

# Medical, epidemiology and dosimetry

A meeting report from a physician's perspective

by Jörg Reußenweber

**In numerous lectures and posters, this year's BEMS, the 26<sup>th</sup> Annual Meeting of the Bioelectromagnetics Society, again provided attendants with a whole host of new insight into the issue of biomedical effects from low-frequency electric and magnetic fields in the range of energy supply, as well as from radiofrequency electromagnetic fields produced by mobile communications.**

This meeting report puts the emphasis on giving a thorough analysis of **therapeutic effects** of electromagnetic fields, as this seems to be the area with the greatest future potential. Thus, the presentation will pay more attention to this aspect than to the rest of the findings.

## Session 2: Epidemiology

(chair: Leeka Kheifets, USA, and C.K. Chou, USA)

**J.J. Morrissey, USA, presented a Comparative analysis of radiofrequency exposure from mobile telephones in different geographic locations.** The objective was to characterize and compare radiofrequency field exposure of Motorola engineers residing in different geographical locations in the US, Europe and Asia in order to examine possible health risks in an epidemiological study. The study will also account for the research efforts of the International Agency for Research on Cancer – IARC – dealing with the question of whether mobile phone use is a potential carcinogen. In this context, modified so-called dosimeter phones were developed and sent out to the engineers throughout the world. “Calling habits” of the test persons was recorded for two weeks, at an average phone transmit power of up to 250 milliwatt, and compared across regions. Results showed there were significant differences between average transmitted power levels. This indicates that potential variations of similar magnitude are to be expected between otherwise similar groups of mobile phone users in future epidemiologic studies.



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**S. L. Bell**, England, spoke about the **Effect of GSM mobile phones on human hearing: Methodological approach and preliminary results.**

The purpose of this preliminary investigation was to present the experimental procedure and the work in progress performed in the framework of the GUARD project to assess potential changes of the hearing function of humans after exposure to low intensity electromagnetic fields produced by GSM mobile phones. Another aim was to derive otoacoustic emissions and brain stem potentials. Methodology: Different individuals were compared (between-subject paradigm), and intraindividual comparisons were performed (within-subject paradigm). Test persons were healthy volunteers participating in double-blind tests – as depicted above – before and after the use of a commercial mobile phone. There were two test runs, one with genuine exposure, the other under sham exposure conditions. Half of the participants was exposed to 900 MHz, 2 Watt, the other half with 1800 MHz, 1 W. Sham exposure was performed using a “dummy mobile phone”. Exposure itself and sham exposure took place on different days.

Results of this pilot study showed the practicability of both study design and test protocol. There were no problems during recording or performance of the two test runs. The longest session was approx. two hours. All mobile phones were tested prior to the experiment, ie power, frequency and the spatial field distribution. Eventually, the preliminary results of this study gave no evidence of significant field effects on the

hearing system of humans, neither at acute nor at chronic exposure.

**J.D. Bowman**, USA, dealt with **Methods for assessing occupational exposure to electric and magnetic fields for the INTERPHONE study on mobile phones and cancers of the head.**

The INTERPHONE study is a population-based case-control study which is being conducted in 13 different countries. In addition to mobile phone radiation, interviewers also ask subjects about known risk factors for brain tumors, saliva gland tumors or acoustic neuroma. Controls were randomly drawn from the general population and matched to respective cases by age and gender. Methodology: All involved study centers conform to a common test protocol. Each participant had to fill in a computer-assisted personal questionnaire.

Six different frequency bands with potentially different biological effects were selected for exposure: ELF, VLF-LF, MF-RF smaller than 10 MHz, RF larger than 10 MHz, VHF and UHF. By linking occupational exposure with the answers given to the questionnaire, conclusions on individual occupational field exposure and frequency bands could be drawn, and the individual field situation could be calculated. Interim results demonstrated that 5767 cases and 2364 controls have been interviewed so far. With its expected approx. 10,000 participants, the INTERPHONE study is the largest case-control study ever performed on the topic EMF and cancer in the frequency range of micro-

waves and below, and it is an unprecedented opportunity to estimate for the very first time real occupational exposure in 13 industrialized countries. Apart from mobile radio frequencies also the frequencies of inductive heating are part of the investigation.

**M.A. Kelsh, USA, presented observations on Improving radiofrequency exposure assessment in epidemiological studies on mobile phone users: An overview of research design and preliminary data.**

The objective of this pilot study performed in cooperation with the IT'IS Society, Zurich, directed by Prof. Kuster, was the development of reliable approximation methods for the calculation of radiofrequency exposure in future epidemiologic studies.

