Report on the FGF Workshop in Immenstaad:

"Can electromagnetic fields used in mobile communications provoke sleep disorders and other cognitive changes?"

Siegfried Eggert, Roland Glaser, Frank Gollnick, Lutz Haberland

During the international scientific meeting taking place in Immenstaad, Lake Constance (Germany), on December 8 to 10, 2003, 50 experts from corresponding research disciplines discussed this topic.

The workshop hosted by the Research Association for Radio Applications (Forschungsgemeinschaft Funk, FGF) in cooperation with the European Research Action COST281 and the Ministry for Environment and Transport of Baden-Württemberg, Germany, aimed to discuss current results of scientific investigations on biological effects from electromagnetic radiofrequency fields (RF-EMF), especially on human sleep, and to present recommendations for future research activities. In recent years, particularly results from a research group around the Swiss sleep researcher Peter Achermann has given cause for concern. According to the group, exposure to weak radiofrequency fields used e.g. in mobile radio communications, lead to alterations in brain activity during sleep as was shown in experiments performed with volunteers.

The subject was approached from different angles by two basic contributions and a number of special contributions from the fields of epidemiology (population-based studies), experimental sleep and cognitive research as well as measurement and exposure technology for investigations performed on humans. The meeting intentionally allowed much time for discussion. There were detailed reports on already performed or planned sleep studies, on population studies based on questionnaires, as well as on various studies investigating cognitive performance (perception, response – mainly in humans) under exposure to radiofrequency fields. Thus, the human brain and potential influences from mobile radio fields on its function always were the focus of discussion. The workshop was rounded off by discussions about methods aiming to achieve exact and best possible measurements and evaluations of basal parameters (e.g. EEG recordings, field measurements, types of questionnaires), about appropriate mobile radio field simulation in the laboratory and about adequate test systems and methods to obtain most realistic conditions in experiments.

The meeting was subdivided into the following topical sessions:
- Medical basis of sleep and sleep disorders
- Epidemiological investigations on RF-influences on sleep disorders
- Dosimetry
- Experimental investigations on RF-influences on cognitive processes and sleep disorders

At first, Gerd **Friedrich** (FGF), Norbert **Leitgeb** (COST281) and Peter **Brunner** (Ministry) welcomed the attendees. Brunner used the opportunity to describe the action taken by his ministry to clarify potential health dangers from mobile radio and other high-frequency technologies. In particular, he referred to the recently finished large-scale immission measurements (broadcasting, television and mobile radio) performed in Baden-Württemberg. All achieved values were far below valid limits – the highest measured value did not exceed 11% of the limit.

Medical basis of sleep and sleep disorders

The introductory session dealt with **sleep and sleep disorders from a medical perspective**. Dieter **Riemann** (University Hospital Freiburg) gave a survey on sequence and relevance of the different sleep stages and on the association with hormonal alterations and the biological diurnal rhythm. The various types of sleep disorders (insomnia – sleeplessness, hypersomnia – pathologically excessive sleepiness, parasomnia – sleep regulation disorder) and their possible causes, related to corresponding methods of treatment, were discussed.

In his lecture, Thomas **Penzel** (University Clinics Marburg) focused on the methods of sleep diagnosis and problems of hypersomnia. Numerous methods are applied for characterizing sleep quality, such as recording the

- EEG (electroencephalogram – measurement of electric brain activity)
- EOG (electrooculogram – electrical measurement of eye movements)
- EMG (electromyogram – electrical measurement of muscle activity)
- ECG (electrocardiogram – measurement of electric cardiac activity)
- Movement
- Snoring and
- Respiration.

The subdivision into sleep stages is made by means of the obtained data (primarily from electric brain actvitiy). However, this process is not fully objectifiable since concurring results produced by different evaluations interestingly do not exceed a quota of agreement of 60 to 85%. After that, causes and side effects of hypersomnia were addressed.

The following **discussion** mainly focused on the **objectivity of sleep measurements**: Are there methods for measurement sensitive enough to prove also very slight effects on human sleep? Is it possible to measure individual sleep variability, and how many nights do you need for this? Are there methods for objective sleep course recording requiring less expenditure than complete EEG measurements, such as methods less disturbing the sleep of volunteers that may be applied at home and under everyday conditions? Obviously, there still are no definite answers to these methodological questions. Available hand-held recording devices such as the mini device QUISI operating with only a few electrodes, provide data of limited conclusiveness.

