( \mu T \) in order to test the predictions of the interaction models proposed by Lednev. In a second series of experiments, the static magnetic field was kept at 37 \( \mu T \) and the calcium efflux was studied at the fixed frequency of 50 Hz and 217 Hz of the time-varying magnetic field and amplitudes between 0.5 and 10 \( \mu T \).

**Results.** The experimental work is in progress. Parameters to be studied are: (i) The width of the resonance at 30 Hz, the possible occurrence of sub- and superharmonic resonances, the calcium efflux ratio as function of \( \text{Bac/Bdc} \), and for the second series, the calcium efflux as function of \( \text{Bac/f} \), where \( f \) is the frequency of the time varying field. The results will be reported at the congress.

**Conclusions. References**

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**P-114 LARMOR PRECESSION AS A MECHANISM FOR WEAK MAGNETIC FIELD BIOEFFECTS: THERMAL NOISE AS AN ESSENTIAL COMPONENT OF MAGNETIC FIELD DETECTION**

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**Summary of Abstract.** It is shown a Larmor precession model (LPM) describes how thermal noise energy translates into information about the magnetic field environment. The results describe a precessing oscillator, bounded within an envelope determined by the ensemble average of the increase in oscillator amplitude due to thermal forces. Thermal forces continually ‘pump’ energy into the precessing thermal component, increasing the oscillator amplitude so the magnetic field bioeffect itself is driven by thermal noise.

**Objectives.** This study further develops the classical model of an ion strongly bound in an oscillator potential, with oscillator frequency in the infrared. The motion is thus that of a thermally driven oscillator rather than a ‘random walk.’ Rather than simply rapidly and randomly ejecting an ion from a binding site, thermal noise forces themselves contribute to
the increasing amplitude of the precessing oscillator in a manner determined by the ensemble average for the oscillator position. In other words, the bound ion undergoes precession at the Larmor frequency until the thermal accumulation increases the oscillator amplitude beyond the binding site radius, at which the ion is assumed to have left the binding site.

**Methods.** LPM is suggested to produce a coherent modulation of thermal fluctuations of the hydration angle between the ion and the net electric dipole moment of the electrified interface at the binding site, \(\cos(\theta)\), with an associated probability of occurrence \(P(\cos\theta)\). The interaction energy for an ion in its aqueous environment is described via the angle of hydration between the ion and net hydration dipole moment in its vicinity. Thus, the potential energy of the ion/hydration system may be taken to first order, so that the energy required to orient, e.g. rotate through an angle \(\theta\), the relative angle between the dipole field and the ion follows the familiar dependence \(U = \mu E \cos \theta\) on the effective electric field \(E\) felt by the dipole at a distance \(r\) from the ion. Thus, for an ion in the outer Helmholtz plane, the reactivity \(R(t)\) for the precessing oscillator is a function of its angle with respect to the reduced point dipole of the electrified interface.

**Results.** The results predict resonance conditions for AC and combined AC/DC field combinations with no fitting of adjustable parameters. Taking the average of 100 phases of the incident AC field and the limit of long binding lifetime = 10 Larmor periods of the DC field, LPM predicts different resonance regimes for parallel vs. perpendicular field combinations, as shown in figure 1. The further detection of different responses and resonance behaviors for parallel vs. perpendicular AC/DC field combinations is thus an important test for the validity of LPM. Also, the introduction of the perpendicular AC/DC combination results in a breaking of the cylindrical symmetry of the parallel field case, yielding a \(z\)-component in the plane of precession. Given the possibility that this additional dimension of precession is a biologically relevant endpoint, \(R(t)\) could be modulated by a term in mean \(z(t)\) as \(R(t) \rightarrow R(t) \times \text{mean}(z(t))\), and LPM predicts biphasic responses, as shown in figure 2.

**Conclusions.** Thermal forces play an integral role in the detection of the magnetic field. The resonance behavior of LPM reflects the inherent geometrical information encoded in the AC/DC field combination, suggesting that a wide variety of precessing targets may exhibit similar responses to specific applied field combinations. One such result suggests that fields can be configured to actually inhibit a biological process. If this possibility is verified by experiment, a non-invasive treatment for pathologies such as ectopic bone formation and malignancies without side effects could emerge.
Figure 1. Left: Phase-averaged LPM resonances for binding lifetime = 10 Larmor periods of DC field from mean cosine measure. LPM resonances sharpen with increasing bound lifetime, are independent of ensemble of initial conditions and require no fitting of moveable parameters. Right: LPM reactivity for perpendicular AC/DC field combination, also taken for binding lifetime = 10 Larmor periods of DC field and averaged over 100 phases. LPM predicts significantly different resonance conditions for parallel vs. perpendicular AC/DC field combinations.

Figure 2. Left: Time series of Z-component of precessing oscillator for perpendicular AC/DC field combination, as a function of AC frequency and ratio of AC/DC amplitudes, shown here for AC frequency = Larmor frequency of DC field. Perpendicular field combination introduces variation into spatial direction of precession axis, yielding complex but predictable dynamics. Right: Predicted LPM resonances determined by mean z-displacement taken over binding time = 4 Larmor periods of DC field. Inhibitory and excitatory responses are possible for particular perpendicular AC/DC field combinations.
**P-115 INVESTIGATION OF FREQUENCY SPECIFICITY OF QUASI- AND MILLIMETER WAVE EXPOSURE THROUGH OCULAR TEMPERATURE MEASUREMENT AND HEAT TRANSPORTATION**

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**Summary of Abstract.** Frequency Specificity of Millimeter wave Exposure was investigated through ocular temperature measurement and heat transportation.

**Objectives.** The frequency response of the quasi- and millimeter wave was examined from the ocular temperature measurement and the heat transportation in the anterior chamber.

**Methods.** 0.2% Micro-capsulated thermo-chromic liquid crystal (MTLC) was injected into anterior chamber of Pigmented rabbits. The rabbits were exposed unilaterally to a 26.5, 35, 40 GHz millimeter wave with lens antenna for 3 minutes. The maximum power density at the center of the corneal surface of each frequency was exposed to the rabbits. Anterior chamber slit image was recorded during exposure. Ocular temperature changes (cornea, lens) during 400 mW/cm$^2$ exposure were measured with a Fluoroptic thermometer with another rabbit group. The penetration depth of each frequency from the corneal surface was calculated from an electric constant of the cornea.

**Results.** Calculated penetration depth of each frequency was follows; 0.83 mm (26.5 GHz), 0.66 mm (35 GHz), 0.59 mm (40 GHz). Changes of the corneal (C) and lens (L) temperature (maximum temp. − pre-exposure temp, average of 5 rabbits) were 26.5 GHz: 1.8°C (C), 0.7°C (L), 35GHz: 8.7°C (C), 2.9°C (L), 40 GHz: 15.5°C (C), 4.3°C (L). Cornea and lens temperature rose with the frequency. Normal aqueous convection (non-exposing) was gradual that rises on the lens side and descends by the cornea. The normal convection was changed in reverse when 35 or 40 GHz was exposed (300 mW/cm$^2$). It rose on the cornea side, and descended on the crystalline lens side. 26.5 GHz exposure did not show any clear convection change. 1500 mW/cm$^2$ exposure condition showed the convection that rose on the lens side, and descended on the cornea side.

**Conclusions.** It was clear that ocular temperature and heat generation part was changed by millimeter wave frequency.

**Acknowledgements.** This study was supported by a safety guideline study of the Ministry of Internal Affairs and Communications of Japan.
**P-116 MECHANISM BY WHICH ELECTRIC AND MAGNETIC FIELDS CAN MODIFY BIOLOGICAL SYSTEMS**

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**Summary of Abstract.** This is a review paper of mechanisms by which electric and magnetic fields can modify biological systems. It will trace these effects from the physics through the chemistry and biology to the potential for modifying health effects.

**Objectives.** The objective of this review is to help the audience develop a chain of logic that shows the steps that will be required in order to develop models and an understanding of both the levels and lengths of exposure to electric and magnetic fields that lead to biological changes and in turn have the potential to lead to health effects.

**Methods.** Some of the literature is reviewed and an attempt is made to show how the forces exerted by electric and magnetic fields lead to changes in current flows and modifications of molecular configurations. The induced currents are compared with the natural diffusion currents. These currents are related to changes in chemical reaction rates and signal to noise ratios are estimated. Biological amplification mechanisms of signals are discussed along with some effects on oscillating systems. These effects are discussed with respect to signaling pacemakers and the immune system. The numerous feedback systems can either amplify or stabilize the biological processes and it is common that the response to the first signal can be either larger or smaller that to a later signal in a repetitive sequence. An example of training a neural network in the presence of noise will be used to show how systems can be trained detect weak signals.

**Results.** A chain of logic is developed that can help lead to an understanding of the levels, exposure times and characteristics of electric and magnetic that can lead to biological changes. This approach should help lead establishing the conditions under which these fields can result in health effects.

**Conclusions.** Biological systems are extremely complex with many feedback loops that have a wide range of time constants and that may be dispersed in space so that a signal applied in one place may affect process at a distance and later times. Thus it is not surprising that we have a long way to go before we can build a complete chain of logic that will take us from the physics to health effects.

**Acknowledgements.** Many members of BEMS and my students for over 30 years have contributed to my learning a little of what we are going to need to know to make electric and magnetic field a safe and useful tool for humans.
**P-117 SELF-FIELD THEORY: THE SPECTROSCOPY OF THE PHOTON**

Tony Fleming. Biophotonics Research Institute, Highett, VIC, Australia.

**Summary of Abstract.** The mathematics of self-field theory provides an expression for the photon mass \( m_\gamma = \frac{(h\omega_\nu_e)}{(8\pi c^3)} \) that evaluates to \( 0.396 \times 10^{-55} \text{ kg} \) \( (0.221 \times 10^{-19} \text{ eV}) \) where \( \omega_\gamma \) is an integer photon transition frequency estimated to be 54 from the experimental value of the Lande g-factor of the electron. The evaluated photon mass is compatible with the experimentally known fine-structure constant \( \alpha = \frac{c}{v_e} = \frac{(8\pi m_\gamma c^2)}{(h\omega_\gamma)} \). Like the de Broglie wavenumber, the transition frequency of the photon must be an integer within each cycle of the electron or nucleon in order to maintain dynamic stability. This provides a theoretical quantum mechanism by which strong and weak bonds form. The length of transit may vary as long as its overall phase length is an integer multiple of \( \pi/2 \). This theoretical mechanism helps explain the structural changes seen within the cell-cycle and the delayed luminescence observed from strands of DNA exposed to electromagnetic radiation.

**Objectives.** The spectroscopy of the photon as given by self-field theory (SFT) can be understood by the composite nature of the photon. This leads to a completely new level of structure inside atoms and molecules, including macromolecules such as DNA. This new level of photonic structure inside atoms underpins the knowledge of chemistry known from quantum field theories (QFTs) including the ‘golden era’ of quantum mechanics that followed its inception in the 1920’s. As well as non-negligible photon mass, the composite photon introduces a previously unknown mechanism by which relatively small changes in energy can change atomic and molecular structures. This has major implications for medical science and gives theoretical understanding to the structural changes observed within the cell cycle.

**Methods.** Before SFT, the photon was considered a wave-particle that was not understood mathematically. The main mathematical differences between SFT and the QFTs were discussed previously [1]. According to the Heisenberg uncertainty principle (HUP), and current quantum theory, light is the only means on which to base experimental evidence; therefore we cannot know anything about systems beyond uncertainty; we must always deal with a knowable level of inaccuracy [2]. To Heisenberg and current QFT it is impossible to look inside the photon. The photon has thus remained enigmatic, both a wave and a particle. The potential of the photon has been modeled inside QFT as a dirac-delta function leading to numerical errors within QFT when its probabilistic solution is normalized. If we do not know what its internal structure is, how can we hope to model it correctly mathematically? Yet this is only true if we use the photon experimentally.

We can get around this limitation by modeling the photon mathematically. This is not looking at it with our eyes but with our intellect. We need to know somehow what it is doing internally otherwise we end up with an uncertainty, a numerical inaccuracy related to an incorrect model of its internal dynamics. By using our intellect we can come up with a model for the internal structure and see if it stands up to experimental scrutiny. This is what has been done with SFT. A model for the photon explains internal atomic field motions, ionospheric layering, rainbows, the structure of snow flakes, how avalanches occur, how homeopathy and a range of alternative therapies work in general, acoustic therapy,
photon chemistry, and how gluons appear to be formed from phonons and photons [3-4]. Mathematically the photon needs to be modeled having two independent motions otherwise if it is modeled with only one motion, it is over constrained. Recently SFT has been used to provide deterministic eigensolutions to the Maxwell-Lorentz equations for the hydrogen atom [5]. Planck’s constant was seen as the energy per cycle of the principal eigenstate. The photon is assumed to collide coherently with both the electron and the proton each time it transits between the two particles. Assuming a polygonal motion circumscribes a circle representing the Bohr mageton, the photon collision frequency is estimated as 54 from the experimentally known value of the Landé g-factor of the electron. This quantum number can be seen as an extension of the de Broglie wavenumber [6].

**Results.** Based on a composite photon, an analytic expression for photon mass is readily obtained, \( m_\gamma = \frac{h\omega_\gamma \nu_e}{8 \pi c^3} \) that evaluates to \( 3.96 \times 10^{-55} \) kg \((0.221 \times 10^{-19} eV)\) where \( \omega_\gamma \) is an integer photon transition frequency within each cycle. This expression is found to be compatible with the fine-structure constant \( \alpha \), where \( \alpha = \frac{c}{\nu_e} = \frac{8 \pi m_\gamma c^2}{h \omega_\gamma} \) [7-8]. Within atoms and molecules, photon substructure confirms the physics known to quantum mechanics and the QFTs in general. Further, photon substructure introduces a previously unknown quantum mechanism by which bonds vary between strong and weak structures. The photon mechanism is also seen as the theory behind the delayed ultraweak luminescence discussed by Van Wijk [9].

**Conclusions.** Compared to the changes of state of the electron, a relatively weak spectroscopy is associated with the dynamics of the photon inside atoms. This spectroscopy explains the observable structural changes of proteins such as DNA as the cell-cycle proceeds, from supercoiled to rigid. The integer photon transition frequency \( \omega_\gamma \), related to the role of the photon as the binding energy of atoms, is key to understanding how molecules and atoms range from weak to strong bonds. The length of transit may vary as long as the overall phase length is an integer multiple of \( \pi/2 \). The fact that that the expression for the photon mass is related analytically to the fine-structure constant gives validation to the SFT interpretation of the photon’s role as the binding energy within atoms and molecules.

**References:**

P-118 ACOUSTIC/MAGNETIC FIELD ASSISTED PERFUSION IN PERIPHERAL VASCULAR DISEASE

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Summary of Abstract. The goal of this study was to assess the effectiveness of an acoustic device combined with static magnetic fields, a Cyma\textsuperscript{®} 1000, on a cohort with peripheral vascular disease (PVD). All subjects under study showed a marked application improved perfusion indicated by Thermography.

Objectives. The goal of this investigation, using Thermography and pulse assessment by palpation as an indicator, was to examine the value of the frequencies specific to arterial support in increasing arterial flow to areas where acoustic fields combined with dynamic static magnetic fields were applied.

Adequate blood supply is vital to the health of all cells and organ systems and essential for sustaining life. The function of the circulatory system is to deliver oxygen and nutrients to all cells. It also removes carbon dioxide and waste products maintaining optimal tissue pH. Since oxygen is mainly bound to hemoglobin in red blood cells, insufficient blood supply causes tissue to become hypoxic, or, if no oxygen is supplied at all, anoxic. Anoxia can cause necrosis (cell death). Without viable perfusion, organ systems suffer; the sequelli of ischemic cascade and cellular degradation ensues, thus life ends. When perfusion is impeded, the ischemic cascade ensues within seconds to minutes, necrosis due to ischemia usually takes about 10-12 hours.

Methods. The device the, Cyma\textsuperscript{®} 1000, delivered five acoustic frequencies, 900-1300 Hz, chosen for arterial support. The array of eight static magnets, seated in and around the diaphragm, were permanent neodymium magnets. The field strength of the magnets had a surface magnetic induction of 2000 Gauss peak or 200 mT. These static magnets produce a dynamic magnetic field that oscillates at the same frequency as the acoustic frequencies, inductively linking with the cell’s own electromagnetic field.