Methodologically, this study was comprised of four major exposure categories:

- 1) characteristics of the user, e.g. anatomically: body height, weight, wearing metal-rimmed glasses or jewelry;
- 2) technical characteristics of the mobile phone, e.g. service provider, frequency range, antenna type, mobile phone position, etc.;
- 3) environmental factors such as mobile radio base station density, use of mobile phone inside or outside of buildings, used material, time of the call, etc.;
- 4) duration and frequency of use (ie the individual behavior of the user, such as call frequency, conditions of use): results showed that the 215 participants made 5 calls per day on average (with an average duration of 15.5 min). It is planned to use the data of this pre-study as a basis for future larger epidemiologic studies.

**G.G. Neubauer, Austria, spoke about the Feasibility of future epidemiologic studies on possible health effects of mobile phone base stations.**

The purpose of this feasibility study was to assess

health risks for the 1 billion users worldwide (400 million people in Europe) potentially related to residing near mobile radio base stations. This pre-study is all the more important, as exposure to radiofrequency electromagnetic fields will further increase – not least due to the UTMS boom and other recent technological developments.

Methodologically, it shall be divided into three steps:

- analysis of existing study designs used in previous epidemiologic studies
- comparison and analysis of dosimetric concepts
- organization of expert workshops

Expected results will provide new insight especially into health aspects of mobile radio (well-being, general health).

**O.P. Molchanova, Ukraine, depicted a New concept for risk assessment and management of radiofrequency electromagnetic field exposure on the basis of neuro-fuzzy networks.**

Objective of study was to develop a new approach of radiofrequency field health effects risk assessment on various aspects of human health by creating a neuro-fuzzy network based on the theory of L. Zadeh. The existing knowledge about the association between radiofrequency exposure (exposure conditions) and established health dangers was to be obtained from literature and, in a second step, used to design a hierarchical cause-effect scenario.

Neuro-fuzzy networks have the following advantages: They include the limits for a wide frequency range, consider several safety factors, formalize expert knowledge about established and hypothetical health dangers, allow future improvement of risk assessment by incorporating new data into the system, and they allow to extract new knowledge from the system only made possible by applying neuro-fuzzy logics.

### Session 3: EMF therapies

(chair: Art Pilla, USA, and Gabi Nindl, USA)

**M.L. Rohan, USA, addressed the *Anti-depressant effects of low-frequency fields with large field strengths in the range of nuclear magnetic resonance tomography.***

The objective of this study, which is highly interesting from a medical point of view, was to investigate the effects of electromagnetic fields as are produced by nuclear magnetic resonance (NMR) on mood change in patients suffering from bipolar depression.

Methodology: 54 persons, out of which 40 suffered from bipolar depression and 14 were healthy, participated in the study. 30 bipolar depressive patients were examined by NMR; 10 bipolar depressive patients were only sham-exposed to the NMR device. The 14 healthy persons were also examined with NMR. After examination, the mood of all test persons was explored via a questionnaire.

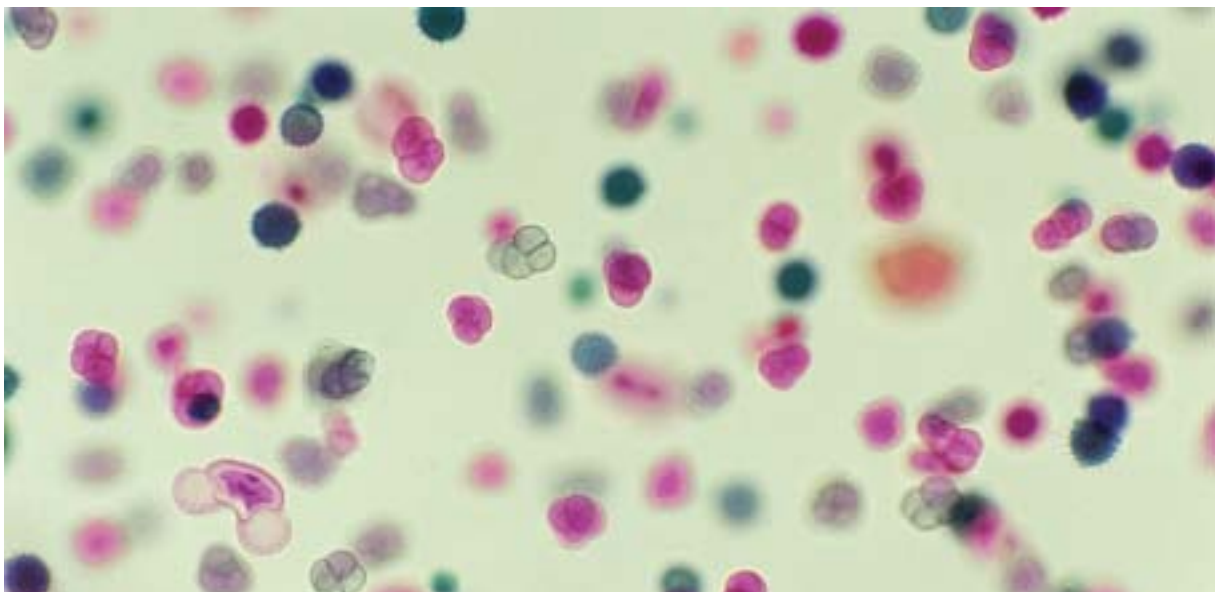
Results showed that 23 of the 30 bipolar test persons having been examined by NMR, 3 of the 10 bipolar persons having been sham-exposed, and 4 of the 14 healthy control persons with NMR examination reported improvement in mood. Conclusion: This unexpected effect was possibly due to the interaction of fields with some neural circuits. Further studies are planned.

