Workshop

"Radiofrequency Fields and Health – Conclusions after 17 years work of the FGF

Special Topic: Radiofrequency Electromagnetic Fields and Brain Physiology – What is the Connection?"

Abstracts

Organized by

FGF E.V.

STATE MINISTRY OF ENVIRONMENT, BADEN-WÜRTTEMBERG

CONTENTS

SCOPE

Concept of the Workshop

The Research Association for Radio Applications (Forschungsgemeinschaft Funk e.V., FGF) will cease to exist on December 31st, 2009. This event will be used as an opportunity to summarize not only the work of FGF but also that of the whole scientific community in the field of biological and health effects of radiofrequency electromagnetic fields (RF-EMF). For this purpose representatives from different administrative and scientific bodies will present and discuss their assessment of the state of scientific research and necessary actions for the future.

Before these conclusions are drawn the workshop will be dedicated to the question whether RF-EMF used – for instance – for mobile communication can have effects on brain functions (e.g. the EEG, sleep patterns, and cognitive tasks). It will be a follow-up of a workshop in 2007 arranged by the same organizers ("Sleep Disorders, EEG-Changes, Altered Cognitive Functions – Is There a Connection with the Exposure to Mobile Communication RF Fields?"; see: http://www.fgf.de/english/research_projects/ws16.html) where the latest state of the art in this field of research was summarized. Almost no other research area investigating the exposure of RF-EMF has found such consistent positive results (apart from thermal effects at high exposures). Although these results are rather small biological effects and do not seem to imply any health risk, they stimulate the discussion about possible effects below the safety levels for RF-EMF. Additionally, they motivate the debate on so far unknown demodulation mechanisms, because most of the effects were found only at exposure with low-frequency modulated RF-EMF. On the other side there are also a number of studies which could not find effects, sometimes with the same exposure conditions. However, research in this area made progress and brought out a lot of significant new results. Recently, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) stated in their review: "There is some evidence of small changes in brain physiology, notably on spontaneous EEG, and somewhat more variable evidence of changes in sleep EEG and regional cerebral blood flow but these may be of limited functional consequence; no changes were seen in cognitive function.". The Scientific Committee on Emerging and Newly Identified Health Risks of the European Union (SCENIHR) recommended it its "Research needs and methodology to address the remaining knowledge gaps on the potential health effects of EMF" among others research on "RF field mechanisms and verification of important but preliminary findings (experiments testing the existence of modulation-specific effects or demodulation of RF signals in biological structures; experimental studies on EEG patterns and sleep)".
The first two days of this workshop are meant to bring together representatives of the working groups which recently have worked on the topics of RF-EMF influence on brain physiology, including effects on sleep and cognitive functions as well as related research on mechanisms. The meeting will offer broad space for discussing their results.

As well as the seven workshops before that were organized by FGF together with the Ministry of Environment Baden-Württemberg, this probably last workshop in this sequence will aim to provide a consensus among the scientists regarding the scientific state of the art and recommendations on follow-up experiments.

Participation in this workshop is mainly by invitation. However, every scientist working in these fields of research is invited to send an abstract for presentation or to declare her or his interest for participation. Abstracts will be reviewed by a scientific committee. In the case your abstract will be accepted, your travel costs (economy fare) will be reimbursed by the organizers.

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- Landgrebe, M. *et al.* Cognitive and neurobiological alterations in electromagnetic hypersensitive patients: results of a case-control study. Psychol Med 1-11 (2008).

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COMPUTATIONAL ELECTROMAGNETIC ANALYSIS IN A HUMAN HEAD MODEL WITH EEG ELECTRODES AND LEADS EXPOSED TO RF SOURCES AT 915 MHZ AND 1748 MHZ

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An electromagnetic analysis of a human head with EEG electrodes and leads exposed to RF sources was performed by means of Finite-Difference Time-Domain simulations (XFDTD software (Remcom Co., State College, PA) on an MRI-based human head model (twenty-nine anatomical structures, 1mm3 isotropic resolution) [Angelone LM. PhD Thesis 2008]. RF source models included a half-wave dipole, a patch antenna (192×136 mm2, 10 mm thickness, 61mm distance from the head), and a realistic CADbased mobile phone model simulated at 915 MHz and 1748 MHz. Two realistic EEG electrodes and leads configurations were modeled, with both a standard 10-20 montage and an expanded 32 electrode cap (**Figure 1**). A comprehensive volumetric assessment of SAR changes over the head with and without leads was conducted. Both conductive (metal) and high resistive (_ = 0.01 _ m) EEG leads were evaluated. When compared to the case without leads, the model with EEG leads showed up to 2-order of magnitude increase in local (1mm3) power absorption in the epidermis and 40-fold increase in the brain.

Conversely, there were no significant (i.e., less than 20%) changes in antenna radiation efficiency, wholehead averaged SAR or 10g averaged SAR with both EEG configurations compared to the control case of no leads. Peaks 1g- and 10g- averaged SAR were below 2 W/kg and 1.5 W/kg, respectively, with all of the RF sources evaluated (i.e., dipole, patch antenna, or mobile phone). Results varied with the two realistic configurations of EEG caps and with the number of EEG electrodes and leads. High-resistance leads reduced significantly the enhancement of SAR at the electrodes. These results show that conductive leads and electrodes used can generate measurement issues in EEG studies due to the antenna effects of the leads during RF exposure of human heads. The results of this study indicate that the effect of RF exposure on EEG is not a simple issue to resolve. Since EEG recording measures very small electrical variations in the brain, it is important to realize that there is an induced current carried by the conductive leads into the head. Whether any observed effect is directly due to the RF fields or indirectly due to the RF induced current must be sorted out in order to understand the biological effects of RF exposure. The issue of how the changes of SAR at the electrode sites due to the current induced in the metallic leads can affect the EEG recordings and sleep quality (even after the RF exposure is turned off) is subject for other investigation.