After the successful results of a prior study consisting of a control group, having normal perfusive ability, and a second group with a range of pathological conditions that included PVD, it was decided that a further study was warranted. Bilateral limb Thermography and manual pulse assessment by palpation of both dorsalis pedis pulses and posterior tibial pulses was used to monitor perfusion and pulsitile blood flow at baseline; baseline pulses were absent or greatly diminished in the entire cohort. Thermography and pulse assessment
were repeated after the application of the Cyma® 1000. After obtaining and reviewing a
detailed medical health history and a medical examination; a group of 10 subjects, between
the ages of 57 and 93, that had a history of PVD, was selected. The study cohort consisted
of 6 female and 4 male subjects. Baseline Thermographs and manual pulse assessments
were obtained before any intervention. After evaluating the baseline thermographs and
pulse assessments, the acoustic device (Cyma® 1000) was used to deliver specific audible
frequencies that ranged from 900 to 1300 Hz. These frequencies were administered for 15
minutes to the areas of pathology of anterior lower legs and feet, bilaterally. Informed
consent was obtained from each candidate before their participation in this investigation.

**Results.** The results of this investigation were very positive. Objective improvements in
perfusion shown by follow-up Thermography and pulse assessment that indicated an increase
in arterial blood flow and palpable pulse quality, as compared to baseline Thermography and
pulse assessment (baseline pulses were absent or greatly diminished in the entire cohort), in
100% of the group under study. Follow-up Thermography also showed a significant decrease
in inflammation in areas of inflammatory PVD, and a significant decrease in dependent
edema as well.

**Conclusions.** All subjects under study showed a marked application improved perfusion
indicated by Thermography. Dorsalis pedis pulses and posterior tibial pulses were also
greatly improved. The previously absent pulses became palpable and in cases where palpa-
bale pulses were diminished, pulse quality was significantly improved. Follow-up Thermog-
raphy also showed a significant decrease in inflammation in areas of inflammatory PVD,
and a significant decrease in dependent edema as well.

**References:**
vol. 354, 6, 2006
Core Lesions of the Thoroughbred Racehorse. BEMS 27, Dublin, June 19-25, 2005;
Figure 1. Thermographic Imaging and Pulse Assessment for case where increase in perfusion and lowering of inflammation ensued application
Cymatherapy®: Homeodynamics of PVD

Figure 2. Second sample

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**Summary of Abstract.** A simple potential formulation is used to calculate the distribution of the electric field in bone materials (tissues). The algorithm arises for biological tissues of centimeter-to-meter scale exposed to 60 kHz Capacitively Coupled Electric Fields (CCEF). There is growing evidence that electric and magnetic fields can influence biological functions. Applications such as CCEF were then put forth to resolve some bone related disorders as an alternative procedure to conventional intervention of orthopedic surgery. The evaluation of electric field in such tissues correlates the therapeutic effect to the local characteristics of the field and gives an important insight about bioelectromagnetic interaction, obtaining significant understanding of healing mechanism and bone rebuilding. The geometrical details of our model allow an accurate evaluation of the field in all the treated tissues.

**Objectives.** The present work describes a customizable model of vertebral column of a human normotype, obtained through the assemblage of various couples of a single parametric-variational vertebra. The simulation allows to acquire information about the complex phenomenon of the bone reconstruction and the effects of electrostimulation. The algorithm should be useful in calculating the response of biological materials subject to applied excitation.

This model can be used to increase the efficiency of present imaging techniques in the informative contribute to the orthopaedic and traumatologic medicine, and it can be used for ergonomic, static and dynamic analysis of the vertebral column. The algorithm should be useful in calculating the response of biological materials subject to excitation including modeling and electrical stimulation.

**Methods.** The Finite Element Method (*FEM*) is often used for modeling bone behavior, to predict bone strength in vivo. In previous works we used a trouble-free model of arm and spine focusing the algorithm that we apply to a real image. The Computer Aided Design (*CAD*) technique is applied in design of artificial protection systems to prevent cranioencephalic trauma. We use a customizable spinal column model with CAD/FEM techniques obtained from a sagittal Magnetic-Nuclear Resonance (*NMR*).
From the study of the anatomical characteristics of the vertebra, we can gather all the important information for the correct definition of a realistic model of the vertebra. Studying the morphological characteristics, both general and specific, variations, that can be found both between vertebra and vertebra and among individuals, become evident. The application of the vertebra model to a specific individual occurs through the variation of shape parameters and is verified with the use of appropriate geometric constructions. The CAD model is managed through an external spread sheet, in which the characteristic dimensions are entered, once they have been acquired from a sagittal magnetic resonance, and the shape parameters are calculated through the use of appropriate coefficients. Also ligaments, spinal chord, muscles and skin are modeled in order to evaluate the electric field.

Bone tissue has very interesting structural properties; this is essentially due to its composite structure, composed of inorganic and organic material, and water. Inorganic components are mainly responsible for the compression strength, while organic components provide the corresponding tension properties. Each tissue is assumed to be homogeneous and electrically neutral.

A 60 kHz 20 Vpp signal is placed on a pair of external electrodes placed directly onto the skin at the sides of the spinal column, at 10 cm distance from one another, as in the clinical practice.

The dielectric characteristics of tissues and electrodes are shown in table.

**Results.** The electric field is evaluated in the various tissues as shown in the figures, providing a description of the evolution of the entire analyzed phenomenon. In Fig. 1 we show the distribution of current density in the whole geometry. The extension of the color palette ranges is from 0 to 1 A/m² (sections without color have a value of current density higher than 1 A/m²).

In Fig. 2 we consider the current density in a longitudinal section.

The obtained values confirm previous results of simulation according to the literature.

**Conclusions.** The correlation between the exposition and the process of recovery is not an objective immediately achievable. The obtained results, the simplicity of the model, the conformity of such results with the experimental data at the moment represents a good support for investigation of CCEF effects on biological processes.
**Figure 1.**

**Figure 2.**
MICROWAVE TOMOGRAPHY FOR BREAST CANCER DETECTOR

Taehong Kim¹, Jong Moon Lee², Soon Ik Jeon², Jeongki Pack¹. ¹Chungnam National University, Daejeon, South Korea. ²ETRI, Daejeon, South Korea.

Summary of Abstract. Microwave imaging technology has studied for the breast cancer detector. In this paper, we simulated a simple structure of the cylinder, compared with it.

Objectives. Breast cancer is one of the most common cancers in women. X-ray mammography has drawbacks such as uncomfortable or painful breast compression and exposure to ionizing radiation. Such drawbacks augment the search for techniques that image other physical tissue properties. Microwave imaging is a method that has been proposed to complement mammography. Tumor detection at microwave frequencies is based on the significant contrast in dielectric properties between malignant tumors and normal fatty breast tissues [1]. We have studied a method of the breast cancer detection using CMI (Confocal Microwave Imaging) method in the past [2][3]. The objective of this paper is to study a microwave tomography method for breast cancer detector.

Methods. Active microwave imaging involves illuminating the breast with microwaves and then forming images with energy transmitted through or reflected from the breast. Image reconstruction method involves iteratively matching the measured and the computed data. The forward simulation computes the scattered fields received at the antennas. The computed data are compared to the measured data, and nonlinear reconstruction procedures using optimization algorithms are applied to obtain an update for the material electrical properties used in the breast model. This process is repeated until the convergence between the measured and the computed data is obtained. We performed a microwave tomography study for breast cancer detection system using the FDTD method forward algorithm with [4] and a modified LM (Levenberg-Marquardt) algorithm the optimization algorithm with [5]. Figure 1 shows the process of imaging reconstruction. We applied two-dimensional FDTD method with TM (Transverse Magnetic) mode. The incident wave used a pulse with broad-band characteristics. The perfectly matched layer with five absorbing layers was used. The plane wave was excited using TF-SF (Total-Field Scattered-Field) method.

Results. Figure 2 shows the original and the reconstructed image from a single reflected pulse. The original object is a cylinder with the relative permittivity 30 and the radius 20 cm. The reconstructed result is similar to the original image. The reconstructed image depends on many conditions such as frequency, measured antenna number, incident wave number, sampling number, and measurement time, etc.
Conclusions. We simulated the inverse problem for microwave tomography. Microwave tomography for breast cancer detector is studied to overcome the drawback of the X-ray mammography. The development of computer technologies and efficient algorithms will make three-dimensional objects be reconstructed in real-time. The study for an efficient algorithm for breast cancer detection is under way at present. will make three-dimensional objects be reconstructed by real-time. The study for an efficient algorithm for breast cancer detection is under way this present.

Acknowledgements. This work was supported by the IT R&D program of MIC/IITA. [2007-F-043-01, Study on Diagnosis and Protection Technology based on EM]

![Flowchart for image reconstruction using microwave tomography](image1)

**Figure 1.** Flowchart for image reconstruction using microwave tomography

![Original image and reconstructed image using microwave tomography](image2)

**Figure 2.** Original image and reconstructed image using microwave tomography
**P-121** RADIO-FREQUENCY TRANSMISSIONS FROM CELLULAR TELEPHONES DO NOT INTERFERE WITH NUCLEAR MEDICINE BRAIN IMAGING EQUIPMENT

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**Summary of Abstract.** The effect of cellular telephones on cerebral blood flow (CBF) is a hot topic. Nuclear medicine brain imaging is a common and well-established method for determining CBF. However, before studies can be carried out using cellular telephones and nuclear medicine equipment, we must first determine whether or not cellular phones affect nuclear medicine equipment. Experiments were conducted using a cellular telephone positioned as close as possible to potentially sensitive photomultiplier tubes comparing uniformity, resolution, and position of acquired images with the cellular phone in both the ON and OFF states. We discovered that cellular phones do not significantly affect the performance of nuclear medicine equipment. Therefore, nuclear medicine can be used to measure changes if any in CBF due to cell phones.

**Objectives.** Several studies have investigated the effects of radio-frequency electromagnetic fields from cellular telephones on cerebral blood flow (CBF) [e.g. Huber et al 2005 Eur J Neurosci 21(4):1000-6, Huber et al 2002 J Sleep Res 11(4):289-95]. Single Photon Emission Computed Tomography (SPECT) is a commonly available, established and sensitive nuclear medicine clinical modality for measuring CBF. SPECT relies on the use of photomultiplier tubes that are known to be sensitive to electromagnetic interference. Thus, before CBF studies can be conducted using cell phones in close proximity of SPECT equipment, any possible interference of SPECT equipment due to cell phone interference must be investigated.

**Methods.** Experiments were conducted to investigate the impact of cell phones on SPECT images in terms of: spatial resolution, spatial distortion, and image uniformity. Experiments were conducted using 4 North American cell phones on an anthropomorphic fully tissue-equivalent head phantom (Radiology Support Devices, Long Beach, CA, USA). To assess spatial resolution and distortion, the phantom was fitted with 4 capillary tubes filled with radioactive Tc-99m – which is commonly used in SPECT. To assess uniformity, the phantom was filled with a uniform distribution of 200 MBq of Tc-99m. After preparing the phantom, the cell phone was attached directly to the phantom exterior (Fig 1A). The cell phone was then reached via an outside land-based phone, and the two phones were left to communicate while SPECT data acquisition was performed using a General Electric Millennium Series SPECT camera (Waukesha, WI, USA). A CD player was placed 3 feet away from the cell phone (outside the field of view of the SPECT camera) to ensure continuous active communication from the cell phone providing maximum cell phone output power. The power of the cell phones used in this study ranged from 0.75 to 1 watt. The cell phone was then switched off, and SPECT was acquired again. SPECT data was tomographically reconstructed using filtered backprojection.
Resolution, spatial distortion and uniformity were all analyzed using clinical quality control protocols.

**Results.** For resolution, the full width half maximum was calculated for all 4 capillary tubes in both x and y directions for each of the cell phones in each of the ON and OFF states. For spatial distortion, the centroid for each capillary tube was calculated in each of the ON and OFF states. A paired t-test was used to show that there is no statistical significant difference in resolution and in the position of the capillary tubes when the cell phone is ON and OFF. For uniformity, visual inspection of the ratio of the uniformity images of the cell ON over the cell OFF did not reveal any differences between the ON and OFF states.

**Conclusions.** The use of cellular telephones in close proximity to SPECT equipment does not affect the resolution, spatial accuracy or uniformity of reconstructed images. Therefore, SPECT can be used to investigate potential changes in CBF due to cell phone exposure. Future work will also evaluate the possible interference between cellular telephones and Positron Emission Tomography (PET) nuclear medicine scanners.

![Figure 1](image_url)

**Figure 1.** (A) Experimental design displaying the phantom with cell phone attached and the SPECT camera. (B) Typical trans-axial slice of a brain SPECT scan. (C) SPECT scan displaying capillary tubes used for resolution measurements. (D) Profile taken from cross hair shown in C. X-axis in units of pixels. Y-axis in units of measured counts. ‘x’ symbols represent measurements from pixels in C. Resolution measurement calculated from full width at half maximum (FWHM) of profile curve.
P-122 ANTIPRURITIC EFFECT OF MILLIMETER WAVE THERAPY IS FREQUENCY-DEPENDENT

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Summary of Abstract. The absence of exact indications and possibly contraindications for Millimeter Wave Therapy (MWT) is one of the reasons why this method of treatment is practically unknown to Western Medicine. In our previous experiments we determined that hypoalgesic effect of MWT is specific, power-, and frequency-dependent. Considering that physiological mechanisms and pathways for pain perception and pruritus are different, in the present set of experiments we studied whether anti-pruritic effect of MWT is also frequency-dependent.

All experiments were conducted on Swiss-Webster mice. Itch was induced by injecting compound 48/80 in the rostral part of the back at a dose 50 µg per mouse. Immediately after the injections, each mouse was placed inside a restrainer and exposed to MW (Used frequencies were 61.22; 53.57; and 42.25 GHz; Average incident power density = 13.3 mW/cm²; Length of exposure = 15 min; Site of exposure = nose) or sham-exposed. In 15-20 min after exposure mice were placed in the observation cage and their behavior was digitally recorded for 45 min. The recordings were evaluated later. The level of itch response was measured by the number of scratches of the injected site during 45 min of observation. Conducted experiments demonstrated that MW frequency of 61.22 GHz is most effective for itch suppression. Inhibition of the compound 48/80-induced scratching was statistically significant. Results of the present experiments are in line with our previous findings about MWT-induced hypoalgesia. The same 61.22 GHz MW frequency was most effective for the treatment of chronic types of experimental pain. We concluded that MWT with these characteristics can potentially be most effective as a supplementary or alternative treatment for pain and itch relief.

Objectives. To determine MWT regimens that produce maximum reduction of the symptoms of experimental pruritus.

Methods. All experiments were carried out on male Swiss-Webster mice. Experimental pruritus was created by injecting compound 48/80 in the rostral part of the back at a dose 50 µg per mouse. Immediately after the injections, each mouse was placed inside a restrainer and exposed to MW (Used frequencies were 61.22; 53.57; and 42.25 GHz; Average incident power density = 13.3 mW/cm²; Length of exposure = 15 min; Site of exposure = nose) or sham-exposed. In 15-20 min after exposure mice were placed in the observation cage and their behavior was digitally recorded for 45 min. The recordings were evaluated later by an observer who was unaware of the conditions of treatment. The level of itch response was measured by the number of scratches of the injected site during 45 min in the observation cage. The received results were expressed in absolute numbers, and then recalculated against individual baseline responses to the compound 48/80 injection (which was done 7 days prior to the experiment).
Results. Conducted experiments demonstrated that MW frequency of 61.22 GHz is most effective for itch suppression. Inhibition of the compound 48/80-induced scratching was statistically significant (Fig.1). Some effect was observed when the frequency of 42.25 GHz was used. However, at this frequency the outcome was not statistically significant.

Conclusions. MW frequency 61.22 GHz can potentially be most effective as a supplementary or alternative treatment for itch relief.

Acknowledgements. This work was sponsored by NIH NCCAM, grant number P01-AT002025

**Figure 1.** MWT-induced suppression of experimental pruritus in mice. N ≥ 15 for all groups. Each column represents the group mean + SE. Value with a statistically significant difference (p<0.05) from the sham control data is marked with asterisk.
P-123 THE SAR ABSORBED BY HEAD IN RADIATION FIELD OF CELL PHONE AND EFFECTS OF HEAD ON RADIATION CHARACTER OF CELL PHONE

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Summary of Abstract. Because head is in nearzone-field radiated by the antenna of cell phone, when studying the SAR absorbed by head in radiation field of cell phone and effects of head on radiation character of cell phone, head and the cell phone must be considered as a whole system. The effect of head on cell phone is embodied in interfering work state of the antenna of cell phone and changing the radiation characteristics. When cell phone is vertically and aslant laid, the radiation orientation diagrams of antenna of cell phone affected by head are simulated by FDTD method and the ratio absorbed electromagnetic power by head are calculated. The results indicate that, in xoy-plane, the patterns of $E_\theta$ and $E_\phi$ radiated by the antenna of cell phone slope away from head, and in zox-plane, the patterns of $E_\theta$ and $E_\phi$ slope away from human trunk. And when cell phone is vertically and aslant laid, 38.0% and 34.4% of the total power radiated by cell phone are absorbed by head respectively. On the other hand, the effect of electromagnetic wave radiated by cell phone on head is embodied in probable harm to head. The whole-head average SAR and localized SAR in head are computed by FDTD method and compared with the basic restrictions formulated by ICNIRP, the results indicate that, the whole-head average SAR absorbed by head do not exceed the basic restrictions for general public and occupational exposure formulated by ICNRP, but the localized SAR (head) exceed the basic restrictions for general public exposure formulated by ICNRP.

