

## The FGF's contribution on biological

by Wilma Dubois

**The FGF began its work in 1992, at the time when the first digital mobile communication network, the mobile communication network of the 2<sup>nd</sup> generation "GSM" (Global System for Mobile Communication) were introduced. Electromagnetic fields (EMF) had been emitted as radio waves by radio and television stations, radar systems, etc. for decades. At that time, mobile radio was used by only about 1 % of the general population of Germany. The number of research investigations published in scientific journals on the topic of mobile communication was low (1992: < 10), there was not much EMF research going on in Germany and it was restricted to technical aspects. With the expansion of digital mobile communication networks and the related installation of transmitting masts concerns over health risks from electromagnetic fields steadily increased.**

It was against this backdrop that two core tasks were presented to the FGF: on one hand the provision of objective and comprehensive information to the public regarding the state of scientific knowledge about biological effects of electromagnetic fields on humans and the environment and on the other hand, the focus of research on high-frequency fields as are used for modern radio technologies. The primary objective of the FGF's research work was to close gaps of knowledge, to strive for higher quality of research as well as insurance the quality of experimental research projects.

### The four phases of research work

After taking stock of available knowledge, highlighting the context of public risk perception and searching for open questions regarding "Electromagnetic Compatibility with the Environment" (EMC), the FGF first decided to conduct own experimental biomedical studies, relying on a basis of five different levels of investigation that comprise experiments with molecules, cells, animals, humans and medical devices (e.g. cardiac pacemakers). Due to the high costs, projects in "epidemiology" were not on the agenda of the FGF.

The 15 years of the FGF's research work can be separated in four phases (1-4), according to the focus of research activity.



# to the research effects of EMF

## First phase: cooperation with the „Research Association Electromagnetic Compatibility of Biological Systems“ and the “Research Initiative North Rhine-Westphalia“

The first phase of research work in the time between 1993-1996 was characterized by the cooperation with the “Research Association on Electromagnetic Compatibility of Biological Systems“ in Braunschweig, di-

rected by Prof. Dr.-Ing., Dr.-Ing E.h. Karl Brinkmann, that existed for more than 20 years, and the Research Initiative NRW on the topic of “Biological effects of electromagnetic fields“. At the end of 1993, this cooperation led to the commissioning of first experimental research projects. Four out of five levels of investigation mentioned above were considered in selection. The focus of interest were possible genotoxic and cancer promoting effects as well as

### The Different Investigation Levels of Research Projects



**Population** – Epidemiological studies (this is not a research topic # for projects supported by the FGF)

*Addresses the question as to whether or not high frequency electromagnetic fields have an effect on an entire population (how often does a certain illness occur in combination with a specific risk factor?)*



**The Individual** – Human studies / animal studies

*Does a controlled application of a specific factor (e.g. a electromagnetic field) trigger a measurable reaction in the body.*



**Cells and Tissue** – cellular biological investigations

*Can the behaviour of cells, cell associations and cell membranes be influenced by electromagnetic fields (localization of the areas effected)*



**Molecules** – Biochemical und molecular biological investigations

*Can biochemical or molecular structures be influenced by electromagnetic fields. (investigating mechanisms which cause the effect)*



**Medical Devices** – investigations on whether or not EMF interfere with electromagnetic devices

*Investigations on the effects of electromagnetic fields on electromagnetic implants, e.g. cardiac pacemakers (if applicable, effects the corresponding standard)*

the effects on cell membrane function (cellular level), the effect of EMF on brain function and hence on the human central nervous system (level of humans) as well as medical devices such as cardiac pacemakers (level of medical devices). Moreover, first experiments with artificial cell membranes (bilayers) were conducted, by which in the following, an intense analysis of “EMF interaction mechanisms“ (molecular level) was initiated.

In this first phase, a total of 16 research projects (plus subcontracts) were performed on the effects of high frequency fields, as are used e.g. for mobile and police radio, television transmitters and for therapeutic ends. Seven scientific (peer-reviewed, reviewed by specialists in the field) resulted in seven publications.