Disclaimer: The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

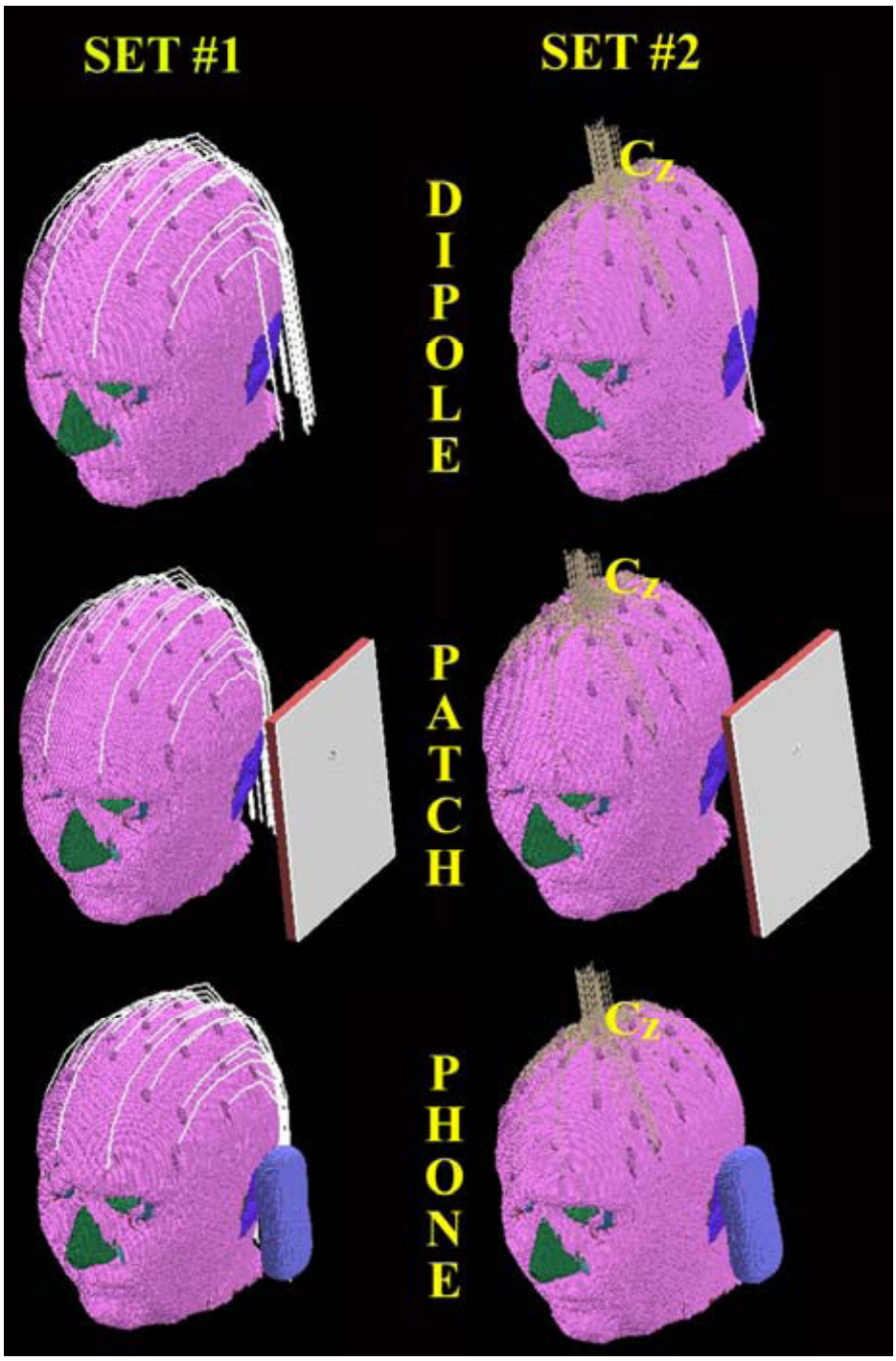

Figure 1. *Three-dimensional view of MRIbased human head model wearing EEG electrodes/leads used for the study. The model of the three RF sources used (dipole, patch antenna, phone) are visible. Thirty-two EEG electrodes with two realistic configurations of EEG leads (Set #1 and Set #2) were evaluated. Both conductive (metal) and high resistive (ρ = 0.01 Ω m) EEG leads were evaluated. Leads were modeled using three to nine segments, depending on the position with respect to the head, with distance from the head between 1 mm and 11 mm.*

TBA

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THE AUSTRALIAN CENTRE FOR RADIOFREQUENCY BIOEFFECTS RESEARCH (ACRBR): RESEARCH PROGRAM UPDATE

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The Australian Centre for Radiofrequency Bioeffects Research (ACRBR) is a government-funded organisation in Australia, created to interpret and conduct research into possible EMF bioeffects. The ACRBR remit expires at the end of 2009. This presentation will summarise the Centre's research outputs to date, with particular focus on the work pertaining to human observational and experimental research. The former work includes epidemiological research in adolescents, assessing associations between mobile phone use patterns and cognitive function. The latter work includes research conducted to determine whether there are effects of 2nd and 3rd generation mobile phones on cognition and human electrophysiological endpoints; whether there are individual differences in such effects; whether 2nd generation mobile phone exposure effects on human sleep are reliable; and whether there are associations between mobile phone use in children and cognitive function. A brief outline of the Centre's research plan beyond 2009 will also be presented.