**J.R. Salvatore, USA, spoke about *Static magnetic fields modifying the effect of chemotherapy in the treatment of human malignancy.***

This study was aimed at optimizing cancer treatment through the use of static DC ('direct current') magnetic fields. This phase I study examined the treatment of human malignancy with a combination of static magnetic fields and chemotherapy.

Methodology: Selected participants were about to be involved in a chemotherapy program for the treatment of advanced cancer. Prior to therapy, a static magnet was placed over the liver of the patient for the following periods: 15 min prior to the start of chemotherapy, then over the whole duration of chemotherapy and finally, dependent on the group, alternatively for 0 min, 15 min or 30 min after the completion of chemotherapy. There were 12 evaluable individuals in each group who were monitored by medical history, physical examination and blood test results. The obtained data were assessed according to the criteria of the National Cancer Institute.

Results showed that the longer the magnetic field was applied, the stronger was the protective effect on the liver regarding several adverse side effects of chemotherapy. In addition, severity of blood count abnormalities was reduced with the duration of magnetic field exposure after the end of chemotherapy.



Conclusion of this promising research approach: Since this phase I study investigating the safety and toxicity profile of a new therapy was successful, the next step would be to examine and optimize the anti-tumor efficacy of this combination of magnetic field application and chemotherapy in further studies.

**M. Brantley, USA, reported on the Reduction of muscle and fascia pain at specific trigger points due to the application of magnetic fields.**

The objective of this just as interesting study (randomized, double-blind clinical study) was to test the therapeutic potential of static magnetic fields for their efficacy on muscle and fascia pain (myofascial pain). 30 test persons were randomly assigned to treatment (14 persons) and sham-exposure groups (16 persons). In a double-blinded experiment, the maximum pain that could be tolerated was recorded at a defined myofascial trigger point by exerting artificially induced pressure on the skin. Moreover, participants had to fill in a pain questionnaire specifically designed by the McGill University.

Results of the study indicate that static magnetic fields with a flux density of 50 mT can decrease pain at myofascial trigger points after 45 min treatment in specific concerned patients. This agrees with findings described in a publication of Valbona from the year 1997 dealing with patients who had been treated for poliomyelitis. This publication demonstrated that therapeutically used static magnetic fields can have positive effects in pain reduction.

**S. Setti, Italy, spoke about Effects of pulsed electromagnetic fields on experimental generated degenerative osteoarthritis (bone and joint inflammation).**

The aim of the study was to examine the effects of pulsed electromagnetic fields on the degeneration of articular joint cartilage in animal experiments performed in a specific strain of guinea pigs, ie animals spontaneously developing osteoarthritis with age.

10 Dunkin-Hartley guinea pigs aged 12 months were included in the study. Each was placed inside a cage with a coil underneath. Five animals were then stimulated with pulsed magnetic fields at a frequency of 75 Hz and a flux density of 1.8 mT, over three weeks for periods of six hours a day, until sacrifice. The animals' knee joints were then examined by microradiography. Results demonstrated that articular joint cartilage degeneration occurred in all animals. But although most sections showed symptoms of articular cartilage degeneration, there was a clear difference between treatment and control groups. The results appear to show that exposure to pulsed magnetic fields reduces cartilage degeneration thus having; the potential for a stimulating effect.

**A.W. Thomas, Canada, presented Possibilities to cause health effects by specific pulsed weak magnetic fields,** ie to achieve pain reduction in animal experiment and, on the other hand, to give evidence of such positive effects in fibromyalgia patients in a placebo-controlled double-blinded test.

Background: One of the strongest reproducible effects of extremely low frequency magnetic fields is the effect on behavior associated with the brain metabolism of endogenous opioids. A specific pulsed extremely low frequency magnetic field pattern was shown to potentially lead to analgesia in snails, rodents and healthy human volunteers. A double-blinded placebo-controlled study was designed to investigate effects of 30 min magnetic field exposure with a flux density of less than 400 Microtesla on pain ratings in female fibromyalgia patients.