## Second phase: new selection process

In the second phase (1996-1999) the FGF selected a new approach to the commissioning of research projects: a group of internationally acknowledged scientists is responsible for the selection in order to emphasize the neutrality and independence of the FGF. Open calls for tender with a selection of topics that followed the recommendations of the WHO Research Agenda; it was published in 1997 in the framework of the WHO EMF Project launched the year before. A total of 17 studies were started in 1997 and, in part, extended to the year 2000. Among them were also literature studies on single topics performed that completed different projects and provided information about the state of research of that time. Possible cancer promoting effects, the effects of EMF on melatonin synthesis as well as possible effects on the offspring were investigated in animal studies (level of animals). Moreover, the experiments with bilayers (molecular level) were continued in the form of calculations, analyses and experimental studies as well as experiments with the cell membrane (cellular level). Investigations of brain activity (EEGs) were continued and expanded by additional neuropsychological tests (level of humans). Another study on cardiac pacemakers concluded the observations on the level of medical devices within the research promoted by the FGF. When commercial applications of electro-

magnetic fields in the upper microwave range (cm/mm waves: 3 GHz to 300 GHz) emerged, a research project investigating possible effects of EMF in this frequency range was planned. 14 peer-reviewed publications were the result of this second phase of FGF research.

## Third phase: UMTS

The third phase of the FGF's research work (1999-2002) stood in the sign of the new mobile communication technology UMTS, the mobile radio system of the 3rd generation, which was commercially introduced in 2004 in Germany. Already in 2001 the FGF was the first research institution in Germany to include investigations on effects of UMTS signals on biological systems in its research agenda. The studies, in part, extended over several years or are still ongoing, respectively. Experiments were conducted both on the level of animals and the level of humans. Two studies were devoted to the effects of UMTS on the central nervous system (CNS): on the cellular level the blood-brain barrier was the object of investigations, on the level of humans the visual system was more closely inspected. The level of animals was covered by a multigenerational study on possible toxicological effects of UMTS fields on the offspring of rats. For comparability with other experiments, also in the international context, the first standardized UMTS signal scheme was developed and published on the initiative of the FGF and is since applied in many, also international, projects.

Moreover, experiments on GSM signals were continued in this phase. Again the effect of EMF on the CNS was investigated and, on the other hand, a topic not yet considered in the experiments was studied: electrohypersensitivity.

In total, besides three literature studies eight experimental studies were promoted in this period. Nine peer-reviewed publications were the result so far.

## Fourth phase: science dialog

The fourth phase (from 2002) began against the backdrop of the increase in intensive research in Europe regarding mobile radio field risk assessment, advanced by large-scale research programmes as e.g.



the “German Mobile Communication Research Programme“ or coordinated European programmes like “REFLEX“, “Perform A“ and “Perform B“. In view of the steadily increasing number of scientific studies on EMF effects on biological systems, the FGF intensified its promotion of the review, analysis and discussion of available scientific literature and the experts’ discussion of current research foci. An important part of this concept is the organization of expert workshops on special topics in order to promote the exchange of information between scientists, to work out the state of the art of science and to make reports available to interested persons. The cooperation with national and international organizations and bodies was intensified, e.g. for five years the FGF functioned as the Secretariat of the scientific coordination action of the EU “COST 281“.

Moreover, the cooperation with the WHO’s “EMF Project“ as well as with the “Research Centre for Electro-magnetic Compatibility“ (*femu*) of the RWTH Aachen was expanded further.