THE EFFECTS OF GSM-MODULATED 900 MHZ RADIATION ON CEREBRAL ACTIVITY USING AN EXPERIMENTAL PICROTOXIN-MODEL IN RATS

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This study investigated the effects of mobile-phone-type radiation on the cerebral activity of seizure-prone animals. The experimental set-up used in this research for exposure of small animals to radiofrequency standing waves allows direct measurement of the power absorbed by the animal. Essentially, the setup consists of a metallic box containing an antenna and experimental animal immobilized in a methacrylate holder; a signal generator feeding the antenna; and a power meter. In addition, the box can also contain a video camera to record the animal's behaviour, and a receiving antenna (connected externally to a power meter and a spectrum analyser) to detect undesired (external) radiation and possible harmonics of the radiating system. The absorbed power measurement trivially allows calculation of whole-body mean SAR from the animal's weight; an assuming local SARs to be proportional to whole-body mean SAR, the latter can be used to adjust organ-specific SAR predictions obtained by simulation using a commercial FDTD program with a numerical phantom. In a first experiment the rats were transformed into an experimental model of seizure-proneness by acute subconvulsive doses of picrotoxin were exposed to 2 h GSM-modulated 900MHz radiation at an intensity similar to that emitted by mobile phones, they suffered seizures and the levels of the neuronal activity marker c-Fos in neocortex, paleocortex, hippocampus and thalamus increased markedly. Non-irradiated picrotoxin-treated rats did not suffer seizures, and their cerebral c-Fos counts were significantly lower. Radiation caused no such differences in rats that had not been pretreated with picrotoxin. We conclude that GSM type radiation can induce seizures in rats following their facilitation by subconvulsive doses of picrotoxin. In second experiment GSM-exposed picrotoxin-pretreated rats showed differences in clinical and EEG signs, and in c-Fos expression in the brain, with respect to picrotoxin treated rats exposed to an equivalent dose of unmodulated radiation. Neither radiation treatment caused tissue heating, so thermal effects can be ruled out. The most marked effects of GSM radiation on c-Fos expression in picrotoxin-treated rats were observed in limbic structures, olfactory cortex areas and subcortical areas, the dentate gyrus, and the central lateral nucleus of the thalamic intralaminar nucleus group. Non picrotoxin-treated animals exposed to unmodulated radiation showed the highest levels of neuronal c-Fos expression in cortical areas. These results suggest a specific effect of the pulse modulation of GSM radiation on brain activity of a picrotoxin-induced seizure proneness rat model and indicate that this mobile phone-type radiation might induce regional changes in previous preexcitability conditions of neuronal activation. Research should be pursued into the possibility that this kind of radiation may similary affect brain function in human subjects with epileptic disorders.

EXPERIMENTAL STUDY OF THE INFLUENCE OF 900 AND 1800 MHZ SIMULATED MOBILE PHONE SIGNALS ON EEG: GENDER EFFECTS

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The present study investigated the influence of electromagnetic fields (EMF), similar to that emitted by mobile phones, on brain activity. Two different groups of people, who took part in two separate experiments, were examined. These groups were homogenous as far as the age and educational level is concerned. In the first experiment nine males and ten females performed a short memory task (Wechsler test), both without (baseline) and with exposure to a 900MHz signal. In the second one ten males and ten females performed the same auditory task with the frequency of the electromagnetic field set to 1800MHz. EEG energies were calculated from the recordings of 15 scalp electrodes of the pre-stimulus signal for the total waveform and for δ, θ, α and β rhythms using the Fourier transform.
Except for the EMF, gender influence on the EEG was also examined. In the first experiment baseline EEG energy of males was greater than that of females, while exposure to EMF decreased EEG energy of males and increased that of females [1]. In the second experiment although no statistical significance was found for the total energy, the energy of the β band in the presence of radiation was significantly greater for females than for males for the majority of electrodes [2].
Finally using Cronbach's alpha coefficient, the spectral power coherence (SPC) among the different frequency bands was calculated for both groups. The results showed that delta rhythm is less consequential in the overall cooperation between the bands than the higher frequency theta, alpha and beta rhythms. Additionally, it has been shown that the radiation effect on SPC is different for the two genders. In the absence of radiation males exhibit higher overall SPC than females. These differences disappear in the presence of 900MHz and are reversed in the presence of 1800 MHz [3].
These findings emphasize the importance to consider individual variability due to sex differences in research which examines the relationship between brain function and EMF.

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INFLUENCE OF ELECTROMAGNETIC FIELDS OF THE MOBILE RADIO SYSTEM UMTS ON THE BEHAVIOUR OF HUMANS IN DIFFERENT DEMAND SITUATIONS

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The use of UMTS mobile phones or other portable transceivers is closely connected to extreme near-field exposure of the user's head to high-frequency electromagnetic fields (EMF). This suggests the possibility of an influence of the EMFs on the central nervous system affecting mental performance. An investigation with human volunteers has been carried out to search for such influences when using a UMTS mobile phone. The UMTS frequencies (around 2000 MHz) are higher than those of GSM 900 and there is no frame repetition rate, the signal is like a noise.

For the used transmission power of 1 Watt, the measured values of the specific absorption rate (SAR) were found to be below the exposure limit values recommended by ICNIRP for general public.

A sample of 24 male volunteers in the age of 20 to 30 years has been exposed alternately to the radiation of one of two generic antennas, fixed at both sides of a helmet in intended use position. In a double-blind-test the reaction behaviour of these volunteers has been analysed while the hand-held device was either switched on or off. According to a balanced experimental design the subject was exposed to different visual demands for three periods of 30 minutes each (sinistral, dexter and non-field exposure). These demands were aimed at different cognitive performances like visual attention, identification of signals, quick response to a certain stimulus as well as a perception illusion known as the "autokinetic effect".

Both time and exposure effects on the dispersion about the mean of the sample have been evaluated by analysis of variance with regard to the response time values, the errors and the parameters of the autokinetic illusion.

With respect to each parameter none of the variances of the average values between the different exposure conditions showed any field influence. The subjects did not perceive the switching on and off of the electromagnetic field. Changes of the well-being were correlated with the high cognitive requirements in performing the tasks, not with the particular mode of exposure.

The test results did not show any influence on the visual information processing or the subjective experience as a result of the exposure to an electromagnetic field of the UMTS mobile phone.

PERFORMANCE MEASURES AND COGNITIVE PROCESSING IN RESPONSE TO ACUTE EXPOSURE TO RF EMF EMITTED BY MOBILE PHONES

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Recent studies (e.g. Preece et al., 1999; Koivisto et al, 2000; Edelstyn et al. 2002; Curcio et al. 2004; Keetley et al, 2006) have suggested that the use of mobile phones may affect cognitive functioning. However, a closer scrutiny of these studies suggests that, since the probability of wrongly rejecting a true null hypothesis was quite high (i.e. > 5%), these findings could simply reflect a statistical artefact.

The main aim of the present research was to overcome the limitations of previous studies providing a thorough evaluation of the impact of the use of GSM and analogue phones on attention and memory in adults.

A series of laboratory controlled experiments will be presented where different samples of about 160 volunteers per experiment (thus highly powered studies) performed a series of attention and memory tasks both while exposed and while not exposed to radiofrequency electromagnetic fields (REF) emitted by the antenna of mobile phones.