Methodology: Female fibromyalgia patients participating in a hospital pain treatment study were given 30 min treatments. They filled in the McGill pain questionnaire and completed analog scales for testing pain and anxiety. Muscle tension and heart rate were recorded throughout the experiment to assess possible physiological correlates of magnetic field exposure.



Results showed a significant effect before and after magnetic field exposure when evaluating and analyzing repeated measurements.

Thus, results confirm earlier findings due to which exposure to a specific pulsed magnetic field induces a significant degree of analgesia, ie absence of pain. The distinctly lower pain ratings of the test persons indicate the potential clinical relevance of this new therapy for pain reduction in female and male fibromyalgia patients alike.

**L.C. Kloth, USA, addressed the topic of wound disinfection and antibacterial effects of 25 kHz ultrasound.**

The study was aimed at investigating antibacterial effects of 25 kHz ultrasound, since chronic wounds in humans still entail large economic costs. Current methods of treatment of chronic wounds such as enzymatic methods or the surgical debridement of ulcerous material etc have their advantages as well as disadvantages. One of the disadvantages is the often very slow or incomplete removal of the dead, ie necrotic tissue vice versa. The so-called sharp debridement, the aggressive removal of suppurative foci can cause extensive bleeding deep within the healthy tissue, or may require anesthesia. Moreover, the necrotic fibrin often is incompletely removed. Ultrasound therapy can be a viable alternative to conventional wound bed preparations and disinfection here.

At application of 25 kHz ultrasound, very small gas vesicles can develop inside the tissue which in turn can dissolve the necrotic fibrin. This effect called microcavitation should be tested also for its effect on bacteria.

Results showed that 25 kHz ultrasound can exert its fibrinolytic effects by selectively destroying necrotic fibrin within minutes without damaging healthy cells or healthy tissue. Bactericides effects, ie bacteria killing effects, were found to be dependent on the output energy of ultrasound and exposure length; the stron-

gest effect was observed at an exposure period of 120 seconds. However, 15 out of 16 culture plates e.g were shown to be sterile already after 60 seconds exposure.

**T. Sorimachi, Japan, reported on A basic study of the effects of low intensity pulsed ultrasound (LI-PUS) on bone formation.**

The aim was to investigate the production of interleukin-6 and the vascular endothelial growth factor (VEGF) in bone metabolism – a comparative study done with or without application of weak pulsed ultrasound in a culture of the osteoblast-like cell line MC3T3-E1.

Results showed that interleukin-6 upregulation reached its peak after 60 min application and held on for up to 24 hours. Further, an increase of VEGF with time was observed. There was also evidence of speed-up bone formation and vascularization from ultrasound application. Conclusion: The pulsed weak ultrasound early on stimulated bone formation, bone resorption and vascularization.

**M.T. Johnson, USA, held a lecture dealing with Mechanisms and the therapeutic potential of non-ionizing electromagnetic radiation.**

Magnets, electric currents and time-varying magnetic fields have played a certain role in human medicine for several years now. Modern clinical medicine would be far less effective e.g. without cardiac pacemakers or bone growth stimulators, nuclear magnetic resonance imaging or electrophysiological diagnostic tools. This lecture gave a survey of the characteristics of natural and artificial electromagnetic fields that are currently in use or under investigation for several therapeutic applications. According to the referee, the knowledge about these characteristics is fundamental for the development of innovative therapeutic methods based on the application of electromagnetic fields. Although awareness of alternative and complementary medicine has existed for centuries in some cultures, such methods have become an area of



heightened interest in recent times, especially regarding pain treatment, cancer therapy as well as the treatment of inflammatory diseases such as psoriasis, tendinitis or rheumatoid arthritis.

There is intense research done on the latter disease concerning its treatment by electromagnetic fields based on the working hypothesis that certain electromagnetic signals have clinically significant anti-inflammatory properties stemming from the downregulation of T lymphocytes (T lymphocytes being activated physiologically by the T cell receptor during inflammation). Further explorations of this hypothesis may provide a basis for the future development of therapeutic tools for non-invasive treatment of inflammatory diseases.

In the following, this highly interesting and promising pathophysiological approach will be presented in detail based on the lecture held by **G. Nindl** et al. of the same working group (Indiana University School of Medicine in Terre Haute) dealing with **The effect of hydrogen peroxide on Jurkat T cells and its regulation by low frequency electromagnetic fields** (lecture 9-1): While hydrogen peroxide and other reactive oxygen species in the past have been recognized to be solely deleterious to cells, it was clarified recently that these small molecules can also have important positive functions as signaling molecules in certain cells such as T lymphocytes. So we may be able in future to regulate the activity of inflammatory cells non-invasively by the application of electromagnetic fields and thus potentially improve the treatment of acute and chronic inflammations in the human body. However, it is critical in this regard to understand how to biophysically regulate the effects of hydrogen peroxide. If we succeed in this, it will probably be possible to find novel ways to treat inflammatory diseases. So the main purpose of the Indiana research group was to investigate the ability of hydrogen peroxide to amplify signal transduction through the T cell receptor in Jurkat cells. Since T cell receptors sec-



only contain amino acid sequences that seem to be important in antibody-catalyzed hydrogen peroxide production, another aim was to find out whether T cell receptors produce hydrogen peroxide when activated with anti-CD3 and PMA. Finally, another objective was to detect whether electromagnetic fields can regulate and modify physiological effects that are hydrogen peroxide dependent.