### A focal point: expert workshops

A well-established element of FGF research activities are the expert workshops on current research topics, which now take place 2-3 times a year. They serve as a platform of in-depth discussion of the present state of knowledge for scientist. They are intended also to discuss their own results and, mainly, the questions that are still open in EMF research. The researchers can get an overview of the current state of knowledge by the observation of planned or ongoing projects. The objective, open character of the workshops quite often gives the possibility to establish productive contact between research groups. Here, the participa-

tion of experts (e.g. biomolecular scientists, sleep researchers or pediatricians) who are not active in the area of EMF research before, but have excellent experience in the methodology and the conclusiveness of studies done in the respective special areas is specially emphasized. The restricted number of participants (about 50) and the space given to discussion allow an in-depth investigation of topics and quite often result in consensus statements. An example for this may be the concept for a metastudy on genotoxic issues with sufficient statistical power, the idea of which was born and presented at the workshop in November 2002 in Löwenstein. This concept led to a recommendation of COST 281, which again was considered and implemented in a currently ongoing project of the German Mobile Communication Research Programme. The selection of the topics of the workshops is based on internal analyses of the present state of research and on recommendations of members of the FGF or other organizations, like for instance the WHO. Areas of research, where several studies have obtained contradictory results, as was the case e.g. regarding investigations of possible interaction mechanisms between electromagnetic fields and biological structures or investigations on the effects of high-frequency fields on the blood-brain barrier, are especially considered. A topic that is presently under discussion, namely whether children are especially sensitive to EMF exposure, was dealt with at one of the FGF’s workshops.

This part of the work of the FGF has been an essential contribution to the quality improvement in the



methodology of investigations, the qualified review and evaluation of the present state of knowledge. The workshop reports are available on the Internet at <http://www.fgf.de/fup/ergebnisse/erg-11work.htm>.

## Literature and information database

The effort to present available knowledge about EMF effects on humans and the environment in a transparent and comprehensible way was linked to the continuous support of the FGF for the literature and information database on the effects of EMF on humans and the environment (knowledge-based literature database, WBLDB). Under the direction of Prof. Silny, the information database on biological effects of low- and high-frequency electromagnetic fields was created at the Research Centre for Electro-magnetic Compatibility with the Environment (*femu*) at the Technical University of Aachen, where both experts and laypersons can get free information on the present state of knowledge through the use of scientific literature.

A compact description of the most relevant biomedical and technical aspects of each publication enables the user to get access to further information, without having to read the entire publications, which are mostly in English. The bilingual (German and English) database, financed by different institutions, was developed over many years and is today the core element of the so-called EMF portal (<http://www.emf-portal.de>), by which the topics and contents of special literature are made more easily comprehensible,

with the help of additional information services like a “glossary“, the database on “exposure sources in everyday life“, the “basics“ and the “forum“ for users. At present, more than 10,000 publications are included, new special articles are included as they come along. All experimental studies from the biomedical area with applications of frequencies as are used in mobile communication have been evaluated regarding their biological and technical contents. Since the official opening of the EMF portal in July 2005 a steady increase in use intensity has been observed (now about 1300 visitors a day). Due to its bilingual character, the portal is also used internationally mainly by visitors from the USA.

## Topics and the context of research work


The FGF is still conducting and accompanying experimental studies among other things to maintain its scientific competence. Within these studies, in part, novel test approaches for the investigation of the impact of EMF were developed, or, by providing initial funding, their development is made possible. So, for instance a new test approach regarding the impact of EMF on sleep quality was checked in a pilot study. The idea was that not the response of volunteers to a provocation with irradiated artificial fields, but the response to the shielding against emissions of EMF (strong attenuation of the impact made responsible by electrosensitive volunteers for their sleep disturbances) should be investigated (project EPROS: Electrosensitive Protected Sleep).

Furthermore, an ongoing animal study accounts for the urgent need for longterm studies. While many of the studies termed “longterm studies“ do not exceed an experimental phase of about two years, this study is a true lifetime study; the animals are exposed, observed and examined until their natural death.

In another ongoing study whole-body dosimetry is calculated under complex field conditions against the backdrop of the steady increase in the simultaneous exposure of humans to many technical electromagnetic field applications.

A multigeneration study, considering possible fetus-damaging effects of UMTS signals etc., is not finished either.





Moreover, several literature studies, e.g. accompanying own studies and workshops of the last years (4th phase), were commissioned.