ANALYSIS OF BIOREGULATION AS INDICATOR FOR AN INFLUENCE OF HUMANS BY ELECTROMAGNETIC FIELDS

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The presentation shows a new approach in the research of influence of the human body system by weak electromagnetic fields.
Functional disorders of the Autonomic Nervous System (ANS) are an increasing medical problem in the western industrialised civilisations. They are mostly caused by unhealthy lifestyle and rising overstimulation. The stimuli might be of a physical, psychological or energetic nature. The human body's reaction is a stimulus response which is controlled by the functional regulation systems in order to adapt to the new situation. This response normally happens autonomously leaded by the nervous system together with hormonal and humoral activities.
The basic functions of the human body are controlled by the ANS which is the fundamental regulation system of the organism. The analysis of the regulation width is internationally established as "heart rate variability" (HRV). However, it is often unspecific to assess of HRV only from the bio signal heart rate. Hence, the new methodological approach for checking the vegetative regulation is the Bio Regulation Analysis (BRA) which also takes into account the breathing characteristics, the arterial blood pressure regulation and the present emotional status.
At Zwickau University of Applied Sciences we realised first experiments to investigate the influence of electromagnetic fields on the bio regulation process with the help of that new approach. The research hypothesis was to show that a more sensitive indication of changes can be achieved by using bio regulation processes than by using other measurements like the EEG to prove changes.
Functional disorders and chronic diseases are normally coupled up with a distinctive sympathetic tonus. When an electromagnetic field is comprehended as a stressor and is insufficiently treated in the biological system, the sympathovagal balance is influenced which can lead to dysfunctions in the biological order. Because the bio regulation is always individual it is impossible to predict a person's reaction to the disturbance factor. Hence, it is necessary to include previous liabilities in the design of the research and to develop a bio-psycho-social model approach.
First experiments with bio regulation analysis showed individual changes that can be interpreted as reduction of vegetative regulation of the ANS. The tested probands are between 20 and 55 years old. The electromagnetic field was sent by horn antenna or broadband antenna with the frequency of 900 MHz pulsed by 217 Hz (D2 mobile phone). The proband's exposition was in a distance of 3 m from the antenna sitting in an up-right position opposite to the antenna. The exposition of electric field strengths were 40 V/m (strong field – critical value for exposition range 1) and 9 V/m (low field – safety value for exposition range 2). The measurements took place in a screened room with 120 dB attenuation.
Consequently, it is necessary to examine the system which is responsible for the general functions of the human organism; due to the fact that a stressor like an electromagnetic field influences the whole body.

EFFECTS OF PULSE-MODULATED RF-EMF ON THE HUMAN BRAIN: CRITICAL FIELD PARAMETERS AND SITE OF INTERACTIONS

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There is increasing evidence that pulse-modulated radio frequency electromagnetic fields (RF EMF), such as emitted by mobile phones, can alter brain physiology. The reported effects include changes in the electroencephalogram (EEG), regional cerebral blood flow (rCBF), changes in intracortical excitability and cognitive function. However, conclusions about possible adverse effects on human health are premature as the underlying mechanisms are unknown.

Different types of RF EMF were applied in our studies so far: a pulse-modulated EMF (pm EMF, "handset-like signal") approximating the spectral content emitted by GSM mobile phones, a non-modulated continuous-wave signal (cw-EMF), a base station-like signal approximating the signal emitted by a GSM base station, pulse-modulated fields with modulation frequencies at 14 and 217 Hz, and sham exposure which served as a control condition in all studies. The spectral content of extremely low frequency (ELF) components varied considerably depending on the modulation scheme used.

Experiments were performed in the sleep laboratory of the Institute of Pharmacology and Toxicology at the University of Zurich in a double-blind, crossover design. Healthy, young men were exposed during an entire night-time sleep episode to an intermittent radiation schedule (Borbély et al., 1999) or for 30 min prior to waking and sleep EEG recordings (Huber et al., 2000, 2002, 2003, 2005; Regel et al., 2007a,b; Loughran et al., 2009).

We demonstrated that exposure to pm-EMF increased spectral power of the non-REM EEG in the spindle frequency range (Borbély et al. 1999, Huber et al., 2000, 2002, 2003; Regel et al., 2007b). We reported first indications of a dose–response relationship between EMF field intensity and the increase in spindle frequency activity (Regel et al., 2007b). Preliminary analysis of recent experiments revealed an increase of power in the spindle frequency range following 14 Hz modulated exposure, which was most prominent in stage 2 sleep of the 2nd sleep cycle (Loughran et al., 2009). Furthermore, analysis of unscored data from the entire sleep episode indicates an increase in the spindle frequency range following pm EMF exposure, and to a lesser extent following superficial exposure, compared to sham (Loughran et al., 2009). Exposure to pm-EMF also increased spectral power in the alpha frequency range prior to sleep onset (Huber et al., 2002) and 30 min after exposure in relaxed wakefulness (Regel et al., 2007a). Furthermore, it increased relative rCBF in the dorsolateral prefrontal cortex ipsilateral to the exposure side (Huber et al., 2002). No effects were observed for continuous-wave radio frequency electromagnetic fields (Huber et al., 2002; Regel et al., 2007a). Some changes in cognitive performance were observed, however no consistent effects could be established.

Our results provide evidence that the pulse modulation of a RF EMF is necessary to induce changes in the EEG during waking and sleep. Our data from the signal characteristics study points towards the involvement of the 14 Hz component as a possible mediator of the observed EEG effects. Moreover, these changes may outlast the exposure period and seem to be influenced in a dose-dependent manner.

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RF-EMF AND SLEEP: THE BERLIN DMF SLEEP STUDIES

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In the framework of the ***German Telecommunication Research Programme*** (DMF) two studies were performed by the sleep laboratory of the CharitéCenter for Neurology, Neurosurgery and Psychiatry of the Charité – University Medicine Berlin. One study aimed at investigating possible effects of RE-EMF emitted by mobile phones on sleep in a laboratory, the other study, an experimental field study, investigated possible effects of RF-EMF emitted by mobile phone base stations on sleep of residents.