Objectives. when studying the SAR absorbed by head in radiation field of cell phone and effects of head on radiation character of cell phone, head and the cell phone must be considered as a whole system.

Methods. FDTD method

Results. The results indicate that, in xoy-plane, the patterns of $E_\theta$ and $E_\phi$ radiated by the antenna of cell phone slope away from head, and in zox-plane, the patterns of $E_\theta$ and $E_\phi$ slope away from human trunk. And when cell phone is vertically and aslant laid, 38.0% and 34.4% of the total power radiated by cell phone are absorbed by head respectively.

Conclusions. The results indicate that, the whole-head average SAR absorbed by head do not exceed the basic restrictions for general public and occupational exposure formulated by ICNRP, but the localized SAR (head) exceed the basic restrictions for general public exposure formulated by ICNRP.

Acknowledgements. Prof.Yongjun Xie, Prof.Xiaomiao Zhang
**P-124 DEVELOPMENT OF POLYMERIC HUMAN JELLY PHANTOM**

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**Summary of Abstract.** We developed various types of jelly phantoms and measured electrical properties and storage characteristics at mobile bands.

**Objectives.** Development of jelly type simulating head phantoms for checking the temperature changes in strong electromagnetic field.

**Methods.** Using an appropriate material composition in Table 1 including polyethylene, de-ionized water, and sodium chloride, brain jelly phantoms shown in Figures 1 (a) and 1 (b) were prepared following Figure 1 (c) and their electrical properties were evaluated at 835 MHz.

**Results.** Dielectric constant of the jelly phantom were decreased with the increasing the amount of polyethylene, de-ionized water and sodium chloride (Figure 2 (a)). Electrical conductivities were also decreased with the increased amount of polyethylene and de-ionized water, but the conductivities increased with the increased sodium chloride amount (Figure 2 (b)). Also, regardless of the type and content of the material for the manufacturing phantom, storage characteristics showed a sustainable stability up to 6 months, specially 70 to 80 wt% of the phantoms have been kept their weight (Figure 2 (c)).

**Conclusions.** It can be proposed that jelly phantoms can be a tentative method for testing the temperature variation with the strong environmental electromagnetic fields.

**Acknowledgements.** This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MOST) (No.R01-2006-000-11338-0).

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**Figure 1.** Real photographs of jelly phantoms with an elapsed time of (a) 0 and (b) 6 months and (c) schematic diagram for the manufacturing process of jelly phantom.
Figure 2. (a) dielectric constant, (b) electrical conductivity of jelly phantoms as a function of material content at 835 MHz, and (c) storage characteristics of the synthesized jelly phantoms.

P-125 FREQUENCY DEPENDENCE OF MAGNETIC FIELD ATTENUATION IN SOME SIMULANT HOMOGENEOUS HUMAN TISSUES

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Summary of Abstract. The optimal magnetic field frequency inside the human body to transmit rf energy by inductive coupling to untethered capsular endoscope was surveyed. By physical theory and by circuit experiment 1 MHz was better than the lower frequencies because more emf is induced. From the computation result magnetic field above 3 MHz in the body can be attenuated to give thermal loss in some simulant homogeneous human organs.

Objectives. For wireless power transmission to capsular endoscope by inductive coupling the higher frequency magnetic field inside the human body generates more power by Faraday’s electromagnetic induction law. But the higher frequency electromagnetic field is more easily absorbed as the form of thermal loss which is converted from the field attenuation in the human body. The highest frequency to give the negligible magnetic field attenuation in some simulant
homogeneous human organs with the phenomenal dielectric constants or electrical conductivities was pursued in this research.

**Methods.** Although the magnetic field inside the human body should be calculated with a fine human model at the computation field frequency, we used a commercial simulation tool (Ansoft HFSS) for computation without a human model for the conservative and simple calculation. We surveyed the relative permittivities and electric conductivities of human organs to find high permittivities or conductivities at the computation frequencies. In Table 1 the relative permittivities and conductivities of those organs between 100 kHz and 31.6 MHz are shown. All of the organs in Table 1 are supposed to be non-magnetic materials. We calculated the magnetic field in the vacuum first for reference and calculated the H-field in the three different homogeneous organs. The magnetic field is generated by one turn rectangular current loop of 240 mm × 300 mm laid on z = 0 plane in Figure 1. The simulating conducting source wire is 10 mm × 10 mm squared cross section, and 1 Ampere peak current of each frequency in Table 1 flows at a time along the wire. The geometry of the homogeneous organ is a rectangular parallelepiped 180 mm × 240 mm× 180 mm in Figure 1 for reasonably simulating the abdomen of the male adult. The volume of the computation box surrounded by perfect magnetic conductors is 1,440 mm × 1,800 mm × 1,080 mm. The calculated H-fields in the homogenous organs were compared with the reference value in the vacuum.

**Results.** H-fields were computed at the origin point of the Cartesian coordinate which is the central point of the simulant tissues. The computed H-fields in each medium are shown in Fig. 2. In vacuum the H-field intensity grows very slowly as the frequency goes up which seems to be by radiation. As the computation frequency band in Fig. 2 goes higher, H-field is attenuated first in CSF which has the greatest loss tangent among the three tissues. At 3.16 MHz the attenuation is noticeable.

**Conclusions.** The computed H-fields in Fig. 2 in the simulant organs showed extremely small differences ( < 10⁻³) from the field in vacuum at 100 kHz which means 100 kHz magnetic field gives very little thermal effect in the organs of human. So we can use a higher frequency than 100 kHz for more efficient electric power generation in the electronic devices in the human body.

For cerebral spinal fluid (CSF), the attenuation frequency (energy absorption) can be higher than 1 MHz. So we can use up to 1 MHz for more efficient power transmission to the electronic devices in the human body without experiencing magnetic field attenuation in the body. If we use a fine human model for computation the beginning frequency of attenuation will be even goes higher.

**Acknowledgements.** This research has been supported by the Intelligent Microsystem Center (IMC; http://www.microsystem.re.kr), which carries out one of the 21st century’s Frontier R&D Projects sponsored by the Korea Ministry of Commerce, Industry and Energy.
Figure 1. Dielectric properties of some body tissues in the frequency range 100 kHz ∼ 31.6 MHz.

<table>
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<tr>
<th>Tissue name</th>
<th>Frequency [kHz]</th>
<th>Conductivity [S/m]</th>
<th>Relative permittivity</th>
<th>Loss tangent</th>
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<tr>
<td>Vacuum</td>
<td></td>
<td></td>
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<td>Wet skin</td>
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(Ref: http://mirem.ifac.cnr.it)

Figure 2. Computation geometry with a current source, a current loop, and a homogeneous tissue inside.
**Figure 3.** H-field intensities versus frequency in four homogeneous media (vacuum, wet skin, small intestine, and CSF) at the origin point in Figure 1.
P-126 TEST-BED SYSTEM TO STUDY MICROWAVE TOMOGRAPHY TECHNOLOGIES FOR BREAST CANCER DETECTION

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Summary of Abstract. One test-bed system was developed to prove microwave imaging technologies based on microwave tomography. The application of this microwave tomography is to detect breast cancers in a human body. This test-bed system is made of microwave sensing blocks and RF signal processing modules and image reconstruction processing parts with display. After fabrication, the test-bed reconstructed the object images successfully which were bottle phantoms. In this test-bed, the algorithm is based on FDTD solving.

Objectives. The objective of the test-bed fabrication is to have technology basement to realize the microwave tomography based on inverse scattering problem. The application of this microwave tomography is to detect breast cancers finally in a human body. The microwave imaging test-bed will allow for us to understand the inverse scattering method theoretically and to prove new microwave tomography technologies before designing and realizing the final clinical breast cancer detection system.

Methods. This test-bed system consists of the microwave sensing part, the RF signal processing part, the image reconstruction part. The image reconstruction part has an image display. To display images effectively and to analyze them scientifically, the system is supported by the effective graphical user interface functions, GUI. The GUI is focused on two themes that would be useful for us which is running a set of object image reconstructions and viewing a full set of object images. The image reconstruction algorithm in the test-bed uses the FDTD forward solver. For optimization, it uses the Gauss-Newton method. The system is designed to use frequencies from 500 MHz to 3 GHz for the microwave sensing signals.

Results. The system was operated to measure the permittivity of a bottle phantom with high dielectric liquid in this case. The test-bed and its reconstruction algorithm made the liquid phantom permittivity contrast images successfully. The measured liquid permittivity data showed that they matched their exact values almost.

Conclusions. The test-bed system is fabricated to study the microwave tomography technologies effectively, it showed us the reconstructed images very well, and it proved the technology potentialities. By further study, the system will be modified and redesigned to be a clinical test-bed system finally.

Acknowledgements. This study was supported by the IT R&D program of MIC/IITA.(2007-F-043-01, Study on Diagnosis and Protection Technology based on EM)
Figure 1. Fabricated Test-bed System

Figure 2. Test Results: Reconstructed Images
**P-127** STIMULATION BY EXOGENOUS MAGNETIC FIELDS GENERALLY PRACTICED FOR OSTEOPOROSIS TREATMENT, COULD HAVE AN EFFECTIVE POTENTIAL TO DEACTIVATE NEUROLOGICAL DISEASES?


**Summary of Abstract.** Although the connection between the loss of MBD mineral bone density (osteophenia and osteoporosis) and mental decline in elderly people is well-known the complex relation between calcium deprivation and brain degeneration is still unknown. Due to the fact that the stopping the process of MBD impairment in its early stages could contribute to preventing the frequent age-linked brain degeneration processes, the importance of looking into this relation becomes evident. Low frequency exogenous magnetic field (EMF) promotes the magnetic stimulation of human tissues, it being perhaps a very interesting turning point. The fact that extremely low frequency (ELF) EMF applications increase the oxygenation and the regeneration of the nervous tissue supports their utilization (EMF having a strength of picoteslas pT) in the treatment of several neurodegenerative processes, that include some of the central nervous system degenerative processes such as Alzheimer and Parkinson diseases.

The utilization of EMF having a strength of mT (militeslas) to induce bone tissue formation during the repair process of bone consolidation and to control osteoporosis is well established. These therapeutic applications of magnetic fields involve the production of growth factor which, in addition, cause spiral osteocytes to generate the ciliary neurotrophic factor (CNF) that is related to the repairing of the trauma-associated neural damage.

It is also possible that during a magnetic stimulation treatment for osteoporosis, the far magnetic field of the coil applied around the waist of the patient reach inadvertently his head, with enough strength to work as a simultaneous treatment for neurodegenerative problems.

**Objectives.** It has been established that there is a link between the deprivation of calcium known as osteoporosis and mental decline in elderly people. Both situations can be treated by means of magnetic stimulation.

This study is intended to assess the efficacy of two types of treatment: simultaneous magnetic stimulation of the head and the hip and the stimulation of the hip alone.

**Methods.** When applied over the hip, a feeble fraction of the therapeutic magnetic fields reaches the head unintentionally. The strength of such fraction is calculated.

**Results.** The strength of the magnetic field that is inadvertently applied over the head satisfies the parameters established by Salkind in order to treat degenerative problems that affect the brain.

**Conclusions.** The link between the magnetic stimulation treatment of the hip osteoporosis and its effects on degenerative processes may be explained on the basis that the magnetic field increases the permeability of the blood-brain barrier.

However, the beneficial effects of the magnetic stimulation on degenerative processes are more likely to be due to the fraction of the field that is generated by the electric current that runs through the coil over the hip.
Acknowledgements. We would like to acknowledge the Research Unit of Clinic CEMTRO (Madrid, Spain), for the help during the performance of this study.

P-128 MILLIMETER WAVE TREATMENT IS INCOMPATIBLE WITH ORAL KETAMINE IN EXPERIMENTAL MODEL OF NEUROPATHIC PAIN IN MICE

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Temple University School of Medicine, Philadelphia, PA, USA.

Summary of Abstract. Millimeter Wave Therapy (MWT) is based on the systemic biological effects that develop following local skin exposure to low power electromagnetic waves of millimeter range. In our previous experiments we determined that MWT-induced hypoalgesia is a specific and reproducible phenomenon that involves the peripheral and central nervous systems, as well as endogenous opioids. MWT was effective in suppressing acute, chronic non-neuropathic, and chronic neuropathic types of pain. The effect was power- and frequency-dependent. In the present set of experiments, MWT was combined with different doses of oral ketamine to potentiate the antinociception effect of the treatment for the most resistant to conventional treatment neuropathic pain. Ketamine is a non-competitive NMDA receptor antagonist, which was also shown to suppress neuropathic pain.

The unilateral Chronic Constriction Injury (CCI) of the sciatic nerve in Swiss-Webster mice was used as an experimental model of neuropathic pain. On the 13th day after the surgery mice were treated with a combination of Ketamine (1, 10, 50, and 100 mg/kg in 0.2ml of H2O by gavage) and exposure to MW (Frequency = 61.22 GHz; Average incident power density = 13.3 mW/cm²; Length of exposure = 15 min; Site of exposure = nose). Animals were treated for 10 consecutive days (one dosage of Ketamine and/or one MWT each day). The level of mechanical allodynia was evaluated using the wire surface test during the treatment, and 10 days after the treatment was over.

The results of the experiments were unexpected. Both treatments significantly decreased the level of neuropathic pain in mice if applied separately: Ketamine (most effectively in the dosage of 50 mg/kg) during the treatment, and MWT — in the post-treatment period. However, when used together, the treatments canceled each other. Furthermore, when MWT was combined with 50 or 100 mg/kg of Ketamine, the level of neuropathic pain in experimental animals significantly increased. We concluded that Ketamine treatment should be considered as a contraindication for MWT.

Objectives. To determine the effectiveness and type of interaction in combined treatment with MW and oral ketamine for suppressing the symptoms of experimental neuropathic pain.
Methods. All experiments were carried out on male Swiss-Webster mice. Experimental neuropathic pain was created in animals by surgically constricting the right common sciatic nerve. The Wire Surface Test (WST) was used to evaluate mechanical allodynia in mice during the treatment and in the post-treatment period. The Integral Index of Pain and Discomfort (IIPD; which incorporated such endpoints as the number of paw protective movements, the total time the injured paw was held above the wire surface, and the total number of vertical movements) was used for the quantitative evaluation of pain in the WST. Ketamine (a non-competitive NMDA receptor antagonist) was administered for 10 consecutive days, starting from day 13 after the surgery (Fig.1). The following doses of Ketamine were used: 1, 10, 50, and 100 mg/kg in 0.2 of H2O via gavage.

MWT was conducted using Russian-made generator G4-142. During the exposure to MW animals were restrained for 15 min (duration of exposure). Based on our previous results, the nose was chosen as the area of exposure in all the experiments. Each mouse’s nose during the exposure was located at the center of the antenna aperture at a distance of 0-1 mm from its front edge. The peak power density at an output power of 30 mW and frequency 61.22 GHz was 56 mW/cm². The average incident power density within the antenna aperture was 13.3 mW/cm².

10 experimental groups were created:
1. CCI + Sham MWT Starting from the day 13 after the CCI, once a day, for 10 days animals were restrained for 15 min, but not exposed to MW
2. CCI + MWT 10 times, once a day mice were exposed to MW only
3. CCI + Ket1 For 10 days, once a day mice were treated with 1 mg/kg of oral Ketamine only
4. CCI + Ket10 10 mg/kg of oral Ketamine
5. CCI + Ket50 50 mg/kg of Ketamine
6. CCI + Ket100 100 mg/kg of Ketamine
7. CCI + Ket1 + MWT In addition to MWT mice were treated with 1 mg/kg of oral Ketamine
8. CCI + Ket10 + MWT
9. CCI + Ket50 + MWT
10. CCI + Ket100 + MWT

Results. The experiments demonstrated that MWT with the above parameters can suppress CCI-induced neuropathic pain in mice. In the post-treatment period the level of IIPD becomes statistically significantly lower than that of sham exposed animals. During the 10 days of treatment and the first 5 days after the treatment was over, the level of neuropathic pain was suppressed by Ketamine treatment when dosages of 10 and particularly 50 mg/kg were used. Some exacerbation of the level of pain was noticed in the post-treatment period when 100 mg/kg of Ketamine was applied. At the same time, combination of the treatments was completely ineffective. The treatments canceled each other. Furthermore, when MWT was combined with 50 and 100 mg/kg of oral Ketamine, a statistically significant increase of level of pain was registered during the 20 days of experiment.