The methodological approach was as follows: Jurkat E6.1, a human T lymphocyte cell line, was activated with anti-CD3 and phorbol myristic acid (PMA). Then the quantity of interleukin-2 secreted into the culture medium was measured electrochemically using an ELISA technique and a recently developed hydrogen peroxide electrode. Electrochemical results were verified using the hydrogen peroxide indicator Amplex Red. Hydrogen peroxide dependent Amplex Red color changes were quantitated and recorded using a Bioek EL 808 plate reader. In the following, programmed cell death was monitored. In initial experiments, a field generator of the company EMF Therapeutics was employed generating a 120 Hz pulsed magnetic field, flux density 15 mT. In subsequent experiments, a newly developed field generator was used.

Results and discussion: For the evaluation of biological effects from hydrogen peroxide, activated Jurkat cells were exposed to a 0 to 80 micromol hydrogen peroxide concentration. It was found that concentrations of 40 to 60 micromol of this substance promoted optimal interleukin-2 production, which was proportional to the number of cells. In contrast, hydrogen peroxide inhibited cell growth in non-activated control cells, induced programmed cell death and had no effect on interleukin-2 production.

These remarkable findings show that hydrogen peroxide stimulates the cellular consequences of cell activation at the T cell receptor in activated Jurkat cells, which are a model of inflammatory T cells. In contrast, for a long time hydrogen peroxide has been considered to be a cell toxin; and it was observed that hydrogen

peroxide indeed exhibited its known toxic effects in normal, proliferating, non-activated Jurkat cells.

Earlier experiments showed that electromagnetic fields downregulated interleukin-2 production of Jurkat cells. Based on similar amino acid sequences between antibodies and T cell receptors, it was hypothesized that T cell receptors might catalytically produce hydrogen peroxide, which could then act as an autocrine factor to regulate T cell activity. A real-time hydrogen peroxide monitoring system equipped with an electrode was developed to look into this possibility – a system which is able to detect up to 1 micromol hydrogen peroxide. The system was validated by using the CD3 antibody as a catalyst. These experiments demonstrated that hydrogen peroxide was produced at a rate of approx. 30 nanomol per min and millimol CD3 antibody. It was observed in earlier experiments that the rate of reaction catalyzed by the CD3 antibody appears to be dependent on electromagnetic fields. These accumulating data promise to give insight into the mechanism of interaction between electromagnetic fields and biomolecules. After demonstrating the utility of the hydrogen peroxide electrode, it was employed to examine hydrogen peroxide production by intact Jurkat cells as well as membrane preparations of Jurkat cells enriched with T cell receptors. Enriched membrane preparations were demonstrated to actively catalyze hydrogen peroxide production. This was seen as evidence for hydrogen peroxide being an autocrine factor of T cells, ie a factor produced by T cells themselves as a messenger substance (for communication between cells). Since hydrogen peroxide catalysis by antibodies now appears to be EMF-sensitive, such fields are hypothesized to exert an influence on hydrogen peroxide production in these systems and, correspondingly, hydrogen peroxide dependent signal transduction in intact cells. So, according to this physiological mechanism, a positive effect on the inflammatory process from field exposure becomes plausible.

## Session 8: Biophysical and biological dosimetry I

(chair: Frank Prato, Canada, and Jim Weaver, USA)

**Vijayalaxmi**, USA, described **Genotoxicity in mice exposed to millimeter waves**.

The aim was to find out whether the exposure to millimeter waves will cause genotoxic effects or at least modify the genotoxic effects of cyclophosphamide, a chemotherapeutic used in the treatment of various malignancies. Results did not provide any evidence of genotoxic effects of millimeter waves – neither in peripheral blood nor in bone marrow stem cells. There was neither an increase in micronuclei formation in red blood cells.

**F. Thoss**, Germany, spoke about a model to explain an association between the **Geomagnetic field and light sensitivity of the visual system**.

The aim was to describe a scientific model clarifying the association between the geomagnetic field and the visual system, and to verify assertions derived from this. It was shown that an influence of weak magnetic fields on the human visual process can be proven, supposedly this mechanisms underlying the geomagnetic compass orientation of animals.