Laboratory study

In a double-blind, randomized, sham-controlled cross-over study, possible effects of long-term (8 hrs) continuous RF exposure (GSM 900 and WCDMA/ UMTS) emitted by cell phones on the micro- and macrostructure of sleep were investigated in a lab environment. An adaptation night, which served as screening night for sleep disorders and as an adjustment night to the lab environment was followed by nine study nights (separated by a two weeks interval) in which subjects were exposed to three exposure conditions (Sham, -GSM 900 and WCDMA/UMTS). The sample comprised 30 healthy male subjects within the age range 18-30 years (mean ± SD: 25.3 ± 2.6 years). A cell phone use at maximum radio frequency (RF) output power was simulated, the transmitted power was adjusted in order to approach, but not to exceed the SAR limits of the ICNIRP guidelines for general public exposure. 13 out of 177 variables characterising the initiation and maintenance of sleep in the GSM 900 and 3 in the WCDMA exposure condition differed from the sham condition. The few significant results are not indicative of a negative impact on sleep architecture. Analyses of power spectra of the sleep EEG revealed that with regard to sleep period time the only difference observed for GSM900 exposure was an increase for two frequencies out of the β-frequency range (21.0 Hz and 22.0 Hz). A stage specific approach showed that power spectra were significantly increased for frequency bands 6.5, 7.5 and 8.5 Hz during wake, and for 1.5 – 2.5 Hz and 6.5 Hz during NREM1 sleep. Effects seen during NREM2 sleep were restricted to the β-frequency range (18.0 – 24.0 Hz). No effects were seen for REM and slow wave sleep. With regard to UMTS exposure nine out of 400 tested variables showed significant changes: for wake 8.5 to 9.5 Hz, five sporadic frequencies in NREM1 sleep (2.0, 6.0 6.5, 8.0, and 15.5 Hz), and one frequency (7.5 Hz) when NREM1 and NREM2 sleep are combined as light sleep. A very detailed analysis of the microstructure "spindles" led to some sporadic statistically significant differences under GSM900- and/or UMTS exposure. However, the number of statistically significant results was far below the number expected just by chance considering the multiple testing situation. Furthermore there were no systematic changes concerning number, duration, density, frequency and amplitude of spindles in total NREM sleep, in NREM2 sleep and in slow wave sleep. From the present results there is no evidence for a sleep disturbing effect of GSM 900 and WCDMA exposure.

Field study

In residents of mobile phone base stations the subjective perception of a disturbed sleep is a frequently mentioned complaint attributed to the emitted electromagnetic fields (EMF). The present study aimed to disentangle EMF and non-EMF effects of mobile phone base stations on objective and subjective sleep quality of residents in an experimental setting using a double-blind, sham-controlled, balanced randomized cross-over design. In total 397 volunteers were recruited from sites, where no mobile phone service was available. All participants were exposed (verum and sham) at home by an experimental base station. Data acquisition comprised individual measurement of EMF exposure at the pillow,

questionnaires on sleep disorders, overall sleep quality, excessive daytime sleepiness, attitude towards mobile communication and subjective (morning and evening protocols) and objective (derived from frontal EEG and EOG recordings) sleep data. Analysis of the subjective and objective sleep data did not reveal any significant differences between the real and sham condition. During sham exposure nights objective and subjective sleep efficiency, wake after sleep onset, and subjective sleep latency were significantly worse in subjects with concerns about possible health risks resulting from base stations. The present study did not provide evidence for short-term physiological effects of electromagnetic fields emitted by mobile-phone base stations on objective and subjective sleep quality in a representative population sample of residents. However, under sham condition subjects with concerns about possible health risks slept significantly worse.

NEUROBIOLOGICAL FINDINGS IN ELECTROHYPERSENSITIVE PEOPLE – RESULTS OF A SERIES OF TRANSCRANIAL STIMULATION AND FMRI EXPERIMENTS

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DO UMTS ELECTROMAGNETIC FIELDS AFFECT BLOOD CIRCULATION OF THE HUMAN BRAIN? A NEAR-INFRARED IMAGING STUDY

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1. Introduction

We used near-infrared imaging (NIRI) to measure potential effects of UMTS electromagnetic fields (UMTS-EMF) on the cerebral activity, blood perfusion, and/or oxygenation. The aims of the study were to investigate 1.) potential effects on different time scales (short-term: changes occurring within 1.2 – 80 s, mid-term: changes over the measurement duration of 30 minutes) and 2.) the dose-dependency of potential effects. To set the amplitude of potential short-term changes in relation to a normal functional activation, in addition a motor cortex activation measurement was performed.

2. Materials and Methods

Sixteen healthy, right-handed, male non-smokers (age: 26.8 ± 3.9 y) participated voluntarily in the study. All subjects gave written informed consent prior first experiment. Subjects were briefed to abstain from alcohol, medication and sport on the day of the study and to maintain the same time of getting up, sleep hours and coffee levels for each of the four measurement days.

2.1. UTMS-EMF Exposure Setup

The measurements were carried out in a room with very low electromagnetic background fields. Absorber walls around the measurement bench prevented reflections of UMTS-EMF. Each subject was measured under four different conditions on four different days at the same day time: i) maximum peak SAR 2 W/kg, ii) maximum peak SAR 0.2 W/kg, iii) sham, iv) motor cortex activation. The three exposure measurements took place at measurement day 1-3 and were carried out in a controlled randomized, cross-over and double-blind paradigm.

The NIRI sensor was positioned at T3 (international 10-20 EEG positioning system) and a planar patch antenna (Huber & Suhner, Switzerland, SPA 2000/80/8/0/V) emitting the EMF at a distance of 4 cm. The UMTS-EMF signal was a wideband code division multiple access (W-CDMA) downlink signal [Zwamborn et al., 2003] similar to a base station.

Specific absorption rate **(**SAR) of the exposure setup was simulated with SEMCAD X and the results were verified with dosimetric measurements. The agreement of simulation and measurement was quite good. Maximum peak SAR (over 10 g) applied was 2 W/kg [Lehmann et al., to be published].

2.2. Optical Setup

NIRI measures changes in deoxy- and oxyhemoglobin concentration (HHb, O_2Hb), which reflect cerebral activity, perfusion and/or oxygenation. The NIRI sensor without metal parts was custom built to be insensitive to UMTS-EMF. It consists of 2 detector and 8 source positions. A total of 16 light bundles, the measured paths, are collected. 10 m long glass fibres enable to place the NIRI electronics outside the absorber walls of the exposure chamber.