Conclusions. 1. MWT significantly decreases the level of neuropathic pain in the post-treatment period in mice following CCI to the sciatic nerve
2. Ketamine decreases the level of neuropathic pain during the treatment and in the early post-treatment period
3. Combination of MWT and oral Ketamine treatment results in exacerbation of symptoms of neuropathic pain in mice following CCI to the sciatic nerve
4. Ongoing treatment with Ketamine should be considered as a contraindication for MWT
5. Mechanisms of MWT-Ketamine interaction need to be studied further

Acknowledgements. This work was sponsored by NIH NCCAM, grant number P01-AT002025

Figure 1. Time-schedule of experiments in mice with CCI to the sciatic nerve. WST — Wire surface test. MWT — millimeter wave treatment.

P-129 STUDY OF THE FEASIBILITY OF AMELIORIATION OF THE VIRAL, BACTERIAL AND/OR FUNGAL LOAD BY APPLYING A NON-INVASIVE IN-VIVO BIOCOMPATIBLE BIPHASIC AND ELF ELECTRIC FIELD AND/OR PULSED MAGNETIC FIELD.

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Summary of Abstract. Anecdotal reports regarding therapeutic In-vivo non-invasive biocompatible application of pulsed Magnetic fields, which have the potential to create currents of several uA within living tissue, and square biphasic wave ELF electric field as an alternative treatment for various human conditions which involve some degree of sepsis, were examined, as well as a set of publications regarding bacterial and viral inactivation.
A promising correlation has been observed between both, suggesting that several parallel, partially understood phenomena may be causing the observed therapeutic results. Our experiments will examine feasibility of these field effects and explore possible mechanisms of action, by separating the effects of time of exposure, frequency, waveform, electric, magnetic, electromagnetic fields in a controlled temperature environment in an effort to build a connection between the observed phenomena in the claimed in the anecdotic reports and the related bibliography.

**Objectives.** To create a link between the observed anecdotic data and past scientific publications. Our Lab experiments will enable us to separate the effects of electric, magnetic and electromagnetic fields on easily (and inexpensively) cultured bacteria, including Escherichia coli and bacillus subtilis in order to be able to build a good model for the explanation of the observed anecdotic reports. This in turn will help to optimize the parameters for setting the adequate ranges to be able to give a scientifically supported basis over which can be envisioned an alternative treatment for some diseases.

**Methods.** In the anecdotal reports studied, a square, 4Hz biphasic current is applied non-invasively by placing electrodes over the ulnar and radial arteries on the wrist of the volunteer, expecting that several uA per millimeter squared pass through the infected blood or tissue. The treatments usually consist on the application of field generating devices constantly over a period of thirty minutes. A total of one application was claimed to be effective. The treatment can be accompanied by inducing current of the same magnitudes specifically over infected organs, by means of a repetitive magnetic pulse. This is hoped to cause mainly an antiseptic effect on the surrounding tissue, being the septic blood the preferred target, in order to drop significantly its pathogenic load. At the same time, this is hoped to be transparent to other tissue, causing no significantly irreversible change. Similar significant decrease in viral infectivity has already been reported for the HIV virus in [1, 2, 3, 4]. Among other mechanisms that may be lowering the pathogenic load by means of cell signaling, change in ph, etc. Regarding lab work, the microorganisms will be suspended in a distilled water solution with different salt concentrations depending on the case, and in a controlled temperature environment; fields with the previously mentioned properties can be applied with different intensities and frequencies in order to find the specific microorganism inactivation threshold and range determined by these parameters.

Results. Anecdotal reports claim that the currents being applied are improving the patients condition, and it is hypothesized that this is due to a significant reduction in the viral and/or bacterial load in the blood and target tissue. Our lab settings will enable us to vary the fields, times of exposure, waveforms and salt concentration in a controlled manner, in order to experimentally set the ranges of inactivation of the previously mentioned microorganisms. Our preliminary results indicate that a $4\mu\text{A}$ per millimeter squared current density, results in a $1\log$ inactivation of $B.\ subtilis$ in water, while in an isotonic solution there is no inactivation. Follow-up experiments to understand the mechanisms of the observed differences in inactivation are ongoing.

P-130 DESIGNING AN IMPLANTABLE GPS ANTENNA TO TRACK THE ELDERLY WITH DECLINING MENTAL CAPACITY

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Summary of Abstract. A miniature implanted inverted-F antenna is studied and designed for the GPS (global positioning system) tracking of a person. The antenna was modeled and analyzed in an implantable scenario using HFSS. An antenna prototype was built and tested when immersed in a body simulating liquid confirming good return loss and satellite signal reception capacity.

Objectives. The objective of this work is to analyze and design a miniaturized Hilbert Planar inverted-F antenna (PIFA) for implantable GPS application. The antenna when subcutaneously implanted in a person’s body will help locate the elderly with declining mental capacity (Alzheimer’s disease) with the help of an implanted GPS receiver.

Methods. The geometry of the proposed Hilbert PIFA is shown in Fig. 1. The antenna trace width and the gap between the traces was $0.65\text{ mm}$. More detailed studies on the Hilbert PIFA can be found in our earlier works [1]-[3]. The substrate and superstrate used for the antenna was Duroid 5880 (dielectric constant, $\varepsilon_r=2.2$, loss tangent: $\tan\delta = 0.0009$) primarily because it has very similar properties like the biocompatible material Teflon (dielectric constant, $\varepsilon_r=2.1$, loss tangent: $\tan\delta = 0.001$) and because it was readily available in our laboratory. The heights of the substrate and the superstrate were $3.0\text{ mm}$ and $1.6\text{ mm}$, respectively. Both the substrate and the superstrate measured $30\text{ mm}$ by $30\text{ mm}$. Parametric analyses of the different factors which can change the antenna performance such as, substrate and superstrate properties, their thicknesses, location of the antenna feed and the shorting pin, and the depth of the antenna inside the human muscle tissue were investigated using HFSS. Finally an antenna prototype was fabricated and tested by immersing it in a body simulating liquid. Return loss characteristics were measured and field tests were performed with the help of a GPS evaluation kit (SIRF Evaluation Kit III). During measurement, the whole antenna was enclosed within a thin layer of water resist
adhesive flexible sealant to protect the antenna from being shorted out by the conductive fluid. An RG174 cable was used to connect the antenna with a network analyzer cable through a hole created in one of the side walls of the container which was also sealed with the sealant. Muscle tissue equivalent fluid was prepared according to the recipe described in [4] using distilled or deionized water, sugar, and salt resulting in a test material which had a dielectric constant of 53.8 and conductivity of 1.4 S/m at 1575 MHz.

**Results.** The antenna was resonant at 1575 MHz and had a bandwidth of 4% within 2:1 VSWR. Field test for the GPS antenna in air is compared with that of the antenna immersed in the body simulating solution. Fig. 2(a) shows field test results for the antenna in air. Clearly since the antenna was designed for operation within the human body it did not perform well in air and hence it was not successful to lock into any satellite when interfaced with the GPS Kit and a laptop computer. This is evident from the red circles shown in Fig. 2(a) and from the non-existent C/No data. On the other hand as shown in Fig. 2(b), when the antenna was immersed in the body simulating liquid the antenna was able to lock into seven satellites (green color represents satellites with signal locked). At least four satellites are required for the GPS system to work properly. The Tracking View screen displays the locations of the satellites in the azimuth and elevation planes. The outer circle represents the horizon (Elevation=0 degrees), the inner circle represents 45° and the center point is directly overhead (Elevation=90 degrees). Az and El represents the azimuth and elevation locations of the satellites respectively. The vertical straight line towards N represents the 0 degree angle. The C/No of these useful satellite signals were 28, 27, 25, 25, 22, 24, 25 dBHz, respectively.

**Conclusions.** An implantable GPS antenna is analyzed, designed, and measured. Field test results demonstrated that the antenna can lock into satellites when immersed in a body simulating liquid.

**Acknowledgements.** This work was supported in part by the National Science Foundation Career Award ECS 0237783.

**REFERENCES:**
Summary of Abstract. The most serious period during heart surgery is the time when the blood is re-introduced to the heart. At that point, the heart has been deprived of adequate oxygen (i.e., ischemia) and re-oxygenation (i.e., reperfusion) produces reactive oxygen species that can be life threatening. Studies on myocardial function have shown
that the protein hsp70, stimulated by an increase in temperature, leads to improved survival following ischemia reperfusion (I-R). Low frequency electromagnetic fields (EMF) also induce the stress protein hsp70, but without elevating temperature. We have examined the hemodynamic changes in concert with EMF preconditioning, the upregulation of the HSP70 gene and the induction of hsp70 protein to determine whether improved myocardial function occurs following I-R injury in a rodent model.

**Objectives.** Sprague-Dawley rats were exposed at 8µT 60 Hz in a custom made exposure cage for 30 minutes prior to I-R. Ischemia was induced by ligation of left anterior descending coronary artery (LAD) for 30 minutes, followed by 30 minutes of reperfusion. Blood and heart tissue samples were taken at 10 minute intervals for hsp70 detection by Western blot and RNA detection by rt-PCR.

**Methods.** Quantification: density of the bands on the films was measured using image analysis software (ImageJ v1.38, NIH). Statistics: Continuous variables were expressed as Mean ± standard error and compared using two-tailed t-testing. Paired t-testing was used to evaluate significance within groups at multiple time points. A p-value of less than 0.05 was considered statistically significant.

**Results.** A clear effect on systolic contractile function in EMF-treated animals was found after reperfusion, as shown by significant increases in contractile function, such as, left ventricular (LV) maximum power and cardiac output. These changes occurred without evidence of concurrent LV hypertrophy or at the expense of reduced diastolic function, which might have been expected with pressure-volume overload seen after ischemic injury. EMF induced significantly high levels of both HSP70 RNA transcription and hsp70 within thirty minutes after initial exposure. These elevated levels persisted for more than three hours. Additionally, ventricular diastolic function (relaxation at constant volume), was markedly improved in EMF-treated animals. Significant recovery of myocardial function was seen in EMF treated rats after 10 minutes of reperfusion and survival was sustained for more than 120 minutes.

**Conclusions.** In the experiments reported here we applied EMF to increase hsp70 levels and improve survival following I-R. While stress proteins in cells and tissues have been previously utilized as diagnostic markers and prognostic indicators, a safe, non-invasive method of augmenting endogenous defense mechanisms as a therapeutic tool, such as EMF exposure, has significant clinical potential. The data indicate that exposure with EMF prior to reperfusion, in a mammalian model, induces upregulation of the HSP70 gene and subsequent increased levels of hsp70 protein and, most importantly, improved ventricular function after ischemia-reperfusion.

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**P-132 EFFECT OF ELECTRICAL STIMULATION ON NEURAL STEM CELL GROWTH AND DIFFERENTIATION**

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**Summary of Abstract.** To successfully apply stem cells therapeutically to treat nervous system injuries and neurodegenerative diseases, control of stem cell growth and differentiation is necessary. Individual cues present in vivo which contribute to changes in stem cell behavior are best discovered and studied in vitro. We have designed and fabricated a microelectrode device to combine electrical cues with chemical, physical and biological cues and investigate the effect of these cues on neural progenitor cells (NPC) derived from the hippocampus of adult rats and humans. The device allows for selective stimulation of individual cells present in microgrooves that physically confine the cells. Before using this device we must determining the properties of an electrical signal that will differentiate the greatest number of neurons by using methods which allow a large population of NPC to be stimulated. Currently, platinum electrodes are used to stimulate NPC with biphasic pulses.

**Objectives.** The aim of this research is to characterization effects of electric stimulation on neural progenitor cell growth and differentiation.

**Methods.** Adult hippocampal NPC from rats and humans are used in these experiments. Glass coverslips containing NPC are placed, between two platinum electrodes, in differentiation media. Cells are stimulated every day for six days for 1 hour. After six days in vitro, cells are labeled immunocytochemically to determine the obtained cell fate. Fluorescent microscopy images are captured and cells are counted to determine the percentage of cells that have differentiated to each of the neural cell lineages. Once optimal parameters are found cells will be stimulated locally using a microelectrode array. A microelectrode array with the ability to combine electrical cues with chemical, physical and biological cues and investigate the effect of these cues on NPC has been designed and fabricated by our group. The device allows for selective stimulation of individual cells present in microgrooves that physically confine the cells. The effect of neural stem cell growth and differentiation in response to the combination of electrical and topographical/chemical/biological cues will be investigated.

**Results.** Preliminary results indicate that electrical impulses increase the adoption of the neuronal fate by NPC

**Conclusions.** The use of electrical stimulation in combination with other cues that guide differentiation will be useful in the development of stem cell based therapies.

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P-133 SINGLE EXPOSURE TO 1439MHZ PULSED TDMA FILED DOES NOT AFFECT GLIAL CELLS: A TIME DEPENDENT STUDY.

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Summary of Abstract. The widespread proliferation of mobile phones has led to the concern of possible adverse effects of electromagnetic fields (EMF). Here we conducted experiments to estimate the effects of EMF on cells of the central nervous system, which are closely located to mobile phones when they are in use. Glial cells (microglia and astrocytes) are the main constituents of the central nervous system, where they perform important functions, such as structural and nutrititional. Both cells are known to produce specific proteins when damaged. Microglia produces ionized calcium-binding adaptor molecule (Iba1) in response to ischemia. Astrocytes produce glial fibrillary acidic protein (GFAP) during degenerative alterations, such as Gliosis. Some reports have examined the influence of EMF on the rat brain assessed by changes of Iba1 and GFAP expressions, however results are still controversial. In the present study, we aimed to clarify the effect of EMF on glial cells, dependent on the period of exposure to EMF.

Objectives. To evaluate the time-dependent effect of EMF on glial cells, and the possible reversibility of the effect.

Methods. Rats, weighed 220-300g, were used. They were randomly divided into three groups; group (i) sham group (n=24, not exposed to EMF, but placed in the exposure system for 120 minutes), group (ii) rats exposed to lower EMF output (n=24, SAR=2W/Kg, 120 minutes, single exposure), and group (iii) rats exposed to high EMF output (n=24, SAR=6W/Kg, 120 minutes, single exposure). Each group was divided into three groups according to the period between EMF exposure and sacrifice: (a) rats sacrificed on the day of exposure, (b) rats sacrificed on the third day after exposure, and (c) rats sacrificed on the seventh day after exposure. The expression of Iba1 and GFAP proteins were examined by immunohistochemistry, using formaldehyde-fixed, paraffin-embedded micro-sections of the rat brains. The primary antibodies against Iba1 and GFAP were commercially purchased.

Results. No deaths were observed during the study, and all the rat brains were immunohistochemically analyzed. The grade and extension of immunohistochemical staining for Iba1 and GFAP were assessed in the (i) cerebral cortex, (ii) hippocampus (CA3), (iii) stratum and (iii) hypothalamus. Also, the morphological changes of astrocytes and microglia, stained for GFAP and Iba1, were examined.
Throughout the study, no significant difference was observed either in the grade or the extension of immunostaining between the sham and the exposure groups (SAR=2W/Kg and SAR=6W/Kg), neither in the morphological changes of astrocytes and microglia.

**Conclusions.** In the present study, we clearly demonstrated that single exposure to EMF at SAR=2W/Kg and 6W/Kg does not affect either the viability or the activity of rat glial cells.

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**P-134 INTRACELLULAR DNA DAMAGE INDUCED BY INTENSE SINUSOIDAL ELECTRIC FIELDS**

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**Summary of Abstract.** Intense electric fields with frequencies exceeding 1 MHz are known to cause intracellular effect to mammalian cells. Here, it is experimentally demonstrated that intense burst sinusoidal electric fields (IBSEFs) induces intracellular DNA damage. The 100 MHz, 200 µs long IBSEFs with various amplitudes up to 200 kV/m were applied to Chinese hamster ovary (CHO) cells. The intracellular DNA was investigated by means of the comet assay method. The result indicates that DNA damages occur in the cells exposed to the IBSEF with moderate amplitudes exceeding 10 kV/m. The comet pattern of the IBSEF treated cells is different from that of ultraviolet treated cells, which implies that the IBSEF might be a different type of stress than ultraviolet for the CHO cells. Additionally, according to the electrophoresis analysis against IBSEF treated naked DNA, which showed no damage, intracellular electric fields are suggested to trigger the biological process for DNA damage.