**O.P. Gandhi**, USA, addressed the **Comparison of standard absorption rate peaks and standard absorption rates (10 g averaged) for a standardized anatomic human model (specific anthropomorphic mannequin) for exposure to radiofrequency fields at 835 MHz and 1900 MHz**.

Different head models were tested to answer the question whether they may be useful for the detection of the individual standard absorption rate SAR of new devices to be certified and thus for controlling the compliance with national limits both in Europe and in the United States at 835 MHz and 1900 MHz. For both frequencies, the position of the mobile phones either held to the cheek of the artificial head or at a 15°-tilted position was tested.


The Visible Man Model as well as the Utah Anatomic Model were tested each with an axial antenna length of 20 mm resp. 40 mm. Then the peak SARs both for 1 g and 10 g were listed in tables. Results showed that there are considerable differences between the European and the US head models. The corresponding abstract deals in depth with the technical differences between the models.

**P.A. Mason**, USA gave an **Overview of the radiofrequency dosimetry research done by the U.S. Air Force**.

Accurate dosimetry is a critical part of any scientific effort to detect and to assess defect and to the effects of electromagnetic fields on biological systems. But a high-quality dosimetry is also essential to permit the replication of dubious findings by other, independent laboratories. Dosimetry further includes the development of corresponding anatomic and mathematical models. This study applied a human model developed by the U.S. Navy and the U.S. Air Force.

Aims: 1) Object orientation with respect to the incident field was to be made possible. 2) The use of whole body or partial body models was to be made feasible. Since validation of animal dosimetry models is difficult or impossible to assign to humans, animal dosimetry models were developed for the comparison with empirical animal data. Good agreement between theoretical and empirically determined data obtained from animals confirms the validity of SARs predicted in the human model. Validation of the computer model with empirically obtained results and the subsequent refining of the model are essential for future collecting of empirical values required for establishing revised exposure limits.

**A.A. Pilla**, USA, presented **Requirements to EMF dosimetry for physiologically (and thus health) significant and relevant bioeffects**.



Preliminary remarks: Weak, time-varying electromagnetic fields, as well as pulsed time-varying magnetic fields and magnetic DC fields or ultrasound, do have therapeutic effects. At least, they can be considered as an additional therapeutic tool in the treatment of diseases of the musculoskeletal system, where they are partially of great relevance. This presentation was meant to provide the corresponding background.

The results of this analysis provided clear evidence for cases where the ion/ligand binding with known binding kinetics is the field-sensitive part. Corresponding field patterns can be derived to achieve an adequate physiologically meaningful bioeffect. This may explain why many of the signal variants from the range of ultrasound and pulsed magnetic fields – as well as relatively weak static magnetic fields – appear capable of producing significant clinical effects.

## Session 10: Instrumentation and methodology

(chair: Joe Bowman, USA, and Asher Sheppard, USA)

**J. Wilén**, Sweden, presented a **Description of an exposure system used in a provocation study with mobile radio signals.**

This was an attempt to provide a comprehensive description of the exposure system in a provocation study performed in test persons reporting health symptoms related to the use of mobile phones. Results showed that the energy emitted by the antennas is relatively homogenous and is distributed across the entire area where standard mobile phones might radiate their energy.

**D.-S. Yoo**, Korea, presented a **Semi-automated image processing system for the simulation of EMF influences in human body models.**

The aim of this study was to develop a semi-automated system for human body image processing. It is meant to be easy to handle for all those who have basic knowledge of the anatomy of the human body and image processing.

**L. Sandrini**, Italy, reported on **The averaged whole body standard absorption rate – a male to female numerical comparison.**

The aim was here to develop a dielectric model of the female body and, on the other hand, to compare SAR distributions of male and female models and to apply a new algorithm. Results of the comparison of male and female models showed that determined differences of whole body SARs were partially due to the different anatomical conformations and to the tissue compositions, e.g. in subcutaneous adipose tissue.

**M.T. Tsai**, Taiwan, held a lecture on **A novel integration system of pulsed electromagnetic field stimulation for bone tissue engineering in bioreactors.**

A well-developed stimulator for the application of pulsed electromagnetic fields was combined with a modified bioreactor for investigating the acceleration of osteoblast growth in in vitro tests, made visible also in the increased activity of alkaline phosphatase at magnetic field stimulation. Results showed that therapeutic effects of pulsed electromagnetic fields could be successfully made evident. There was an enhanced differentiation of osteoblasts inside the bioreactor. Also new insight into prevention and treatment of osteoporosis can be obtained by this technique.

**D. Spät**, Switzerland, spoke about an **Effective evaluation of real-life exposure to typical mobile phone fields of different mobile radio networks.**

This system was developed to record the power control function of different mobile phones in different environments and under different usage conditions (stationary, moving). It covers a multitude of technical parameters and, as a result, was shown to be an effective tool for demonstrating differences between GSM and CDMA networks. Moreover, it helps to assess exposure conditions in epidemiological studies,

as well as to test the quality of mobile radio end devices and mobile radio service providers.