Each measurement consisted of a 3 minute baseline, 16 cycles and 6 minutes baseline. Each cycle included an UMTS-EMF-exposure/stimulation segment of 20s (ON) and 60 s recovery (OFF).

3.Results & Conclusions

The data analysis is still in progress. Preliminary results of short- and mid-term data will be presented.

4. Acknowledgements

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ELECTROMAGNETIC EXPOSITION OF NEURONAL NETWORKS IN VITRO

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Human central nervous system is one of the most sensible organs controlling both vital physiological functions and consciousness. It is therefore since long one of the favorite targets of research activities focusing on possible biological interference of high frequency weak electromagnetic fields (EMF) according to the Global System for Mobile communication (GSM)-standard for current mobile phone networks. Although there is only little evidence of major health risk arising from the exposure of the brain to RF-EMF, some of the published results are inconsistent and obviously some knowledge gaps remain.

Multi-unit extracellular recording from neuronal cell systems cultured on microelectrode arrays (MEAs) is a widely used approach to achieve basic understanding of neuronal network properties, as well as the realization of cell-based biosensors. Here we employ the advantages of this method namely the possibility for long-term measurements to expose three neuronal systems for days and even weeks at radio frequencies of 900 and 1800 MHz.

For the experiments we present a flexible, easy-to-use measurement TEM-cell based setup integrated in a CO_2 incubator and suitable for a large range of sample bins, frequencies and field strengths, respectively SAR levels. Conditions in the so-called stripline are simulated at 900 MHz and 1800 MHz and the setup is optimized in terms of SAR homogeneity. Recording of the electrical communication of neuronal cell cultures are performed and results are presented.

TESTING THE INFLUENCE OF MOBILE PHONE FIELD EXPOSURE ON ION CURRENTS THROUGH CA^{2+} CHANNELS IN MATURE INNER HAIR CELLS OF MICE

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The increasing use of mobile phones led to an increased public concern with respect to possible health risks involved. In response to those concerns, the WHO orchestrates a world-wide research program to which this study contributes via the "German Mobile Telecommunication Research Programme" organised by the Federal Office for Radiation Protection.

During use, mobile phones are in close proximity to the ear and most of their emitted energy is directly absorbed by the area around the ear. We therefore investigated whether mobile phone field exposure had any influence on the functioning of the voltage-activated L-type Ca^{2+} channels $Ca_v1.3$ in mature mouse inner hair cells. Inner hair cells are the cells that transform the acoustic vibrations into neurotransmitter release. The release process – called exocytosis – is triggered by the influx of Ca^{2+} ions through voltage activated Ca^{2+} channels, driven by the receptor potential of the hair cells. The Ca^{2+} channels play a central role in the early transduction process of auditory signals and are known to be sensitive to the cells' metabolic state. Thus, voltage gated Ca^{2+} channels in inner hair cells are an ideal target for a study investigating a possible influence of mobile phone fields on the peripheral auditory system.

Currents through Ca^{2+} channels were measured in whole-cell patch clamp experiments in an acute preparation of the apical organ of Corti of NMRI mice aged 18±2 days. K+ currents were blocked by extracellular TEA and 4-AP and by intracellular use of Cs^{+}. Currents were recorded for 5 min prior to exposure, during a 20 min exposure phase and for 15 min after exposure (40 min recording time). All recordings were carried out for SAR values corresponding to 0.02, 0.2, 2, 20 W/kg (averaged over the bath volume) and a sham. The exposure conditions were randomised and blinded. Three different exposure signal types simulating GSM 900, GSM 1800 and UMTS communication signals were used, and at least 15 cells were measured for each exposure type and intensity.

Maximum current, voltage of half activation and steepness of activation were extracted from IV relationships and current traces. These parameters were subsequently used in statistical tests to evaluate a possible influence of the exposure on the properties of the $Ca_v1.3$ channels.

THERMOSENSOR PROTEIN GRPE OF THE HEAT SHOCK PROTEIN HSP70 SYSTEM AS TARGET FOR ELECTROMAGNETIC FIELDS

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In this study potential conformational changes induced by EMFs on a well-defined protein are investigated. By using proteins the complexity of the investigated object is reduced from the cellular to the molecular level. To enable real-time observation of potential effects of EMFs on their structure, the exposure unit is placed directly in a spectropolarimeter recording their conformational equilibrium via their circular dichroism (CD) signal. Thus, the point of observation becomes identical with the potential interaction site in space and time that will allow for the detection of even small effects. Circular dichroism (CD) spectroscopy is a well-established and widely-used experimental method to investigate structural properties of proteins.

In this study the thermosensor protein GrpE is exposed to EMFs whilst simultaneously monitoring its potential structural changes. The thermosensor GrpE belongs to the Hsp70 chaperone system of Escherichia coli. GrpE is involved in cell stress response and a similar protein exists in humans. Since the α-helical content of GrpE is large, conformational changes can be sensitively monitored by changes in ellipticity in the far UV region. Given that all other physical parameters and solvent conditions, are constant, its conformational equilibrium is exclusively defined by temperature. Provided that all thermal, electromagnetic, chemical and optical conditions within the irradiated volume are known and controlled this configuration should allow for discrimination of non-thermally induced structural changes from those caused by temperature changes. A novel experimental unit allowing for strictly-controlled, real-time measurements was designed.

Measurements using test proteins (helix-bundle derived from the SIV envelope protein gp41; leucine zipper part of the GCN4 transcription factor) were conducted to evaluate the experimental setup. The exposure unit does not change the CD measurement itself, in particular the EMF does not interfere with the CD signal. Further test runs detected EMF-induced temperature rise with time in the irradiated protein solution as predicted by simulations. A large measurement campaign using the protein GrpE was carried out. For the tested proteins no measurable changes of their conformational equilibrium under EMF exposure at 100MHz (up to 1500V/m) and at 1GHz and 1.9GHz (up to 2500V/m) were observed.