**Objectives.** Biological cells exposed on intense pulsed electric fields (PEFs) exceeding 100 kV/m have been investigated fluently, since the intense PEFs are capable of giving unique stress dependent to its pulse duration and intensity. It is reported that PEFs with long pulse duration in the level of micro-seconds or milli-seconds affects the cell membrane to make a pore, the electroporation, while the nano-second pulsed electric field (nsPEF) enables to cause intracellular effect. Since the pulse duration could be discussed as frequency, the electric fields with the frequency exceeding approximately 1 MHz are attractive for the intracellular stimulation. We have proposed the use of intense burst sinusoidal electric fields (IBSEFs) for well-defined fields to the biological target. Here, it is experimentally demonstrated that DNA damage induced to Chinese hamster ovary (CHO) cells exposed on IBSEF with frequency of 100 MHz, various electric field amplitude of up to 200 kV/m, and burst duration of 200 µs by means of comet assay. The mechanisms of the phenomena should be either physical (primary) effect or chemical (secondary) effect. We have performed
an agarose gel electrophoresis analysis against DNA exposed on IBSEF with frequency of 100 MHz, amplitude of 200 kV/m and two burst condition, 200 µs single shot and 5 ms 4 shots for investigating the physical effect.

Methods. IBSEF generator consists of signal generator, pulse generator, and RF amplifier, each controlling the frequency, burst duration and amplitude, respectively. The system was connected to an application cell via a 50 Ω coaxial cable. An application cell consists of two parallel platinum plate fixed on a glass plate by using heat resistant resin. The cell, of which the electrode separation and the cross section are 1 mm and 10 mm², respectively, is regarded as a 66 Ω resistive load. Chinese Hamster Ovary (CHO) cells were employed as our biological target. We have performed the comet assay, a simple, rapid and low cost method, for detecting the DNA damage. The comet assay was proceeded based on the protocol introduced at the Comet Assay Forum. Samples were stained by SYBR Green I, a fluorescent dye which intercalate to double strand DNA, and observed by fluorescent microscopy. We have performed the agarose gel electrophoresis against naked DNA (1 kbp marker)exposed on IBSEF for investigating whether the IBSEF is damaging the DNA directly or not. Electrophoresis was conducted in a TAE buffer, with applying 35 V for 4 hours, and observed using transillumination device.

Results. Frequency of 100 MHz, burst duration of 200 µs IBSEF with various electric field amplitude from 1 to 200 kV./m were applied to CHO cells, and investigated by comet assay. The results were compared with negative control and positive control (5 minutes ultraviolet irradiated cells). Morphologically concerning the comet pattern, a negative control shows a short, thin tail, indicating natural DNA damage during the experiment procedure. The positive control shows a long, thick and smooth comet tail indicating that DNA was shattered into pieces. On the other hand, IBSEF treated cells showed long, but in different pattern as the positive control. The positive comet pattern shows slight or no comet head, which describes that the damages occur in almost entire DNA, while one for the IBSEF showing clear head and thin tail, implying that only a part of DNA was chipped. The comparison between the ultraviolet irradiation and the IBSEF exposure suggest that the effect is totally different from that of UV in the DNA damage mechanisms. DNA damages were evaluated by comet extent, which is defined as the distance between the leading edge and the trailing edge along the direction of electrophoresis. The edges were determined as the positions with a certain brightness level in comet patterns. The result clearly shows that IBSEF with amplitudes exceeding 100 kV/m induces DNA damages. Slight damages were observed even with the lower electric fields of 10 and 30 kV/m.

100 MHz, 100 kV/m IBSEF with two exposure conditions of single 200 µs and 5 ms x 10 shots were applied to a naked DNA (1 kbp DNA marker) for investigating whether the DNA was damaged directly or not. The gel which contained the negative control, IBSEF treated DNA, and positive control (20 minutes ultraviolet irradiated DNA) was stained with SYBR Green II, a fluorescent dye which attaches to RNA or single strand DNA, and observed by a transillumination device. The electrophoresis result of the positive control shows less intense fluorescent than negative control, and the pattern seems to be expanded. This indicates that the ultraviolet irradiation breaks DNA into extremely small pieces. On the other hand, clear changes in ladder patter were no to be detected between the IBSEF
treated DNA and negative control. The result implies that the DNA damage induced by
the IBSEF might not be a direct physical stress to the DNA.

**Conclusions.** In conclusion, we have demonstrated the intracellular DNA damage induced
by applying 100 MHz electric fields with amplitudes exceeding 10 kV/m. The fact that the
naked DNA is not broken by applying IBSEF of sufficiently high energy implies that the
intracellular electric field might be a trigger for initiating biological reaction resulting in
DNA fragmentation different from ultraviolet irradiation, which is known to damage DNA
directly.

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**P-135 NARROWBAND AND BROADBAND RADIOFREQUENCY/MICROWAVE EXPOSURE SYSTEM
FOR REAL-TIME MONITORING OF CELLULAR RESPONSES**

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**Summary of Abstract.** Improvements to and results of studies using a novel exposure de-
vice for real-time monitoring of cellular effects in response to pulsed RF/microwave electric
fields are described.

**Objectives.** Previously we described the design, fabrication and characterization of a novel
exposure system to assess non-thermal effects of radiofrequency/microwave (RF/MW) fields
in the frequency range 0.75 − 6.0 GHz on adrenal chromaffin cells [Hagan et al., 2006]. This
system has the flexibility of delivering broadband and narrowband high intensity electric
fields of up to 2 MV/m to chromaffin cells, while allowing real-time monitoring of cellular
effects at 37 °C using fluorescent imaging techniques. Since that initial description, several
modifications were undertaken to improve 1) the quality of the fluorescence images obtained,
2) the method for continuously perfusing the cells with a balanced salt solution (BSS), 3)
temperature control, and 4) the method for delivery of a drug stimulus to the cells.

**Methods.** Bovine adrenal chromaffin cells were isolated, cultured and disaggregated into
single cells and cells in small clusters as previously described [Craviso, 2004]. The cells
were immobilized on an ITO (indium tin oxide) coverslip, which comprised the bottom of a
specially designed circular cell perfusion chamber, and loaded with the fluorescent calcium
indicator dye, Calcium Green-1. The chamber was attached to the exposure device in which
RF/MW fields are delivered to the cells by means of a carefully designed coaxial applicator
having a highly tapered inner conductor [Hagan et al., 2006]. The entire setup was mounted
on the stage of a Nikon epifluorescence microscope, and observations of the cells were made with a Photometrics CoolSNAPHQ monochrome camera and simple-PCI image analysis software (6.1).

**Results.** Control experiments were carried out in which intracellular calcium level was monitored under basal conditions to assess spontaneous cellular activity, and in response to application of the nicotinic receptor agonist dimethylphenylpiperazinium (DMPP). A variety of conditions were used that included different temperatures (room temperature to 37 °C) and flow rates of the BSS, different injection rates, volumes and concentrations of DMPP, and chromaffin cells at different times in culture (up to three weeks). These results, together with the results of studies underway in which the cells are being exposed to RF/MW fields, will be presented. For a MW-modulated Gaussian pulse centered at 3.5 GHz at an average forward power of 62.5 W, the electric field magnitude at the center of the cell perfusion chamber is as high as 1.09 MV/m within a region of radius 0.16 mm. Higher field intensities are currently possible with the available RF amplifier. The electric field magnitude is symmetrical about the axis of the chamber with concentric circular regions of equal electric field, decreasing to 5.12 kV/m at the outer region of the cell perfusion chamber. This gives us the capability of simultaneously viewing cells on the coverslip that are exposed to different magnitudes of electric field. Because individual cell locations are precisely known with respect to the center of the exposure device during any particular experiment, a one-to-one comparison between their observed fluorescence activity and the computed electric field magnitude at the cell location can be accomplished.


**Conclusions.** Based on our studies, the RF/MW exposure system designed provides us with the ability to record intracellular calcium activity at temperatures to within ± 0.2 °C of a set point in the absence and presence of applied external stimuli that include both drugs and RF/MW fields.

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P-136 PEOPLE EXPOSURE TO EMF IN ITALY. MONITORING NETWORK, RISK PERCEPTION AND COMMUNICATION PROCESS

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Summary of Abstract. The Italian Ministry of Communications established the Italian national Electromagnetic Field (EMF) monitoring network with the technical support of Fondazione Ugo Bordoni (FUB) and in collaboration with the local Environmental Protection Agencies of all Italian regions. Such network and the related public communication campaign had a multiplicity of aims: inform the public about the current scientific knowledge and about the current Italian regulation, inform that the exposure to radio-frequency EMF is well below the prescribed limits in the vast majority of cases; activate procedures to reduce the exposure levels when they exceed the attention thresholds.

Objectives. Some people perceive risks from RF exposure as likely and even possibly severe. At the moment there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects.

Methods. Most of international regulations are essentially based on the guidelines formulated by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The Italian regulator adopted a more precautionary stance than most other Governments concerning electromagnetic field exposure. The protection against acute health effects is defined through exposure limits. (For mobile phone frequency range the limit is $20 \, \text{V/m}$.) The protection against long-term effect is sought by defining the attention thresholds. The definition of a threshold equal to $6 \, \text{V/m}$ for the electric field is a consequence of applying a “caution factor” of 10 to the power density. The quality targets are the set of field values that should be pursued when a new telecommunication infrastructure is planned; it is not important if the structure is isolated or inserted in a context where other installations already exist.

Results. The network is based on remote measurement stations and on a transmission structure, devoted to the measured data flow towards Local Control Centres (Fig. 1). According to the guidelines, the typical duration of a measurement campaign could be between two and four weeks. The guidelines also defined the criteria for correct positioning of monitoring stations, that had to be placed far from sources that could affect the measured values, such as cellular base stations: it is to be remembered that the monitoring network aimed at evaluating exposure levels for the population, hence they had to be placed where the population actually is.
The monitoring stations of all kinds (Fig. 2) are light, compact and easily transportable. This was explicitly required in the auction, because sensors had to be moved in order to monitor the Italian territory as thoroughly as possible. All remote stations operate with photovoltaic arrays and are equipped with a GSM modem, which is used for communication with the relevant Local Control Centre: the downlink is used for remote configuration, programming and polling, while the uplink is used for reporting the measurements and other information such as alarms. Published data consist in wideband mean (over 6 minutes) and peak values of electric field. The 6 minutes averaging period is prescribed by the Italian current regulations.

**Conclusions.** Measured data cannot be anyhow changed: they can be declared either valid or not, without altering their contents; non valid data are recorded for statistical and documentation purposes only. The validation process performed by each Environmental Agency follows a set of guidelines defined in a joint working group coordinated by FUB. In cases corresponding to limits violations, the monitoring results were useful in highlighting this problem, and the necessary procedures for the reduction of the exposure were activated accordingly. Therefore, the monitoring network is an active instrument that local administrations can use to minimise exposure of the citizens to EMF.

The monitored sites have been divided into four different categories, i.e. schools, homes, hospitals and public places (including zones opened to the public like gardens, shops, etc.). Another important part of the communicational process is the direct approach with population. This happened by means of two kinds of vehicles, the BluBus and the BluShuttle, which have travelled all along Italy, showing to the citizens how a monitoring campaign is carried out, what is the meaning of the numbers displayed by the instrument and giving a direct answer to the questions of the citizens who face the problem of EMF exposure in a worried approach.

![Monitoring network architecture](image)

**Figure 1.** Monitoring network architecture
Figure 2. Measurement station
P-137 ANALYSIS OF TEXTUAL DATA IN SIGNIFICANT DOCUMENTS. SOME IMPORTANT WORDS ABOUT ELECTROMAGNETIC POLLUTION

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Summary of Abstract. The object of the communication is a textual analysis of the corpora obtained from the documents listed below. The study singles out the most used terms in order to give an evaluation of the use of such "concepts" in these documents. The results of the analysis presented with various diagrams and tables allow the reader to grasp information about the use of some important words in the analyzed documents.

Objectives. The corpora analyzed are the following.
- WHO. World Health Organization
- COST. European Cooperation in the field of Scientific and Technical Research
- EU. European Union
- ICNIRP. International Commission Non Ionizing Radiation Protection
- IEE. Institution of Electrical Engineers – UK

The textual behavior of the following key words is outlined: exposure, fields, health, risk, RF, measures, frequency, levels, public, electromagnetics, effects, studies

Methods. Our analysis either studies the words used in the various documents either makes a comparison between the corpora.

The size of such corpora is showed in fig. 1 where the occurrences are the number of words. The behavior of terms exposure and field is showed in fig. 2 and fig. 3.

The relative frequency is the frequency of a textual unit (word) in a corpus normalized to the size of the corpus.

The rank is the position (number) of the form (word) in the list sorted for decreasing frequency.

Results. The results here show that some words are repeated strings which have a significant semantic role: some concepts are used in a very particular way in a single document, other concepts are not imperative or absent.

It is possible to obtain conclusions or questions even about the topics treated or to raise fresh questions about the texts.

From the analysis of a single corpus it is possible to obtain information about how the organization producing the document works and about its targets.
Conclusions. The terms exposure and field are imperative in all the analyzed texts. Exposure is highly used in IEE documents, the use of field in COST texts is remarkable. Exposure is almost regular in the various document while field exhibits a behavior very unbalanced. The use of field is cheap in IEE. The illustrated results treat only two terms. It is anyway a suitable description of the cares of the specific literature to such foremost themes, giving an unreplaceable insight about the topics treated in the documents.

The textual analysis, in particular the statistical analysis of a text, cannot take the place of the reading of the text. When a text or a corpus is an object of study it is not possible to be independent from presuppositions. A mathematically founded approach, could give an improvement to the validity of the speculation, especially for the understanding of the contents of a text, allowing to know the sensitivity to the communication of the risk in the studied texts.

This work could be the base for point out a methodology of content analysis of documents about electromagnetic pollution. The corpora are often too large for a normal (traditional) reading. Statistical text analysis is not interpretative: tables and diagram become a careful map of contents.

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Figure 1. Size of the analyzed corpora
Figure 2. Exposure in the various corpora

Figure 3. Field in the various corpora
P-138 THE WHOLE SCAPE OF SCIENTIFIC LITERATURE IN THE
EMF-PORTAL

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Summary of Abstract. The aim of the EMF-Portal is to provide the whole scope of
the scientific results and discussions about the health effects of electromagnetic fields. It is
widely accepted that the aggregation of scientific information is the foundation for the gen-
eration of the current knowledge about EMF, but the complexity of this interdisciplinary
subject makes it difficult to actually obtain this knowledge.
In the past, the primary focus of the EMF-Portal has been the content presentation of experi-
mental medical and biological studies; recently, the scope has been continuously extended
by new contents to now cover the whole range of scientific information.

Objectives. The literature collection of the internet information system EMF-Portal, ac-
cessible at http://www.emf-portal.org, has the objective to provide plenty of up-to-date
information without the need to do time-consuming investigation work via library and In-
ternet databases: The database should provide the bibliographical data of all published sci-
entific information in the area of bioelectromagnetic interaction as well as the contents of the
included studies. In order to cover the whole spectrum of EMF related subjects, the scope
of the database had to be extended widely: Besides presenting medical/biological studies,
it should also be the goal, to offer information about epidemiological studies, publications
on the effects of electromagnetic fields on implants and body support, reviews/surveys, and
international recommendations and guidelines.
All published scientific data should be presented up-to-date and complete. Bibliographi-
cal data of newly published studies should be offered as soon as they are public available,
extending the information with a detailed summary of the important studies shortly after.

Methods. Conventional literature databases mostly provide only bibliographical data of
scientific studies, whereas the literature collection in the EMF-Portal also covers the contents
of the collected publications. The structure reproduces the pattern of scientific publications
in order to represent all essential data about materials, methods and results and thus makes
the studies comparable.
The data model follows the nature of the respective publication to appropriately reproduce
the studies in detail. Several different data models of specific study types have been de-
veloped so far, all created in a similar structure to allow the comparability. Figure 1 shows
the contents of the literature database in the EMF-Portal.
For all types of publications additional features are available supplementing the biblio-
graphic data; the summaries of the medical/biological, epidemiological and publications
concerning medical implants and devices are very detailed. Information about materials
and methods, results, and exposure characteristics are offered. More general descriptors
are gathered for reviews/surveys and international recommendations and guidelines; here
a quick overview of the nature and content of the publication is provided. Particularly the
International guidelines and recommendations are usually ‘public domain’ and hence as a
full text available with free access for everyone.
The literature collection is imbedded into the EMF-Portal, an information system with a unique search engine for extensive queries in all descriptors, an elaborate glossary, and other help tools; all these offers support the user in understanding the interdisciplinary subject matters.

**Results.** Compact, comparable and understandably edited research results from the appropriate studies, as well as other scientific information of the last 25 years are available in the context of the literature database as the major part of the EMF-Portal, an information platform covering the effects of electromagnetic fields on human beings and their surroundings. Currently, the literature collection holds more than 12,000 scientific publications in the area of bioelectromagnetic interaction. This includes nearly 5,000 medical/biological publications, 600 epidemiological studies, almost 300 publications on the effects of electromagnetic fields on implants and body support, 1,000 reviews/surveys, and 70 international recommendations and guidelines. More than 2,000 publications are summarized and presented in a unique structure, which allows a fast and easy comprehension of the contents of each publication.