**P. Preiner**, Austria, depicted **Averaging methods for reliable measurements of the electromagnetic field strength in the vicinity of mobile communications base stations.**

The aim was here to identify averaging methods which allow representative, reliable assertions on field distribution in the vicinity of a mobile radio base station using a limited number of measurement points. Results showed that several templates representing different averaging schemes have to be applied to examine the reliability centering the mean value.

## Session 12: Biophysical and biological dosimetry II

(chair: Junji Miyakoshi, Japan, and Carl Blackman, USA)

**S. Setti**, Italy, reported on **Effects of electromagnetic stimulation on patient recovery after arthroscopic surgery.**

The purpose of this prospective, randomized and double-blinded study was to investigate the therapeutic use of electromagnetic stimulation – specifically effects on cartilaginous knee lesions. Results showed that the electromagnetic stimulation treatment of patients following invasive arthroscopic surgery can certainly be helpful. For example, it can help to reduce medication and thus can eliminate drug side effects in some cases. A fast and complete healing is favoured.

**G. Bit-Babik**, USA, spoke about the **Whole body average standard absorption rate computed in a child body in the frequency range between 1 to 6 GHz.**

The aim was to assess the whole body average SAR for the model of a child aged 1 year exposed to fields in the frequency range between 1 and 6 GHz. Results

showed that presently valid and maximum permitted limits in the frequency range between 2 and 6 GHz are not consistent with the limits recommended by the IEEE radiofrequency standard.

**W.H. Bailey**, USA, addressed the issue of **Long-term monitoring of static electric fields and space charge near AC transmission lines.**

The purpose was to analyze earlier reported long-term measurements of static fields around transmission lines with voltage levels of 230 kV, resp. 345 kV using additional criteria, as well as looking at composition of ions and local meteorologic parameters.

Results showed that the corona activity at a certain distance to transmission lines led to an increase in ambient atmospheric field levels and in ion concentrations.

**Q. Balzano**, USA, depicted **Field and temperature gradients in tissues near resonant circuits.**

Electromagnetic field strengths in tissue near resonant were determined by means of a new calculation program. Results showed that the applied method is useful for calculations in small volumes where high local standard absorption rates and energy densities are present. Further, results indicated significantly increased SARs in very small, defined body regions. However, local temperature increases were less than 0.25 K, if local blood flow is not considered and if SARs along the wire are seen as constant.

**F.J.C. Meyer**, South Africa, spoke about **Accurate compliance zone calculations around mobile radio base station antennas using whole body absorption rate assessment.**

Purpose: The assessment of the spatial peak SAR, resp. the whole body averaged SAR in humans in close proximity to base station antennas is of great relevance for the compliance to international exposure standards. The aim was to accurately calculate



the three-dimensional SAR profile around a typical mobile radio base station antenna used in GSM networks by applying numerical simulation techniques. The purpose was to compare found values to basic restrictions. Results of the investigation showed that the suggested technique can be applied exactly for calculating the SAR close to a mobile radio base station. SAR results could be used in future to calculate accurate and realistic 'compliance zones' around such antennas.

**A.P. Sihvonen**, Finland, reported on an **Improved numerical model for the calculation of exposure to typical mobile phone pulsed magnetic fields.**

Pulsed battery currents generate pulsed magnetic fields and pulsed currents in the head of mobile phones users. In a previous study, a simplified model, based on a simple current loop and spherical head model, had been used, and quasi-static methods were used for the calculation of current density. The simplified model is based on the vector potential representation of the field induced by the pulsed current in a circuit loop. The induced current was calculated from the simple representation of the analytic vector potential by assuming scalar zero potential. Resulting preliminary estimates show that current quotients in the realistic model are distinctly lower than in the simplified model where exposure quotients varied between 0.05 and 0.14. Conclusion: Exposure to pulsed magnetic fields near mobile

phones does not exceed presently valid exposure limits.

**C. Dale**, France, spoke about the **Analysis of the possibility of workers mistakenly touching flat-top antennas of base stations with frequencies at 900 MHz, 1800 MHz or 2100 MHz from behind.**

The purpose of this study was to calculate the local SAR as well as the whole body SAR of a worker touching the base station antenna from behind or the side. The (SAR) assessment was done by simulations and measurements using a generic approach to be able to consider each flat-top antenna as far as possible. Simulations were performed by applying the FDTD method, which is very useful to consider inhomogeneities. The used body model is the three-dimensional Visible Man Model of the Brooks Air Force Base. This human model can be treated either as homogenous or heterogenous; a flattened phantom better matching the antenna back side was selected. Simulations on a one-stage antenna as well as on a two-stage antenna have already been performed in order to examine antenna behavior with increasing height. Measurements according to the CENELEC EN 50383 standard have already been performed too. The flat phantom and the homogenous fluids were defined in this standard.