Population-based (epidemiological) studies and measurements in the direct environment

The session on epidemiological studies began with a lecture held by Ekkehardt **Altpeter** (Unversity Bern) dealing with a shortwave transmitter in Schwarzenburg, Switzerland. Due to health complaints of residents, studies on sleep quality (questionnaire) and hormonal alterations (melatonin) were performed in the 90ies. Whereas, depending on the distance from the base station, there was no statistically distinct effects of the transmitter on normal nocturnally enhanced melatonin production (except a slight increase in the more strongly exposed group at a short-term switch-off of the transmitter), the reported sleep quality showed a definite association with the distance to the transmitter. The closer respondents lived to the transmitter, the stronger were complaints about insufficient sleep and the more rigid was a self-imposed 'sleep hygiene' (e.g. avoidance of heavy meals before sleep). Problems of the study's conclusiveness were discussed, for example the impossibility of 'blinding' this type of survey. The persons living in the vicinity of the transmitter easily could get information on whether it was switched on or off.

Martin **Röösli** (University Bern) lectured on approaches to examine mobile radio effects on sleep in a 'real life situation' – an attempt to combine epidemiological studies with laboratory experiments. A variety of methods is necessary in order to achieve conclusive results: sleep diaries, hormonal tests, interviews, movement recordings during sleep and exposure measurements. In a first study, residents were measured before and after new base stations were put into operation without test persons knowing the exact time of the switch-on. As exposure of participants increased only slightly upon the switch-on of the additional base station, conclusiveness of *methods* could be the only focus of the study. Results themselves were not conclusive. It is planned to produce EMF exposure in future directly in the bedrooms of test persons in order to obtain distinct and reproducible field characteristics. However, the referee emphasized the need to do 'blinded experiments' (where test persons do not know switched on/off conditions of the field source) which is difficult to achieve under these conditions. The need for positive controls (e.g. noise) was discussed.

Hans **Dorn** (acting for Heidi **Danker-Hopfe**, both Charité, Berlin) reported on a similar feasibility study performed in Germany. Mainly, the EEG of volunteers from the township of Flachsmeer was recorded at home by a portable device (QUISI, see above) and then evaluated to determine sleep efficiency. The results of the methodic evaluations were satisfactory (approx. 85% of the recorded nocturnal EEGs could be evaluated). Therefore, further tests are planned. However, possibilities to selectively switch off mobile radio base stations for periods of time will have to be found – which is not easy to put into practice. Subject of discussion was again the problem of 'blinding' participants and, first of all, types of exposure (mobile radio only as a small subset of overall exposure such as from e.g. television and broadcasting!).

Enrique **Navarro** (University Valencia, Spain) reported on an epidemiological survey on reduced well-being in dependency of exposure from transmitters in a small Spanish community. Approximately 100 questionnaires based on the

R. Santini questionnaire (which were 70% of the total of sent questionnaires) indicated an increase of sleep disorders dependent on the distance to the nearest base station in this pilot study. Conclusiveness of the used questionnaires and the performed measurement types (broadband radiofrequency signal instead pure GSM signal) were seriously doubted during discussion.

In the following, the different **confounders in epidemiological studies** regarding sleep and EMF were discussed. The most important confounders are light, activity (physical exercise), temperature, noise and biological rhythm (keyword: shift work). Also hormonal influences such as the female menstruation cycle were addressed.

Regarding methodology, among others the limited conclusiveness of questionnaires was emphasized. Moreover, the need for obtaining defined exposure parameters as well as for blinding volunteers was addressed. The question arose of whether a survey clearly relating to base stations might perhaps lead to suggestive answers. Although further epidemiological studies on the topic doubtlessly are required, it appears to be rather difficult to exclude the mentioned sources for confounders. Therefore, new possibilities for a definite improvement of performance should be found. In summary, this session characterized conclusiveness of population studies performed *to-date* in this area as quite limited and doubtful.

Dosimetry, exposure systems in the laboratory, appropriate simulation of mobile radio signals

Three experts were invited to lecture on issues of dosimetry and construction of high-quality exposure systems for experiments performed with volunteers. Jürgen **Schuderer** (acting for Nils **Kuster**, both ETH Zürich) emphasized the need to design such systems in a way that answers of the highest possible significance (i.e. statistically explicit) to the question of possible RF field effects on humans are provided. Therefore, systems are required that provide field exposure which is as realistic as possible related to exposure from mobile radio base stations. Contrarily, they also should be able to achieve near-maximum limit exposure regarding intensity. Only by this, possible effects could be made visible and if proven, could lead to a scientifically founded revision of limits. Thus it is necessary to expose volunteers both to low and to high doses of a very well-defined test signal (dose-effect series). In addition, calculations supported by measurements performed in phantoms should be used to determine the actual exposure values.