**Conclusions.** The EMF-Portal is accessible free of charge at http://www.emf-portal.org

![Figure 1.](image-url)
**P-139 EFFECTS OF MAGNETIC FIELD ON OOCYTES MATURATION AND ITS PARTHENOGENESIS IN MICE**

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**Summary of Abstract.** The author observed the changes of oocytes maturation in superovulation and oocytes in vitro maturation after magnetic field exposure. Meanwhile parthenogenesis of matured oocytes also investigated through one of a protease inhibitor induction. The mRNA level of cyclin B1 in oocytes was measured by semi-quantity RT-PCR method. The results showed that the number of oocytes with first polar body was raised significantly in magnetic treat (2 hr or 3 hr for 15 days) group by superovulation in vivo (P<0.01, P<0.05). The matured oocytes cultured in vitro also were induced increase by magnetic treatment. The matured oocytes of MT group have more parthenogenesis ability result from magnetic hysteresis effects. The mRNA level of cyclin B1 in matured oocytes has little elevated tendency after magnetic field exposure. This change maybe related to oocytes maturation increase.

**Objectives.** Magnetic therapy has been applied to practice for thousand years in China. With the development of magnetic therapy, more and more people are concerned about the influence of strong magnetic field on germ cells, especially on growth and development of oocytes. However, they are little known about magnetobiological effects on oocytes maturation. In this study, the changes of oocytes maturation (extrude the first polar body) in vivo and in vitro after magnetic field exposure were observed using the superovulation and IVM (in vitro oocytes maturation) methods, and parthenogenesis of matured oocytes was also investigated. the mRNA level of cyclin B1 in oocytes was measured by semi-quantitative RT-PCR method.

**Methods.** 1. Animals and treatment: Female, Kunming mice, 4−6 wks of age. The mice were treated with 0.4T, 8Hz frequency magnetic field. The immatured oocytes were treated with 0.02T magnetic field. 2. Oocytes in vitro maturation (IVM): Mice were induced to superovulate by intraperitoneal injection of 10 IU of pregnant mare serum gonadotrophin (PMSG). after 48 hours, ovaries were removed. Oocytes were released by a sterile needle in M2 medium. The immatured oocytes with cumulus cells were collected and cultured in M16 medium containing 10 IU/mL PMSG in a CO2 incubator for 15 hours. 3. superovulation Oocytes collection: The mice were injected PMSG, after 48 hours, HCG (10U/per mouse) was injected, then superovulated oocytes were remove. Ovarian cumulus was deleted by 0.1% hyaluronidase. Matured oocytes was counted under stereomicroscope. 4. Semi-quantitative RT-PCR: The oligonucleotide primers are cyclin B1: 5’TATTGGGCGCCGGGTCACCA3’, 5’ACTTACTGTAGTTCTTCCACC3’, 417 bp, mGAPDH: 5’ GTAATCCTTGCAGTGAGTGACG3’, 5’CATCTCCATCT GTCTGATCTGG3’, 746 bp. cyclin B1 and mGADPH fragments were amplified by one step RT-PCR kit. The density of the bands was quantified by UVP imaging and analysis system and normalized by mGAPDH. 5. Statistical analysis: The data were statistically analyzed using ANOVA test or Chi-Square test.
Results. 1. The influence of low frequency rotating magnetic field on matured oocytes quantity in vivo: The mice of MT groups were exposed to rotating magnetic field (0.4T, 8Hz) for 2 hours or 3 hours per day, and continue exposure for 15 days. The matured oocytes by superovulation were check under stereomicroscope. The oocytes with first polar body were counted. The percentage of oocytes with first polar body was markedly increased after magnetic field exposure for 2 hours or 3 hours (Table 1).

2. The influence of static magnetic field on oocytes maturation cultured in vitro: The immatured oocytes were selected and randomly divided into control and magnetic treatment group (0.02T), then the oocytes cultured in M16 medium drops in an incubator for 15 hours. The number of oocytes with first polar body was check under stereomicroscope. The percentage of oocytes with first polar body cultured in vitro was significant increased after magnetic field exposure for 15 hours (Table 2).

3. The influence of stable magnetic field on parthenogenesis of matured oocytes: 150 matured oocytes cultured in vitro were selected from control and MT groups, then cultured with 50µM the sodium orthovanadate (SOV) which is a protease inhibitor to induce the parthenogenesis. After 48 hours, more than two-cell blastomeres were counted as parthenogenesis under stereomicroscope. The percentage of parthenogenesis of matured oocytes has the increase tendency after magnetic field exposure has been finished for 48 hours, there is no significant difference compared with control group. (Table 3)

4. The influence of magnetic field on the mRNA level of cyclin B1 in superovulation oocytes: The mRNA of fifty matured oocytes in control and MT group (Rotating magnetic field treatment for 2 or 3 hours once a day for 15 days) was extracted. The gene expression of cyclin B1 was measured using semi-quantitative RT-PCR method. The result was showed that there is no significant difference between MT and control group in the mRNA level of cyclin B1 (control: 1.66±0.45, MT 2hour: 1.89±0.86, MT 3hour: 2.12±0.62, n=3, ANOVA test)

Conclusions. No obviously harmful effects on mice superovulation was found after whole body exposed low frequency constant-strength magnetic field, however the number of oocytes with first polar body was raised significantly in magnetic treat (MT) group in vivo. This interesting results lead the researcher investigated the rate of matured oocytes cultured in vitro, low dose magnetic treatment also induced the oocytes maturation. The matured oocytes cultured in vitro have further developed ability as parthenogenesis induced by a protease inhibitor. The matured oocytes of MT group have more developed ability result from magnetic hysteresis effects. The mRNA level of cyclin B1 in matured oocytes of superovulation has little elevated tendency after magnetic field exposure. This change may be related to oocytes maturation increasing. Further study in time change of mRNA of cyclin B1 should be done in future in order to elucidate the possible mechanism of oocytes maturation induced by magnetic field.

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P-140 WOULD TEMPERATURE-BASED EXPOSURE LIMITS IMPROVE RF SAFETY STANDARDS?

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Summary of Abstract. Existing RF safety regulations limit field exposures at frequencies above 100 kHz to avoid harmful body tissue temperatures, however standards and guidelines are based on reference levels for specific absorption rate (SAR), not $T_{tissue}$. Recognizing SAR as an intermediate quantity suggests basing RF safety standards on $T$ rather than SAR, allowing a direct relationship between exposure (RF power density, electric field strength and magnetic flux density) and associated hazard [Foster and Glaser, 2007]. Our consideration of the pros and cons led to the conclusion that for certain device-related localized exposures and all exposures above $\sim10$GHz, $T$ might lead to simpler and clearer safety regulations, but for other circumstances, particularly far-field whole body exposures, $T$-based criteria are problematic and not an improvement over SAR.

Objectives. To evaluate potential benefits of $T$-based reference levels in comparison to existing SAR-based approaches.

Methods. We examined the proposition that increased $T_{tissue}$ is a necessary and sufficient condition for limiting human exposure to RF energy by considering spatial characteristics of RF heating and physiological responses of specific human brain regions.

Results. Historically, whole body average SAR, regional and partial body averages, localized extremes (SAR hot spots), and SAR in volumes <1cm$^3$ have been examined by direct measurements using calorimetry and temperature or field strength measurements over the areas and volumes of interest. Recent attention to higher frequencies and devices used close to or within the body have led to a proliferation of computer-based dosimetric models at millimeter resolution where direct measurements of $T$ or SAR are difficult or impractical. Importantly, high spatial resolution of SAR does not correspond to a similar resolution in $T_{tissue}$ because diffusion and convection quickly broaden $T$ distributions spatially and inhibit temporal gradients. Using a simple model for localized heating at 10 W/kg, Foster and Glaser [2007] showed that $\Delta T_{max}$ for a volume 1mm in radius is $\sim10^{-2}$ K with a thermal response time measured in seconds. In contrast, SAR can be strong near a small source or dielectric discontinuity and pulsed fields can change SAR arbitrarily fast. The Pennes bioheat equation relating RF heating, diffusion, and heat loss by blood perfusion in tissues leads to expression of the equilibrium temperature change $\Delta T_{eq}$ as $\approx SAR\tau_{eff}C^{-1}$, where $C$ is heat capacity and $\tau_{eff}$ an effective thermal response time [Foster and Erdreich, 1999]. Blood perfusion spreads any localized heating such that 1cm is roughly the smallest distance over which $T$ varies significantly in perfused tissue.

Discretized computer models determine SAR and subsequently $T$ by assigning anatomically appropriate dielectric and thermal properties to each voxel and subjecting the entire volume to a particular RF field pattern. Fine-grained determination of SAR and $T$ can be difficult because dielectric and thermal properties can have sharp transitions at tissue interfaces, such as at the superficial layers of skin where tissue hydration is non-uniform, in
anatomically layered muscle, fat and connective tissue, and in air-filled cavities. $T$-based models lose precision because they require additional parameters that unavoidably increase overall uncertainty, although the practical impact is uncertain. Current $SAR$-based whole body limits have a foundation in the cessation of operantly conditioned behavior detected across mammalian species in association with $\Delta T \sim 1K$ for the body core, but without specification of $\Delta T$ at the critical site(s) [D’Andrea, 2003 p S46]. Difficult questions arise in determining a permissible $\Delta T$ in specific tissues, with the hypothalamus providing a strong example. In order to control body temperature, it operates with a control loop gain of 30-40 [Guyton, 1976] such that an induced hypothalamic $\Delta T$ of 0.5K causes thermoregulatory responses appropriate to an environmental change of 15-20K. This illustrates that a $T$-based safety standard could not be applied universally to all body tissues. Because $T_{\text{tissue}}$ and not only $\Delta T$ above a variable baseline can be critical, safety margins for exposures involving a large part of the body would be affected by clothing, environmental humidity, temperature, air flow, and body hydration, thereby reducing universality of such guidelines. The effect of heating rate, which has not been studied sufficiently, also may be significant.

A complete reformulation of existing standards would require recasting more than 40 years of research in order to select frequency-dependent thresholds for $T$ and $\Delta T$ for various body regions and tissues, whole- and partial-body exposures, near- and far-field conditions, resonance and non resonance conditions, and for models representing a variety of body sizes and morphological types. Conceptually, refocusing the standard on the existing temperature data appears simple, even elegant, but, given the diversity of exposure, questions left unexamined in the past might need reexamination using tools newly available.

What can be gained by using temperature as the explicit variable for standard setting? Benefits are obvious for localized exposure cases where $SAR$ is high over one or several voxels because the relative range for $T$ will be less extreme than for $SAR$, permitting more realistic field exposure limits. Foster and Glaser [2007] noted other benefits: simpler compliance and guidance for future millimeter wave scientific research. What is lost? Because $T$ instead of spatial peak $SAR$ is useful for only a fraction of all RF safety standard applications, further complexity would be added to an already complicated standard.

**Conclusions.** We see potential advantages for reference levels expressed in terms of $T$ and $\Delta T$ that would be more practical for exposures at high frequencies ($>10\text{GHz}$) and from localized internal and external sources, particularly in the near field of small devices where exposure of deep tissues is severely attenuated. We do not see benefits from a revision over the full range of exposure scenarios, which would need considerable effort and research with doubtful advantages over existing standards and guidelines that have gained wide acceptance. More thought is needed to assess the practical advantages and acceptability of a standard with dual criteria for its reference levels.

References:
P-141 EXPOSURE ASSESSMENT OF THE ELECTRIC AND MAGNETIC FIELDS OF ENERGY SAVING BULBS

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Summary of Abstract. Energy saving bulbs are strongly recommended in national energy saving programs. However it was recently suggested that these bulbs generate electromagnetic fields (EMF’s) which might be hazardous for exposed individuals (Crürem, 2007). In order to verify these allegations we measured the waveform, the harmonic content, the electric and magnetic field of 8 different types of energy saving bulbs at different distances using a halogen and an incandescent lamp as control lamps. The measurements were performed by means of the most adequate measurement equipment. We found that the bulbs produced ELF (50 Hz) and IF (27 – 29 kHz) electromagnetic fields. It was concluded that the electric and magnetic field were in compliance with ICNIRP(1998) reference levels. On base of the precautionary principle and avoidance of possible interferences with pacemakers it was recommended that the energy saving bulbs have to be placed at least 20 cm away from individuals.

Objectives. On base of the of the ICNIRP (1998) guideline interpretation, testing the allegation that the EMF’s generated by energy saving bulbs are hazardous for exposed individuals

Methods. The waveform of the electric and magnetic field were measured by means of the Fluke ScopeMeter (190-serie). The harmonic content and the electric and magnetic field were measured by means of ELT-400 equipment (Narda). The strength of electric and magnetic fields were measured by means of the PMM frequency analyzer (PMM EHP 50 A). The distances between the tip of the probe and the lamp under test were 0, 5, 10, 20 and 40 cm respectively. The lamp sample consisted of 7 energy saving bulbs or compact Fluorescent Lamps with integrated ballast (CFLi)and 2 control lamps:
1. CFLi 11 W
2. CFLi 15 W
3. CFLi 20 W
4. CFLi 13 W
5. CFLi 20 W
6. CFLi 15 W
7. CFLi covered 20 W
8. HALOGEN CLASSIC A ES 42 W (control)
9. INCANDESCENT SYLVANIA BRILL.SATIN 60 W (control)

The measurements were performed in a typical installation setup and environment with a single naked lamp. Note that in a real installation environment many parameters such as grounding, line voltage, temperature or luminaries with metal enclosures can more or less...
influence the results of the EMF magnitude. Lower values might be obtained if lamps are installed in luminaries with appropriate grounding and metal enclosure.

**Results.** The tables 1 and 2 show the magnetic induction field (B-field) and electric field (E-field) obtained at different distances from the 9 lamps respectively. Measurements were performed in the 12 − 1000 frequency range.

Even in the worst case measurement situation (Distance = 0 cm), neither the B-field nor the E-field exceeded the ICNIRP (1998) reference level recommended for the general public in the 8 − 800 Hz frequency range. The strength of the E- and B-field from the control lamps are nearly in every case substantially below those generated by the energy saving bulbs.

Since the energy saving bulbs also generated a substantial E-field in the first and second harmonic on the one hand and in the intermediate frequency range from 27 − 90 kHz on the other hand, the ICNIRP (1998) summation formula for the E-field was applied on the data of table 3 in order to decide whether the ICNIRP (1998) reference level for multiple frequencies was exceeded or wasn’t.

Table 3 shows the E-field strength as a function of the frequency obtained in the worst case situation (Distance = 0 cm).

The result of the summation formula (Σ) in table 3 shows that the E-field of every energy saving bulb is smaller than 1 and by consequence in compliance with the ICNIRP (1998) reference level for multiple frequencies.

Because the measured B-field is very weak in every frequency domain when compared to the reference levels the summation formula was not applied for this field.

**Conclusions.** We conclude that the B- and E-field generated by energy saving bulbs are stronger than those generated by halogen and incandescent lamps. However, both fields of the energy saving bulbs are in compliance with the ICNIRP (1998) reference levels so that after the interpretation of this guideline no health risk has to be expected for the exposed people. Anyway since rather high E-field strengths are generated nearby the bulbs in different frequency ranges, on base of the precautionary principle it is advised that those lamps are placed or fixed at about 20 cm from people.

This recommendation is also based on the fact the interference between the E-field and older pacemakers (produced before 1990) could occur when the bulbs are too close to wearers of this implants.

**Acknowledgements.** We are grateful to the department of Environment, Nature and Energy of the Flemish Government for funding this study.
P-142 EXPOSURE ASSESSMENT OF THE MAGNETIC FIELD GENERATED BY PORTABLE SPOT WELDING DEVICES USED IN SMALL AND MEDIUM-SIZED ENTERPRISES

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Summary of Abstract. Portable spot welding (PSW) is a type of resistance welding where high currents are used and consequently strong magnetic fields may be produced. PSW is mainly used in SMEs and in a less extend in big industries for welding metal sheets. The aim is to define if the magnetic induction field (B-field) produced by PSW-devices is in compliance with the ICNIRP(1998) reference levels and basic restrictions for occupational and general public to which young school welders should belong. ICNIRP(1998) guidelines instead of the directive 2004/40/EC are used because both occupational and general public are considered in the present paper. The results showed that the waveform of the PSW devices is sinusoidal and the fundamental frequency 50 Hz without any important harmonic content. From the B-field measurements we conclude that the PSW devices generate B-fields exceeding the occupational reference level at 1 cm from the welding contact point and the one for the general public at a distance of 10 cm from the contact point. Though the 100 $\mu$T general public level is exceeded at the chest of the welder in normal welding position, the induced current density calculated in the worst case situation is substantially weaker than the current density limits for workers and for the general public. In order to avoid possible interference between the generate B-field and electronic implants, it is advised that wearers of pacemakers or other electronic implants do not use PSW devices.