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17 YEARS OF SCIENTIFIC WORK BY FGF: EMF RESEARCH, RESEARCH ANALYSIS, SCIENCE DIALOGUE

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FGF began its scientific work in 1992 at a time when the first digital mobile communication network was launched in Germany with the rollout of the 2nd generation Global System for Mobile Communication (GSM). Looking back on FGF's history, four periods of differently focused activities can be identified: After a short period of taking the then existing knowledge stock, analyzing the risk perception at that time, and identifying open research questions regarding "Electromagnetic Compatibility with the Environment" (EMCE), the FGF's work at first concentrated on funding own experimental biomedical research. This was done at four investigation levels, which were experiments on the molecular level, on the cellular level, with humans or animals, and on medical devices. Due to the high costs, epidemiology never stood on the research agenda of FGF. The first research phase from 1993 to 1996 with 16 research projects (plus sub-contracts) was characterized by a cooperation with two German research initiatives, one at the University level ("Research Association Electromagnetic Compatibility of Biological Systems", University Braunschweig) and one at the Federal State Government level ("Research Initiative North Rhine-Westphalia). In the second research phase from 1996 to 1999 a total of 17 studies were started following a newly established proposal selection process, involving a group of internationally acknowledged experts to gain highest possible neutrality. The third phase of FGF's research funding activities (1999 to 2002) was mainly dedicated to the 3G mobile communication technology UMTS, which was commercially introduced in Germany from 2004 on. In 2001, FGF was the first research institution in Germany (and one of the first worldwide) that included investigations on the effects of UMTS signals on biological systems in its research agenda. For better comparability amongst research laboratories, the first standardized UMTS test signal was developed and published by order of FGF and is in use until today. Besides three contracted literature surveys, eight experimental studies were funded in this period. In the fourth phase from 2002 on, in view of dramatically increasing EMF research activities in Germany, Europe and worldwide (e.g. German Research Programme, REFLEX, Perform A and B), FGF's activities switched more and more from original research funding to active science dialog and research analysis.

Until today, FGF organizes highly respected scientific workshops on special EMF research topics and provides intensively investigated, written topic analyses on selected EMF themes. From 2002 on, FGF enforced in parallel the active communication of daily and weekly EMF news to the public and provided its members with a large pool of information material. Nevertheless, the quarterly magazine "FGF-Newsletter" and the weekly bulletin "Infoline" exist already since 1993 and 1994, respectively. From the first planning activities in 1993 on, FGF co-funded and supported scientifically the EMF literature database at the University of Aachen, nowadays known as "EMF-Portal" which contains the most complete publicly and for free accessible EMF publication collection with currently more than 13.000 titles.

Single main topics within the 17 years of scientific work by FGF comprised the search for possible interaction mechanisms, the effects of RF EMF on the central nervous system (including blood-brain-barrier), cancer promotion, reproduction, and genotoxic effects. Additionally, eight more topics were pursued on a smaller scale and over shorter periods of time: possible effects or influence of EMF on cell membranes, cardiac pacemakers, the melatonin synthesis, the vegetative nervous system, and the lifetime of animals. Moreover, two studies each on electrohypersensitivity and on lessons learnt from studies about cellular stress response, and further one numerical dosimetry study on occupational exposure to the radiation of base station antennas.

FIFTY YEARS OF RESEARCH PROGRAMS ON BIOLOGICAL EFFECTS OF MICROWAVES: WHAT HAVE WE LEARNED?

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For many years the possibility that exposure to microwave energy, at levels below those that are thermally injurious, might cause health problems has been a subject of ongoing controversy. When I first became involved with this issue, as a new PhD assigned to the Naval Medical Research Institute (Bethesda, MD) there was considerable public debate about the safety of military radar systems to residents in the surrounding communities. Since then, debates have taken place, mostly in the public arena but also to a much lesser extent among scientists, about possible health risks of: military radar and communications systems, police radar, microwave ovens, and mobile telephones and their base stations. In response, industry and governments around the world have sponsored many research programs and conducted many expert assessments of the now-extensive scientific literature on this topic. I review some of the changes that have occurred over time in the research programs on this topic. One striking change has been the improved sophistication of agencies in targeting research. Whereas in the 1970s, much of the research (at least that sponsored by U.S. government agencies) was exploratory in nature, and involved biological systems and endpoints with no clear relevance to human health, in recent years there has been a progressive shift towards more focused research, with endpoints more clearly related to health risk assessment. The overall quality of research programs, while even now is highly variable, has improved greatly over the years. One lesson has been that issues related to replication of research findings can be easy to raise but very difficult to settle, and can lead to excessive resources being devoted to research topics that are unlikely to be of much use in health risk assessments. Finally, however inefficient and controversial the process has been, on the whole health agencies have responded in an exemplary way to address citizens' health concerns about possible health effects of microwave energy. The problem now is how to move forward, given the declining support in this area.

REVIEW OF EXPOSURE TECHNIQUE AND DOSIMETRY FROM THE 1990S UP TO NOW

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In this contribution the development of radio-frequency exposure equipment for biological experiments and of the corresponding dosimetry will be reported starting with the beginning of the early 90s of the last century up to now. The report mainly follows the work which has been sponsored by the FGF and which in part has also been done at the Chair of Electromagnetic Theory of the Wuppertal University.

In parallel to the massive increase of base station sites for the GSM-mobile communication system in the early 1990s public fear grew concerning possible health risks through being exposed to electromagnetic fields produced by mobile phones and even by base stations. One reason for this were published reports on experiments which proofed – according to the authors – the risks. Critical reviews of many of these papers, however, called into question whether the outcomes stated by the authors were correct. Often there were doubts concerning the reliability of the exposure equipment applied by the researchers: Did the equipment actually produce the fields inside the target the researcher believed?

One of those experiments was that of von Klitzing on presumed effects of RF-fields on the EEG of volunteers. The doubts concerning his procedure motivated the FGF to initiate further experiments on possible effects of signals produced by mobile phones on the human. One of the main improvements of these new investigation was that the concept should be developed in an interdisciplinary group of physicians and of engineers thus guaranteeing that the necessary expertise from the medical/biological as well as from the technical side was available. Also the following steps – performance of the experiment, evaluation and discussion of the results - were done within the group. The first experiment on exposure of volunteers we provided with the technical equipment was followed by some more, especially on possible effects on sleep-EEG. Using the example of these experiments the special engineering challenges, the state of art at that time and the improvements obtained will be demonstrated in the report.