Result: In a first step, the antenna model was validated between the stages "measurement" and "validation". Then the measurement fluid was validated

through simulations in a homogenous and a heterogeneous phantom. Besides the analysis of tissue depth distribution in the Visible Man Model, validation of the homogeneous fluid was conducted as well.

Finally, the measurements and simulations at 900 MHz, 1800 MHz and 2100 MHz were performed. A two-stage antenna was used to test the effect on the local and the whole body SAR. As was expected for the two-stage antenna, the whole body SAR was nearly identical with that of the one-stage antenna, whereas the local SAR is divided by 2. The result can then be extrapolated to any antenna height. Results demonstrated that 'classical' antennas (of a height of more than 1.3 meters) and 'classical' input power (of less than 40 W per band for tri-band antennas) allow workers to touch the back or the side of the antenna. The contact is possible if the hand or the respective body part stays behind the metal back panel of the antenna.

## Overall evaluation of the 2004 BEMS meeting from a medical point of view

Looking back at the BEMS meeting, my attention was mostly aroused by the numerous contributions on the topic of the application of ultrashort electric pulses at cell membranes presented by the working group around K.H. **Schoenbach** of the Old Dominion University in Norfolk, Virginia.


There seems to be a large potential in this, also for healing. For if we succeed in opening the cell membrane without note worthy further damaging cells, pharmaceuticals e.g. can be brought directly into the cells – and that could be a blessing in tumor treatment, etc.

Reports of promising curing and soothing effects based on electromagnetic fields are increasingly part of the picture presented by the BEMS meetings in recent years. Neuromuscular diseases such as tendonitis, treatment of depression and tumor treatment with the help of electromagnetic fields, as well as

especially pain treatment, play an increasingly important role even in so-called established medicine. Physicians begin to reconsider their skepticism about magnetic field therapies. This trend is clearly visible e.g. in Germany and will probably continue. The application of electromagnetic fields often is an adjuvant, ie it is an addition to the overall treatment that should not be underestimated, though. We should also mention in this context the consciously used placebo effect which, in addition to established interaction mechanisms of electromagnetic fields that help to cure or at least soothe symptoms, also mobilizes and supports the psychological self-healing powers of patients. In summary, besides potential health risks of low and radiofrequency fields, the Bioelectromagnetics Society increasingly addresses potentially curing and soothing field effects and will continue to do so – a trend which has been observed over several years. The posters also clearly illustrated this. From a medical point of view, there was the impression that the involved industrial groups increasingly perceive humans not only as telephone customer but also accept their personal integrity. This means that the individual well-being of people using this technologies becomes an issue. As a physician, I do welcome this change of paradigm.

From a medical perspective, the facts about the phenomenon of electrosensitivity are worth mentioning:

In his lecture on **In vitro attained evidence for the existence of electrosensitivity**, the scientist **D. Leszczynski**, STUK Radiation and Nuclear Safety Authority, Helsinki, emphasized that he had found clear evidence for the possible existence of the phenomenon of electrosensitivity by applying high-throughput methods. I would like to add however that Leszczynski, in my opinion, takes his conclusion too far. It is true, the cell response to typical mobile radio fields depends both on the genotype and the phenotype of cells and there are different or even contradictory



reactions for different genes. But you cannot automatically conclude that the human whole organism – which consists of billions of single cells as it is – will respond the same when exposed to fields. Leszczynski's assertion tends to support the argument that electrosensitive persons could be a subgroup of general population being oversensitive to electromagnetic fields due to genetic predispositions (ie affected by the genotype).

However, considering this from a medical or holistic point of view, we should bear in mind that the whole organism of humans and animals, in contrast to the single cell or tissue sample, has steering –, compensation – and regulation mechanisms. In vitro tests naturally can detect these only to a certain extent. But their relevance should not be underestimated. Further discussion of portability of in vitro results to the whole organism is required.

So there is some doubt whether far-reaching conclusions such as this regarding the health relevance of presented results are justified.

In summary, we can say that the results presented during the meeting again failed to give evidence justifying public concern. There was an overall tendency to objectify matters associated with the issue of biomedical field effects based on scientific knowledge. From natural science and from medical point of view, improved knowledge is required to resolve still open questions related to potential health dangers or biomedical effects from electromagnetic radiofrequency fields as are used by mobile radio technology, as well as low-frequency electric and magnetic fields of energy technology. It is just scientific research, not least the research into the human whole organism, that will help to relativise and to dissolve unfounded fears.

*Dr. med. Jörg Reußenweber, specialist in physiology at the Center of Electropathology (director: Prof. Dr. med. Eduard David), Medical Faculty of the University of Witten/Herdecke*