Objectives. To define if the B-field produced by PSW-devices is in compliance with the ICNIRP(1998) reference levels and basic restrictions for occupational and general public on the one hand and with limits for interference with pacemakers and/or other active implants on the other hand.

Methods. The waveform of the electric and magnetic field were measured by means of the Fluke ScopeMeter (190-serie). The harmonic content and the magnetic induction fields were measured by means of ELT-400 (Narda). The distances between the tip of the probe and the spot welding contact point were 1, 10, 20, 30, 40, and 50 cm respectively. Six repeated measurements of the B-field were performed at each distance from the contact point. The distribution of the B-field over the whole body was measured in the normal welding position of the operator.

The PSW was a TECNA model with the following characteristics:
- SN: 2 kVA nominal power at 50% duty cycle
- S(max): 11 kVA nominal power at 50% duty cycle
- U(20): 1.75 V secondary no load voltage
- I2cc: 7.4 kA max. short circuit sec.

The welding duration is 1.3 seconds.

Results. Table 1 shows the 50 Hz B-field strength measured under different conditions at distances ranging from 1 to 50 cm from the spot welding contact point.

At a distance of 1 cm from the contact point the B-field exceeds in any case the occupational
ICNIRP (1998) reference level of 500 µT. As for young school welders it is important to mention that the reference level of 100 µT recommended for the general public is exceeded at a distance of 1 and 10 cm respectively. If we extrapolate the data of table 1 to the compliance testing CENELEC prEN 50444 and prEN 50505 (2006) protocols [Basic standard for the evaluation of human exposure to EMF from equipment for arc welding and allied processes] where the point of investigation is 20 cm away from the cable, we see that the B-field is compliant with both reference levels at 20 cm from the contact point during spot welding.

Table 2 shows the distribution of the B-field over the body of the welder during the PSW welding.

The strongest B-fields are observed on the hands (213 & 435 µT) and at the chest (108 µT) respectively.

Since a good fit between the calculated induced current obtained by the ICNIRP(1998) simplified formula $J = \pi R f \sigma B$ [1] and complex models has been shown for a sinusoidal waveform and a body for homogeneous and isotropic conductivity (NIR workshop on Calculation, Kielce 2007), we applied formula [1] for estimating the current induced in the chest of the welder. The calculation was performed in the worst case situation with:
- a current loop radius (R) in the chest of 0.50 m
- a frequency (f) of 50 Hz
- a conductivity (σ) of 0.2 S/m
- a B-field of 108 µT

Even by using an unrealistic induced loop radius of 0.5 m the in the chest/trunk induced current density was calculated to be 0.17 mA/m². It is much below the 10 mA/m² and 2 mA/m² current density limit for workers and general public respectively.

Since it is not clear if the interference level of a 50 Hz B-field with pacemakers produced before 1990 is 100 or 200 µT a precautionary rule is that carriers of such implants do not work with PSW devices.

**Conclusions.** From the B-field measurements we conclude that the PSW devices generate B-fields exceeding the occupational reference level at 1 cm from the welding contact point and the one for the general public at a distance of 10 cm from the contact point. Though the 100 µT general public level is exceeded on the chest of the welder in normal welding position, the induced current density calculated in the worst case situation is substantially weaker than the current density limits for workers and for the general public. Thus, according to the interpretation of the present ICNIRP(1998) guideline the B-field generated by PWS-devices should not contain direct health risks for the exposed operator. However, since relative strong B-fields are produced on the chest of the operator, wearers of pacemakers or other electronic implants should not use PSW devices in order do avoid interference problems.

**Acknowledgements.** The presented results are a part of an ongoing two-years’ collaboration project between the Belgian Welding Institute and VITO concerning a pre-standardisation project on EMF’s generated by different welding procedures. We are grateful to the Belgian Bureau for Standardisation (Het Bureau voor Normalisatie (NBN))” of the National Government for funding this project.
P-143 ASSESSMENT OF THE OCCUPATIONAL RF EXPOSURE LEVEL OF MAINTENANCE TECHNICIANS WORKING FOR A FRENCH MOBILE PHONE OPERATOR

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Summary of Abstract. The objective of this study is to assess the electromagnetic fields exposure of maintenance technicians during their workdays for downlink contributions only. 24 maintenance technicians have carried, during 3 workdays, personal exposimeters able to record the ambient electromagnetic field exposure level. The results show that the mean value of electromagnetic field is 0.2 V/m [CI95%: 0.2-0.3 V/m] corresponding to 0.001% of the lowest worker limit (in power).

Objectives. The technicians of maintenance have to maintain the radio site equipments (antennas, transmitters..) in service to insure a good quality of service. They mainly operate on roof or mast (where different kind of antennas are installed: GSM 900 MHz, GSM 1800 MHz, UMTS; but other contributors like FM or TV may coexist) to realize preventive or curative actions on radio sites. 220 workers of BOUYGUES TELECOM insure that mission for more than 100 000 interventions in 2006. To guarantee the safety of workers, beacons and safety perimeters are placed around the antennas where exposure limits [1] may be exceeded. When workers need to operate closer to the antennas, various procedures, like radio site shut down, have been established. Regarding the regulation, a European directive [2], which has not been transposed in France, requires the employer to assess the electromagnetic fields level to which maintenance technicians are exposed. The objective of this study is to assess the electromagnetic fields exposure of maintenance technicians during their workdays for downlink contributions only.

Methods. 24 maintenance technicians from the Centre-Alpes region have carried, during 3 workdays, personal exposimeters able to record the ambient electromagnetic field exposure level. 2 exposimeters were used simultaneously: DSP120 Antennenissa (able to record expositions level between 0.08% and 12.31% of the field public limit in 12 different programmed bands: FM, TV3, Tetra, TV4&5, GSMtx, GSMrx, DCStx, DCSrx, DECT, UMTStx, UMTSrx, Wifi) and Radman Narda (able to measure and record electromagnetic fields level between 6% and 162% of the power public limit for all contributors between 1MHz and 40GHz). Concerning the mobile telephony bands, only downlink-bands have been considered (corresponding to fixed installed source). Exposimeters were configured with optimal settings to estimate in a most precise way the exposure level: for the DSP120, measurement period has been fixed to 5 seconds for a recording of 597 minutes (9h57); concerning the Radman, the measurement period has been fixed to 30 seconds for 13 hours of recording). A cycle of recording began from the place of residence and ended on the way
back, the two exposimeters were placed in a carry bag. At the end of the workday, participant downloaded data which has been validated at various level to determine if they were correct and if the analysis is possible (no empty files, correct configuration, synchronisation between the 2 exposimeters). The participants informed their activities in a daily index form.

**Results.** Recordings have been realized from 2006.11.22 to 2007.01.12 with 24 workers, 71 workdays have been collected. Data from 68 workdays by 23 workers are exploitable. One day of measurement corresponds to 75 000 values of electromagnetic fields. To use all this data, exposure indicators have been defined (175 indicators for DSP120 and 54 for Radman). From these indicators, averages have been calculated: mean field = 0.2 V/m [CI95%: 0.2-0.3 V/m], mean of maximum field = 7 V/m [CI95%: 2-11 V/m], percentage of measures below 0.13 V/m = 55% [CI95%: 50-61%], percentage of measures below 1 V/m = 97% [CI95%: 96-98%], percentage of measures above 5 V/m = 0.1% [CI95%: 0-0.4%].

**Conclusions.** This study shows that the occupational radiofrequency exposure of the maintenance technicians working for a French mobile phone operator measured with personal exposimeters is extremely low, thanks to the safety procedures (beacons, safety perimeters, radio site shut down). The mean value of field is 0.2 V/m [CI95%: 0.2-0.3 V/m] corresponding to 0.005% of the lowest public limit (in power), and to 0.001% of the lowest worker limit (in power) [1].

**References**


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**P-144 TERATOLOGICAL EVALUATION OF MOUSE FETUSES EXPOSED TO A 20 KHZ OR 848.5 MHZ EMF**

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**Summary of Abstract.** We performed a teratological study to evaluate the importance of gestational age with regards to the exposure of middle field (MF) or radiofrequency field (RF) electromagnetic field on pregnant ICR mice. In this study exposure to 30 microT with 20 kHz MF or 848.5 MHz with 2.0 W/kg SAR RF did not cause any observable adverse effects on mouse fetuses.
Objectives. We performed a teratological study to evaluate the importance of gestational age with regards to the exposure of middle field (MF) or radiofrequency field (RF) electromagnetic field on pregnant ICR mice

Methods. The pregnant mice were exposed to a 20 kHz MF magnetic field at 30 microT for 8 hrs/day or 848.5 MHz RF at 2.0 W/kg (SAR) for 45 min/day in a carousel irradiator. The animals were sacrificed on the 18th day of gestation and the fetuses were examined for mortality, growth retardation, changes in head size and other morphological abnormalities.

Results. We examined RF 848.5 MHz with SAR 2.0 W/Kg, which did not induce a temperature increase, and found no observable effect on the prenatal development in fetuses.

Conclusions. Our results suggest that that exposure to 30 microT with 20 kHz MF or 848.5 MHz with 2.0 W/kg SAR RF did not cause any observable adverse effects on mouse fetuses.

Acknowledgements. This work was supported by a Grant from Ministry of Information and Communication of Korea (years 2006 and 2007).

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P-145 THE EFFECTS OF ELF ELECTROMAGNETIC WAVE ON INTRACELLULAR CA2+ CONCENTRATION IN TIME–FREQUENCY DOMAIN

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Summary of Abstract. The intracellular Ca2+ concentration is frequently measured as a studied biological objective, because the Ca2+ is widely concerned with life action. The intracellular Ca2+ concentration is varying. As well known, varying signal can be studied in time domain or frequency domain, but study in time-frequency domain is the most available method, because the results obtained by the time-frequency analysis can show not only the comprehensive characteristics of the spectrum as that in frequency domain, but also the time of each appearance, duration of life and the times of repeated appearance of each dispersive component, so more information of signal can be obtained. Based on the data from experiment, the time-frequency analysis was applied to analyze intracellular Ca2+ fluctuations, and to investigate the bio-effects and the biological window-effect of ELF electromagnetic waves on intracellular Ca2+ levels. The spectra of intracellular Ca2+ fluctuations in time-frequency domain are divided to two classes: continuous spectrum and dispersive spectrum components. Then exposures of electromagnetic waves, the spectra in time-frequency domain are divided to two circumstances, the one that resulted certain changes, and the one, which didn’t. The first circumstance, which was considered to induce a bio-effects in time-frequency domain, presented two unique properties: the continuous spectrum of cellular Ca2+ fluctuations in time-frequency domain was narrowed by the
high-energy spectrum component restrained, and the distribution and the frequencies of the dispersive spectra were changed; The second circumstance, which was considered without induce bio-effects in time-frequency domain, presented without consequences of the continuous spectrum and the dispersive spectra. Furthermore, the pulse frequencies and intensities producing the bio-effects are dispersive and intervallic, which means that ELF pulsed electromagnetic waves induce biological window-effect on the physiological intracellular Ca2+ levels in time-frequency domain. Two frequency- and one intensity-windows were observed within the range of applied pulse frequency and intensity in this research: 16 Hz and 45 Hz, and 53V/m, respectively.

**Objectives.** because the results obtained by the time-frequency analysis can show not only the comprehensive characteristics of the spectrum as that in frequency domain, but also the time of each appearance, duration of life and the times of repeated appearance of each dispersive component, so more information of signal can be obtained. Based on the data from experiment, the time-frequency analysis was applied to analyze intracellular Ca2+ fluctuations, and to investigate the bio-effects and the biological window-effect of ELF electromagnetic waves on intracellular Ca2+ levels.

**Methods.** time-frequency domain analysis

**Results.** The spectra of intracellular Ca2+ fluctuations in time-frequency domain are divided to two classes: continuous spectrum and dispersive spectrum components. Then exposures of electromagnetic waves, the spectra in time-frequency domain are divided to two circumstances, the one that resulted certain changes, and the one, which didn’t.

**Conclusions.** The first circumstance, which was considered to induce a bio-effects in time-frequency domain, presented two unique properties: the continuous spectrum of cellular Ca2+ fluctuations in time-frequency domain was narrowed by the high-energy spectrum component restrained, and the distribution and the frequencies of the dispersive spectra were changed; The second circumstance, which was considered without induce bio-effects in time-frequency domain, presented without consequences of the continuous spectrum and the dispersive spectra. Furthermore, the pulse frequencies and intensities producing the bio-effects are dispersive and intervallic, which means that ELF pulsed electromagnetic waves induce biological window-effect on the physiological intracellular Ca2+ levels in time-frequency domain. Two frequency- and one intensity-windows were observed within the range of applied pulse frequency and intensity in this research: 16 Hz and 45 Hz, and 53V/m, respectively.

**Acknowledgements.** Dr.Haibin Wang
P-146 ESTIMATES OF E- AND H-FIELD SUSCEPTIBILITY OF IMPLANTED PACEMAKERS TO INTERFERENCE FROM MOBILE PHONES


Summary of Abstract. The results of extensive testing performed to characterize the conditions under which pacemaker radiofrequency interference (RFI) occurs have been published by the University of Oklahoma and other institutions. All of these studies reported the separation distance between a subscriber telephone handset (mobile phone) and the pacemaker required for no interference. RF interference to pacemaker operation, as with other types of RFI, depends among other things upon the amplitude (level) of the RF energy. That is, below some threshold level, no interference is found. The level is conventionally measured or calculated in units of field strength, such as volts per meter (V/m). None of the studies that were reviewed measured or reported the field strength required to cause pacemaker interference. Only distances were reported. The distance values are useful to pacemaker wearers using mobile phones, but are not useful for other purposes, such as evaluating pacemaker RFI potential around base station antennas. Hence, the corresponding field strengths occurring at particular positions relative to the transmitting handset are estimated using various models. The field strength data reported here can be used as field reference values, below which no interference is likely to occur.

Objectives. To convert euclidean distance data to field strength using various computer models, including Moment Methods (NEC, WIPL), and Finite Difference Time Domain.

Methods. Computer modeling of various mobile phone antenna types was conducted. Several mathematical models were used to calculate the free-space, near-field, electric and magnetic field strengths at the surface of the body, within which interference with normal pacemaker operation was found to occur. Effects on free-space field strength due to the presence of the body (or equivalent phantom) in the underlying data were considered.

Results. [Preliminary] Reported EMI data on various pacemaker models and types and five mobile phone technologies (IS-95 CDMA, IS-54/55 TDMA [50 Hz], ITU-R M8 TDMA [11 Hz], TDMA [22 Hz], and PCS 1900 TDMA [217 Hz] suggests that interference susceptibility is also dependent upon the ELF modulating component. The greatest potential for pacemaker interference is associated with the TDMA [11 Hz] technology. Preliminary calculations using a moment method model (NEC) suggest that at 850 MHz, an equivalent free-space field strength of about 47 V/m at the location of the body is required to cause interference to an implanted pacemaker. [Additional work is in progress with other methods and models to confirm this result and provide additional results.]

Conclusions. [Preliminary]. The single result suggests that present MPE limit (NCRP Report No. 86) for the public of 46 V/m (spatial peak) may be adequately protective of pacemaker wearers in many cases. Note that peak, not whole-body average, fields are the criteria for pacemaker interference assessment.

Acknowledgements. The views expressed are those of the authors and do not necessarily reflect the views of the U. S. Federal Communications Commission (FCC). Mention of trade names does not constitute endorsement by the FCC.
P-147 IMPACT OF BLOOD VASCULARIZATION MODELS ON THERMAL RESULTS OF NUMERICAL SIMULATIONS

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Summary of Abstract. In this paper, the influence of a blood vascularization model selection with temperature dependency is studied. Four temporal blood perfusion laws are investigated.

Objectives. A 3D numerical model has been developed to determine electric field, SAR and temperature distributions in the human body during radiofrequency fields exposition [N. Siauve et al., "Optimization of 3D SAR distribution in local hyperthermia", IEEE Trans on Magn, vol.40, 1264-1267, March 2004]. The 3D thermal model, meshed from computerized tomography scans, was based on the useful Penne’s bioheat equation which introduces a constant blood perfusion term. However, since vasculature response to heat exposition is strongly temperature dependent, a complementary study has been performed on blood flow impact so as to improve the 3D numerical model.

On the one hand, a literature review on the laws of variation of blood perfusion term as a function of temperature is presented. On the other hand, keeping in mind that the selected law of variation will be finally applied in the 3D model, the influence of most realistic literature laws is studied on a fat/muscle two layers geometry. Then a last study consists in the determination of the factor of scale that must be taken into account for the perfusion variation with temperature: on each tissue (global scale) or on each node of the mesh (local scale).