In a review, Volkert **Hansen** (University Wuppertal) described the different approaches to design an exposure system for sleep studies in the laboratory and a reliable dosimetry. He also dealt with possible field distortions that may develop locally by the use of metal electrodes placed on the head for EEG recording. Moreover, naturally uncontrolled movements of volunteers during sleep should be included in field calculations (primarily head movements).

Gernot **Schmid** (Austrian Research Center Seibersdorf, Austria) spoke about experiments performed with 58 volunteers investigating whether visual perception alters under exposure to simulated UMTS fields. Four different types of cognitive function and visual perception tests could not find any statistically significant deviations compared to control tests without exposure. The focus of this lecture was the specially constructed exposure system used inside a RF-shielded cabin and emitting an UMTS signal by modified stereo headphones which were placed directly on the head of the subjects at an area where normally the mobile phone is held. Thus, the UMTS standard signal reached the test persons' heads in a very realistic way while their hands were free to perform the visual perception tests (screen presentations with special keyboards to answer the tasks).

During **discussion following this session** it was emphasized that presently, from a technological perspective, there is sufficient knowledge and potential to ensure a reliable, reproducible field exposure *in laboratory* sleep studies. The knowledge gained by some experienced working groups should be (even more than until to-date) used in future planning. Contrarily, methodology and dosimetry used *in the domestic environment* (or in to-date performed epidemiological studies) turned out to be still insufficient. Available studies from this research area were evaluated accordingly. The need was identified to develop mandatory recommendations containing (at least technical) minimum requirements for scientifically acceptable epidemiological sleep research by a joint effort of several research groups experienced in this field.

Experimental laboratory studies

Peter **Achermann** (University Zürich) was the first speaker of the session on experimental studies. He reported on three different studies done by his working group on volunteers exposed to a 900-MHz GSM mobile radio test signal during and/or before sleep. The strongest effects could be found *at exposure during sleep*. Primarily, these were reduced short waking periods during the night after sleep onset and enhanced EEG signal amplitudes (in the so-called 'sleep spindles') during non-REM sleep (i.e. especially during deep sleep). REM means 'rapid eye movement', i.e. natural sleep phases where sleep is relatively 'shallow', one is dreaming and there is such (measurable) eye movement. The tests applying *exposure shortly before sleep* showed less pronounced effects – again in the non-REM EEG – which continuously decreased over time at farfield exposure conditions and vanished a few hours after exposure ended. The time course of effects at nearfield exposure conditions was inverted. Interestingly, 900-MHz EMF without GSM modulation provoked no effects in the EEG during this experiment. In future, dose-effect studies are planned. The interaction *mechanism* is so far completely unclear.

Joachim **Röschke** and Klaus **Mann** (both University Mainz) presented different aspects of their joint studies. The sleep EEG, hormonal alterations and heart rate variability had been examined. Whereas hormone status and heart rate showed no significant alterations during exposure to a 900-MHz GSM mobile phone signal, the first study could prove a shortened sleep onset and a reduced rate of REM sleep phases. Although these alterations could also be

found in a follow-up study, they were not any longer statistically significant compared to control experiments.

Subjective symptoms (headache, fatigue, dizziness, skin irritations) in healthy adults and children described as being non-hypersensitive during and after exposure to a 900-MHz GSM mobile phone signal were the topic of the lecture of Christian **Haarala** (University Turku, Finland). Compared to the controls, no alterations could be found.

The final part of this session dealt with **planned, ongoing and preliminary studies** on sleep and brain function under exposure to electromagnetic fields. Norbert **Leitgeb** (University Graz) reported on a recently begun pilot study on persons characterizing themselves as electrosensitive and suffering from sleep disorders. For examination of this situation, every evening a tent is built in the bedrooms of participants (similar to mosquito nets), either with shielding properties of 40 dB or permeable against normally present environmental fields. Participants cannot distinguish between the different used mesh materials. During the ensuing discussion on this project, there was doubt about whether differences between the tents actually were not discernible by volunteers (e.g. by use of a mobile phone or a pocket-radio), especially if neutrality of volunteers is not necessarily to be expected. Leitgeb indicated that the study shall be performed only with cooperative persons which take an own serious interest in clarifying the circumstances of their disorders (i.e. not wanting to falsify the study by cheating).

Anja **zur Nieden** (University Gießen) reported on an epidemiological pilot study on sleep quality performed according to the criteria of general psychological surveys considering a large number of examined parameters. To-date available data provide no evidence for an association between mobile phone use and sleep quality. In the discussion, the relevance of gathering the characteristics of personality structure was underlined. The special (and in this research field novel) design of the questionnaires could be exemplary for other planned epidemiological surveys on the topic of sleep and mobile radio fields. There was huge interest in the final results of the study and first of all in the applied methods.