Another field we were involved in with the development of RF exposure devices from the very beginning was that of in-vitro experiments. There were two starting-points: First, there were reports on genetic damages, which should be examined by own experiments initiated by the FGF together with the research group organized by Prof. Brinkmann at TU Braunschweig. Cylindrical glass containers with small volumes of liquid were positioned in a rectangular waveguide with the dominant mode propagating. We had to learn, how to locate the vessels in order to equalize the resulting specific absorption rates (SAR). The other starting-point were reports on influence of RF-fields on the ion flux through cell membranes: The challenge was the very small size of the cell system, which – although simultaneously exposed to RF fields - had to be accessible to measurement electrodes. We will demonstrate the development from rather simple exposure set-ups to much more sophisticated systems, which were required for the exposure e.g. of hair cells of the inner ear underlying patch-clamp measurements, or of containers with layers of artificial blood-brain-barriers, the impedances of which were measured during exposure.

The third field we supplied with exposure set-ups was that of investigations on restraint as well as on non-restraint small animals like hamsters, rats and mice. Restraining of animals is unavoidable if only local exposure is required. Local exposure means that the target is located very close to the source, that means, in the near field. Then the antenna parameters depend very critical on the actual geometrical data, i.e., special measures are required to

obtain a stable and by this reproducable exposure. Non-restraint animals running free inside their cages must be exposed in an almost uniform field, so that the actual exposure is nearly independent of the position of the animal inside the cage.

The main progress in the field was, however, achieved by the application of powerful numerical methods for the analysis of the fields inside the targets on large computers combined with realistic models. Before the early 90's only approximate equations together with very rough models had been applied, by which often rather poor or even completely wrong field distributions were obtained. We will demonstrate the progress achieved during the last 15 years by comparing models and results of early and of nowadays investigations.

OVERVIEW ON THE EPIDEMIOLOGICAL RESEARCH ON BRAIN RELATED OUTCOMES

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Epidemiological research on mobile phone radiation and brain related outcomes focuses primarily on tumours. Only a few studies dealing with other outcomes are available so far. Other outcomes include behavioural problems, cognitive functions and neurodegenerative diseases.

INTERPHONE and most other epidemiological studies on brain tumour are case-controls studies. This is the most efficient design for rare diseases but has inherent limitations related to the retrospective exposure assessment and the control selection. A recent review of the ICNIRP Standing Committee on Epidemiology concluded: “Despite the methodologic shortcomings and the limited data on long latency and long-term use, the available data do not suggest a causal association between mobile phone use and fast-growing tumours such as malignant glioma in adults (at least for tumours with short induction periods). For slow-growing tumours such as meningioma and acoustic neuroma, as well as for glioma among long-term users, the absence of association reported thus far is less conclusive because the observation period has been too short.”

The availability of cancer registries in many countries is also helpful for the evaluation of a potential brain tumour risk from use of mobile phone. Because nowadays almost everybody uses mobile phone, this should eventually result in an increase of the brain tumour incidence if there is a true risk. Thus, important supplementary information about the temporal trend of brain cancer incidence can be obtained from cancer registries and complement risk evaluation.

However, for other brain related diseases such registries are not available. Thus, the temporal trend of behavioural problems in children and adolescents or the temporal trend of neurodegenerative diseases cannot be monitored. Thus, it is almost impossible to detect an increase in the incidence unless it is very pronounced. Moreover, for some diagnoses the criteria are fuzzy to some extent and changes in the diagnosis practice can result in a strong apparent increase of cases. A typical example would be attention deficit hyperactivity disorder (ADHD) in children. Such issues complicate time trend analyses even more.

For these reasons epidemiological studies of high quality on such brain related diseases are urgently needed. Otherwise, even crude risk evaluation is not possible and considerable uncertainty remains. Actually, there is no supportive evidence why mobile phone research should only focus on brain tumours and neglect all other brain related diseases. Exposure to the brain from use of mobile phone is equally relevant for all of these diseases.

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PROBLEMS OF THE DESIGN AND ANALYSIS OF ANIMAL EXPERIMENTS ON CHRONIC EFFECTS OF EMF

Michael Kundi

RISK ASSESSMENT APPROACH AND OVERVIEW OF SCENIHR WORK ON HEALTH EFFECTS OF EMF

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The Scientific Committee on Emerging and Newly Identified Health Risks, SCENIHR, is one of the three independent non-food scientific committees that are sorting under European Commissions DG SANCO. According to its general mandate, SCENIHR provides "opinions" (written comprehensive documents that "belong" to DG SANCO and/or other bodies within the EC) on questions concerning emerging or newly identified risks and on broad, complex or multidisciplinary issues requiring a comprehensive assessment of risks to consumer safety or public health and related issues not covered by other Community risk assessment bodies. Among the topic areas that SCENHR has covered, electromagnetic fields (EMF) have received considerable attention, leading to the publication of three opinions so far [1,2,3].

The general process when developing a SCENIHR opinion is according to the following steps:
i) Identification of relevant publications. ii) Preliminary examination of the data and selection of those publications that are considered important in order to address the questions posed to SCENIHR. iii) Detailed examination of each of the individual publications selected in step ii) to assess the validity of the findings and to identify those that will be discussed in the opinion. iv) Synthesis of the information from each such identified publication to answer particular parts of the questions posed. This implies integrating the results from all relevant individual studies. v) Integration of the findings into a draft opinion that identifies the risks and the consistency of the data, the important data gaps and areas of uncertainty.

The opinions that SCENIHR has produced on EMF deal with possible effects of EMF on human health [1 and 2], and on research needs and methodology to address knowledge gaps regarding potential health effects of EMF [3]. The structure and the conclusions of these opinions, with special emphasis on radio frequency fields, will be presented during the workshop.

References

[1] Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Opinion on: Possible effects of electromagnetic fields (EMF) on human health. 21 March 2007. 64 pp.
http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf
[2] Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Opinion on: Health Effects of Exposure to EMF. 19 Jan 2009. 83 pp.
http://ec.europa.eu/health/ph_risk/04_scenihr/docs/scenihr_o_022.pdf
[3] Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) Opinion on: Research needs and methodology to address the remaining knowledge gaps on the potential health effects of EMF. 6 July 2009 28 pp.
http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_024.pdf