Methods. In literature, several laws of blood perfusion variation with temperature had been found. Two main methods are used for calculated these laws, the direct method [V. D’Ambrosio et al., ”Numerical model for RF capacitive regional deep hyperthermia in pelvictumors”, Int Fed Med Bio Eng, pp459-466, March 2004], [M. Kowalski et al., ”Model-order reduction of nonlinear models of electromagnetic phased-array hypertermia”, IEEE trans on bio eng, vol.50, 1243-1254, November 2003], [K. Gosalia et al. ”Thermal elevation in human eye and head due to the operationof a retinal prosthesis”, IEEE trans on biomed eng, vol.51, 1469-1477, August 2004], [J. Lang et al., ”Impact of Nonlinear Heat Transfer on Temperature Control in Regional Hyperthermia”, IEEE trans on Biomed Eng, vol.46, 1129-1138, 1999] or the indirect method like the approach of Abraham and al. [J. Abraham et al., ”A thermal ablation bioheat model including liquid-to-vapour phase change, pressure and necrosis-dependent perfusion, and moisture-dependant properties”, International jour heat and mass transfer, vol.50, 2537-2544, March 2007]. In the first case, the perfusion term is calculated directly from temperature value. In the second case, the function of damage of Henriques-Moritz which is usually employed for calculate burn injuries is introduced. This
function of damage is temperature dependent. Based on these variation laws, profiles of perfusion rate have been plotted as a function of temperature (Figure 1) and compared in a range of temperature imposed by the chosen field of applications: hyperthermia treatment planning. Then they had been applied to a fat/muscle two layers configuration. Finally, so as to proposed the best solution for the 3D finite element model the variations laws have been compared when they are applied to local or global scale.

Results. - Variation laws profiles.
Profiles of the variations laws are depicts below in a range of temperature between 35 and 55°C for a fat sample and a muscle one (Figure 1). Three phases are observed, at lower temperatures, perfusion keep constant or slowly increase, then at a critical temperature, perfusion term begin to increase or accentuate his raising with temperature. In the third phase, one can notice that in two cases (D’ambrosio and Abraham laws of variation) a decrease of perfusion term is observed when the necrosis of vascular system occur. In the other cases temperature remain constant and equal to the maximal perfusion rate. It must be emphasis, that Abraham law is give as an example because input values aren’t those of muscle.

- Variations laws applied to a fat/muscle sample.
The variations laws are applied to a fat/muscle sample composed of two layers sample with the following specificities. A convective transfer condition is considered on the fat surface and a constant flux of 2500W/m² absorbed on surface is chosen so as to observed temperature up to 45°C. On rear face of the muscle temperature is assumed to be constant and equal to 37°C. At the interface, continuity of temperature and temperature gradient is considered.
Temperature results on fat and muscle surfaces are shown on the Figure 2. When perfusion rate is constant and equal to the maximum/minimum/average perfusion rate (Cste High/Cste Low/Cste Average configuration), temperature profile is the lower/higher/middle. At steady state there’s a mean deviation of 4.5°C between Cste configurations and the other ones in the case of muscle and 3.3 in case of fat. Differences between the Cste configurations and the configurations temperature dependent can reach 10°C.

- Comparative study of the local and global scale.
In the previous part, at each node the perfusion law has been applied with respect to the temperature at this node. In spite of locally apply the law of variation, the perfusion rate in the whole layer is the same and vary at each time as a function of the maximal temperature in the layer.
Global simulations generates temperature results lower than the for local simulations. For Lang and D’Ambrosio laws, the maximal temperature difference in fat is closed to 1.5°C and in muscle is closed to 2°C. In the case of Gosalia law, temperature differences are respectively closed to 2°C and 3°C.

Conclusions. Relatively to variable perfusion terms, constant ones generate errors not acceptable. Therefore in regard to multiscale study the D’Ambrosio and Lang laws will be apply to the 3D model. However, a main difficulty will be to found the variation law for all human tissues.
P-148 ELECTRICAL SYNCHRONIZATION MODULATION OF THE NA/K PUMPS: COMPUTER SIMULATION

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Summary of Abstract. Behavior of the Na/K pump currents when exposed to an oscillating electric field is studied by computer simulation. The pump current from a single pump molecule was sketched based on previous experimental results. The oscillating electric field is designed as a symmetric, dichotomous waveform alternating the membrane potential from -30 to -150 mV at the membrane potential of -90 mV. Based on experimental results from skeletal muscle fibers, the energy needed to overcome the electrochemical potentials for the Na and K-transports are calculated in response to the field’s two half-cycles. We found that a special designed oscillating electric field can eventually synchronize the pump molecules so that all the individual pumps run the same pumping rate and phase as the field oscillation. They extrude Na ions during the positive half-cycle and pump in K ions during the negative half-cycle. The field can force the two ion-transports falling into the corresponding half-cycles, respectively, but cannot determine their detail positions. In other words, the oscillating electric field can synchronize pumps in terms of their pumping loops but not a specific step in the loop.
**Objectives.** In this study we present the results of computer simulation in study of the Na/K pump synchronization in a physiological running mode by a specially designed oscillating electric field. The results are compared with our experimental results.

**Methods.** Concept of pump synchronization is similar to that of electronic synchronization, but more complicated in practice. In a synchrotron, an acceleration electric field can be applied specifically to the pathway of the electronic beam. Practically, it is impossible to influence one transport without affecting the other in a running loop. Any electric field applied to cell membrane either depolarizing or hyperpolarizing the membrane potential can only facilitate one ion-transport but inevitably hinder the other. Therefore, we have to consider the field effects on both ion-transports simultaneously.

We started from the pump current generated from a single Na/K pump based on a model that ion occlusion and deocclusion steps in each ion-transport limb are the only electrogenic steps. An oscillating electric field was designed including waveform, frequency and magnitude according to the energy differences for the two ion-transports so that one of the half-pulse functions as an energy trap and another as energy barrier for the two transports, respectively. A MATLAB program was developed to simulate the behavior of the two ion-transports when fall into each half-pulses.

**Results.** This study shows that individual pumps with initially different pumping rates and random pumping phases can be synchronized by a well designed oscillating electric field. As a result, the pumps all extrude Na ions during the positive half-cycle and then pump in K ions during the negative half-cycle. The measured positive currents generated by the positive half-pulse are mainly the outward Na currents and the negative currents elicited by the negative half-pulse represent the inward K-currents. In difference from the simultaneously-triggering a specific step in an interrupted mode, pump synchronization in running mode only restrain the ion-transports into the corresponding half-cycles, but the detailed position within the half-pulse can not be determined.

**Conclusions.** This study shows that a well designed oscillating electric field based on the physiological parameters of the Na/K pumps can be used to realize synchronization of the pumping rate at normal pumping mode. This result indicates that by gradually increasing the oscillating frequency and keep the pumps synchronized, the pumping rate can be progressively modulated to higher and higher values.

**Acknowledgements.** This work is partially supported by our research grants from NIH, 2NIGM50785, and NSF PHY-0515787.
P-149 REALISTIC SKELETON BASED DEFORMATION OF HIGH-RESOLUTION ANATOMICAL HUMAN MODELS FOR ELECTROMAGNETIC SIMULATION

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Summary of Abstract. Several techniques have been presented to deal with skeleton driven deformation of 3D skin models for visual purposes only. The work presented here extends and combines these techniques to deal with high-resolution anatomical full-body models, including deformation of all tissues and organs surrounding the rigid bones in an efficient way. This work focused also on a visual system to setup the hierarchical system of bones that drive the anatomical deformation in an easy way.

Objectives. The goal of this work was the development of a system which takes a high-resolution anatomical model and allows a visual setup of the influencing bones. It furthers allows positioning of the underlying bone structure taking into account user-defined joint constraints. The next step is the actual computation of the deformation with immediate visual feedback to the user. The posed anatomical models are finally used to simulate exposure to and interaction with electromagnetic radiation.

Methods. The crucial part of the skeleton based deformation of anatomical models is the setup of the influence regions of the bones. For this a tool has been developed and integrated into the existing electromagnetic simulation platform SEMCAD X. The user defines a set of bones as a hierarchical structure. Such a structure consists of a set of rigid bones connected with joints.

Every bone defines a volume of influence and a spatial weight distribution attached to it. The tool allows the user to manipulate the influence volume such that it matches the bone and the tissues surrounding it. Bones may have regions with overlapping influences. Every vertex in the model has a set of weights for every bone with an influence on it. The resulting transformation of the vertex is computed using a method called Spherical Blend Skinning described in [2] which computes the interpolation of a set of transformations in the quaternion space. To ensure a more realistic deformation, the rigidity of the bone is considered and a simple spring correction is used on the non-rigid parts of the model. This correction takes into account the actual shape of the bone model.

The bone hierarchy allows propagation of transformations through a whole limb if the user moves the parent bone, on the other side the tool makes use of known methods to solve the Inverse Kinematics problem to achieve a desired pose of the bone structure while satisfying defined joint constraints. This work uses a non-iterative method based on Lagrange multipliers described in [1] to simulate the articulation of the bone system which gives to the user a fast and intuitive way to define a pose.

Results. All the methods described in this work have been implemented and integrated into the software package SEMCAD X. Models with millions of triangles have been imported and posed, e.g. high resolution anatomical human whole body models from the Virtual
Family project [3]. A lot of effort was spent on the user interface for setting up the bone influence regions since this step resulted to be the most crucial part and the most time consuming one from a user perspective. This step still requires a lot of tweaking regarding the influence volumes, especially at complex joints like hand bones or the whole torso.

**Conclusions.** This work presents methods inspired by computer graphics based animations applied to the physiological postures of high resolution inhomogeneous anatomical human models. Whereas in computer based animation the sole purpose is usually to deform an empty skin, this novel approach was implemented in the context of electromagnetic simulations with anatomical models.

In particular addressing complex exposure situations, it resulted to be highly valuable to put the anatomical model of interest into the posture being addressed in the investigation, e.g., standing, sitting, operating or being exposed to an EM radiation emitting device, e.g., the influence of a hand holding a mobile phone. Application of the novel methods presented in this work to a variety of inhomogeneous high resolution models in different exposure situations have proven to be successful.

![Figure 1](image-url)
P-150 DESIGN OF BROADBAND MONOPOLE ANTENNA AND SAR ANALYSIS

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Summary of Abstract. This paper proposed a novel broadband printed monopole antenna for PCS/IMT-2000/WLAN terminals. The bandwidth of the realized antenna is 1.590 ~ 2.614 GHz(48.43 %) below the return loss of -10 dB which contain the required bandwidth of PCS/IMT-2000/WLAN band. The simulated and measured values of 1 g and 10 g averaged peak SAR on human head caused by the proposed antenna on folder-type phone were analyzed and discussed. As a result, the measured 1 g peak SAR value is 0.794 W/kg and 10 g peak SAR value is 0.368 W/kg at 1.8 GHz. The results are smaller than the reference SAR limit values that are respectively 1.6 W/kg and 2 W/kg on 1 g and 10 g averaged SAR values.

Objectives. The rapid development of mobile communication technology has led to the growth of various mobile phone services, such as WCDMA, DMB, and Bluetooth, which necessarily requires the development of antennas that are operable on dual or multiple bands. Furthermore, the distribution rate of cellular phones exceeded 95% in South Korea by 2007, suggesting that mobile phones are being used across ages and genders in the Far East. Given these conditions, the influences of mobile communication terminals on the
human body need to be taken into consideration, as the terminals are used so close to the body. This study involved the manufacture of a broadband monopole antenna suitable for PCS/IMT-2000/WLAN bands, so as to analyze the human specific absorption rate, (SAR), of the electromagnetic waves emitted by the antenna.

**Methods.** Firstly, the MWS of a commercial EM simulator CST was used to design and analyze the broadband monopole antenna to be used for the PCS/IMT-2000/WLAN bands. The antenna built was a micro strip antenna in which the emitter and the ground plane existed on different layers. The return loss of the manufactured antenna was measured using the spectrum analyzer. In order to determine the SAR of the electromagnetic waves, calculations using the SEMCD X, an SAR analysis tool, were used, and the determined SAR values were compared with those measured using an Essay-3, an SAR meter, by mounting the antenna on the terminal. The input power, the same as that of the terminal in use, was applied, resulting in the input power of 250 mW being registered at the time of the calculation and measurement of SAR.

**Results.** With a motion frequency band of -10dB or less being 1.590 ∼ 2.614 GHz, (48.4%), the manufactured antenna met all the bands of PCS, (1.750 ∼ 1.870 GHz), IMT-2000, (1.920 ∼ 2.170 GHz), and WLAN, (2.400 ∼ 2.480 GHz). According to the SAR calculation using SEMCAD X, the 1 g average SAR was 0.794 W/kg, and 10 g average SAR was 0.415 W/kg. However, according to the measured results, 1 g average SAR was 0.744 W/kg, and 10 g average SAR was 0.368 W/kg. These were the values meeting the FCC SAR limits: both 1.6 W/kg, (1 g average SAR limit), and 2.0 W/kg, (10 g average SAR limit).

**Conclusions.** With a motion frequency band of 1.590 ∼ 2.614 GHz, the manufactured antenna was applicable for PCS/IMT-2000/WLAN service bands. The measurement of SAR showed that 1 g average SAR and 10 g average SAR were 0.794 W/kg and 0.415 W/kg, respectively, which met the FCC SAR limits. The measurement environment used for this study may differ from that encountered in real life. Therefore, it appears that multiple studies are required in consideration of other factors, such as the hand forms and the locations that may affect SAR values, and the radiation characteristic changes by antenna structure, as seen in the directional antenna.

**Acknowledgements.** "This work was supported by the Korea Research Foundation Grant funded by the Korean Government(MOEHRD)” (The Regional Research Universities Program/Chungbuk BIT Research-Oriented University Consortium)
Figure 1. 1g and 10 g average SARs at the time of an input power of 250mW
Figure 2. SAR measurement results
P-151 DIELECTRIC PROPERTIES OF SKIN OVER THE ELECTROMAGNETIC SPECTRUM

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Summary of Abstract. Throughout the history of electromagnetic (EM) interaction with human tissue, research groups have measured dielectric properties (complex permittivity and conductivity) of human tissue at various frequencies. However, the terahertz (THz) region of the EM spectrum has remained largely unstudied. EM energy impinging on the human body must first pass through the skin, therefore it’s properties are of paramount importance. Empirical datasets in the literature calculate dielectric properties of skin using a human in vivo model. Continuing with this convention, dielectric properties of skin from 20Hz to the UV have been compiled. To span large voids in the compiled dataset (20 - 200GHz; 2-100THz) our group developed an extensive interpolation methodology based on Fourier Transform.

P-152 THE EFFECT OF WATER DISTRIBUTION AND ITS VOLUME CONTENT ON THE DIELECTRIC PROPERTIES OF HETEROGENEOUS BREAST TISSUE.

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Summary of Abstract. Microwave imaging for the early detection of breast cancer is a promising research field and the natural contrast agent is water whose high dielectric property serves as a good discriminant for microwaves. At microwave frequencies, normal breast tissue (high fat, low water, low salt) has low permittivity and loss whereas malignant tumors (low fat, high water, high salt) have higher permittivity and loss. The purpose of this paper is analyzing the complex dielectric permittivity of breast tissue based on cell geometry, volume content and distribution of water in the cell, cell membrane and intracellular spaces. The effective complex permittivity is simulated using full wave simulation of the reflected and transmitted electromagnetic fields (S-parameters) through fatty tissues with different microstructure of the distribution of water and the effective complex permittivity is extracted by inversion of the S-parameters assuming an effectively homogeneous material. The permittivity data that obtained is compared with experimental data fitted to Cole-Cole relaxation models.
Objectives. No theoretical model of the frequency dependent complex permittivity of biological tissue is available today that takes into account the microstructural distributions of its constituents. Empirical models are commonly used by researchers that are based on polynomial frequency fits to measured permittivity data. In this paper, several types of physical models are proposed to predict the complex permittivity of breast tissue based on cell geometry, volume content and distribution of water in the cell.

Methods. The models are implemented in full wave finite element simulation using HFSS Ansoft tool and the effective complex permittivity is extracted by inversion of the $S$-parameters. The natural variability of the literature data for dielectric permittivity of breast tissues as well as the tolerance on experimental data permits several models to be accommodated.

Results. In this paper, two preliminary models have been proposed: cylindrical model and layered cylindrical model. We observed that the layered cylindrical model is more realistic and compares more favorably with experimental data.

Conclusions. In this paper we propose a microscopic model for human breast tissue which will lead to increased understanding of breast cancer tissues. Two different 2D models for breast fat are simulated using HFSS Ansoft tool as well as an analysis of the effective frequency dependent permittivity of these models. In our future work, we plan to do a 3D full-wave finite element simulation.
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