A large-scale Swedish study using a variety of methods will soon examine the influence of mobile radio fields (900 MHz GSM) on sleep quality. Questionnaires, EEG recordings and hormonal tests as well as behavioral tests will be applied (lecturer: Arne **Lowden**, Karolinska Institute Stockholm, Sweden). During the discussion following this session, as well as during general discussion, the attending experts presented quite a few useful proposals and valuable recommendations for improvement regarding this highly interesting soon-to-be-launched study. Also this can be regarded as an important impulse and a worthwhile result of the workshop – right before this study is going to be started.

Within the German Mobile Radio Research Program Michael **Bornhausen** and colleagues (LM University Munich) will examine the influence of GSM and UMTS fields on the behavior of three generations of rats. Inside so-called 'Skinner boxes', the animals will be challenged with automized behavioral tests

with graded complexity (reward after successful performance of a behavioral task) aiming at their potential brain capacity limit. An especially high resolution of obtained data is expected from this approach.

Possible effects of GSM, UMTS, WLAN and DECT signals on the sleep and the wake EEG and on cognitive tests are the subject of a study planned for next year at the University Bern (Reinhold **Berz** and colleagues, InfraMedic AG, Burgrieden-Rot, and University Bern).

Rüdiger **Maier** (University Mainz) spoke about an investigation on effects of GSM signals on cognitive tests performed on volunteers. However, there were no details on dosimetry; moreover, the statistical significance of results was determined only by means of a randomly selected statistical test without giving a reason why just this test and not others (providing no significance) should be the meaningful one. In the discussion on this talk a cooperation with dosimetry and biometry specialists was recommended to the group.

During the subsequent **discussion on experimental studies**, among other things the problem of replication studies was addressed. There will almost never be identical replication of studies since science lives and breathes constant improvement and development and since there is scarce funding for 'mere' repeat studies. However, such replications performed in the own laboratory and, primarily, by other working groups would be highly desirable from a scientific perspective for clarifying only once found and not fully explained effects.

The lack of explanations concerning effects found by some working groups (What is the underlying mechanism?) was discussed as well as the need for cooperation between different disciplines (medicine, biology, biophysics, physics, electrical engineering). As mentioned above, the chair of discussion Peter **Ullsperger** (Federal Institute for Occupational Safety and Medicine, Berlin) proposed convening an expert group for establishing methodological standards for EMF sleep research.

Is there a measurable effect? What is an effect?

The final **plenary discussion** was chaired by Jürgen **Kiefer** (University Gießen). First, the rapporteurs Hans **Dorn** (see above), Siegfried **Eggert** (Federal Institute for Occupational Safety and Medicine, Berlin) and Sheila **Johnston** (Neuroscience Consultant, London) summed up lectures and discussion. Discussion began with the question: Is there an effect on which to base further research, and which methods and test parameters are most appropriate to do this? One of the meeting's conclusions was that there has to be made a definite distinction between exposure intensities produced by the mobile phone during phoning and those fields being weaker by several powers of magnitude to which citizens are exposed by near base stations. Only in the first case, i.e. at fields relatively close to the limit values, there were sometimes measurable effects which have to be seen as preliminary since they were not yet reproduced by independent groups. Discussion dealt with the question of

whether signals of the exceptionally sensitive thermoreceptors of the skin and the brain surface might be responsible for these responses.

The second question directly related to the topic of the meeting was: What is called an 'effect'? How do we define 'sleep disorder'? Only if all groups evaluate their research results according to the same parameters, concurring results could be expected. But despite various proposals made during the workshop (sleep EEG, Bereitschaftspotential, physiological cardiac parameters), study standardization both seems to be impossible and to make no sense. This approach is contradicted by the high complexity of the 'object' (which is the human brain).

The invited experts agreed on the following statements:
● Biological effects may not be confused with health effects.
● Whenever possible, dose-effect relations have to be determined.
● Good statistics and dosimetry with generally accepted standards should be asserted for sleep research.
● Studies should be as far as possible independently replicated to gain scientific validity.

Dr. Siegfried Eggert, Scientific Assistant, Federal Insitute for Occupational Safety and Medicine, Berlin

Prof. Dr. Roland Glaser, in the past Director of the Institute of Biophysics, Humboldt University Berlin

Dr. rer. nat. Frank Gollnick, biologist, for a long time Scientific Assistant at the Institute of Physiology II, University Bonn; presently scientific consultant of the FGF

Dipl. Biophys. Lutz Haberland, Scientific Assistant, Biophysics Department of the Institute of Cell Biology and Biosystems Technology, University Rostock