In the 15 years of the FGF's research the planning, construction and field-calculation regarding applied exposure systems were continually improved and adapted to the state of technology. Examples for this are: the development of a small TEM cell and of several hollow wave guide cells for microscopic "in vitro" tests, several radial wave guides for animal tests or tests with tissues and cells, an antenna system for the nocturnal exposure of volunteers in sleep studies investigating the CNS, as well as the design of special exposure rooms and antenna systems for other human high-frequency experiments. Moreover, the definition of a standardized GSM signal and UMTS signal ("generic test signals") for research commissioned by the FGF served to improve the qualitative standard of EMF research and the comparability of different experiments. Due to the progress of computer technology, sophisticated dosimetry calculations became possible. The quality of experiments on the „biological level“ was ensured by following the standards recommended by the World Health Organization (WHO) in its commissioning. Special emphasis is put on the transparency and the critical discussion of study contents and results promoted by the FGF. This is guaranteed by a competent and continuous project accompaniment, the documentation of results in final reports, by public scientific colloquia on each experimental study, by publishing the results in peer-reviewed special journals and presenting them in a comprehensible manner in the media of the FGF (Newsletter, Edition Wissenschaft, etc.). The above-mentioned expert workshops on current research topics also contribute to this. The research results hence are always made available for scientific discussion and for general information. If possible, external experts are included in each phase of a project (definition of objectives, selection, study design, final evaluation).

### Overview of single topics in research work

Looking back, there were four topics in the aforementioned four phases of FGF research activities, which

were investigated in several phases from different perspectives, as well as five topics that were in the focus for a shorter time.

The following four topics were being investigated over a longer period:

- interaction mechanisms of EMF
- effects of EMF on the central nervous system
- possible cancer-promoting effects of EMF
- possible genotoxic effects of EMF

### Interaction mechanisms

The results of a project with artificial membranes launched in the first years of the FGF's research work (bilayers) in the following led to intense discussion of the topic of possible interaction mechanisms between weak EMF and biological structures. The hypothesis of the study was: if there is an interaction between weak high-frequency fields of radio applications and biological structures, evidence of it should be found also in the model "artificial membranes" without these effects being overlapped by natural processes of cells and the whole organism, respectively. Hence it should be possible to identify the molecular mechanism of a potential interaction and to extrapolate it to complex biological systems. The results of this first study were supported by dosimetric analyses and calculations and followed up in a literature study, a reproduction study and an expanded study with polymer foils. A final publication was submitted to a peer-reviewed journal and shall be published in the near future. Several literature studies and FGF workshops on this topic provided the scientific background and offered the possibility to discuss this fundamental issue on the international level. The investigations of artificial membranes to date are unique in their form.

### Effects of EMF on the central nervous system (CNS)

The effects of EMF on the human CNS as the most frequently investigated topic were also examined in FGF research. Seven experimental studies and six literature studies and workshops, respectively, focussed on this important topic in the 15 years of the FGF's existence. First, the brain activity in the waking state and the cognitive competence at exposure to

EMF was in the focus of interest. Later corresponding examinations were conducted during sleep – they were among the first experiments of this kind. In 2002, a series of contradictory or non-reproducible research results on possible EMF effects on the CNS were available. The FGF initiated another project investigating the cognitive performance under special consideration of the field modulation (pulsed/continuous) and the exposed brain hemisphere. The effects of UMTS fields on the human visual system and the brain blood barrier were examined in FGF studies. None of these studies observed field-specific effects on the study objects. Nearly all studies on this topic promoted by the FGF were published in peer-reviewed special journals.

## Cancer-promoting effects

Overall, three experimental studies on this topic were conducted in the years 1993 to 1998. Two “in vitro” studies examined the growth behaviour of human leukemia cells, one “in vivo” study investigated possible cancer development in mice. None of the studies could give evidence of cancer promoting effects of EMF. In two other “in vivo” studies in rats the focus was also on pathological organic changes and, hence, possible cancer development as well (1996, 1999). Evidence of cancer initiation at field exposure was not found, either. For in-depth discussion of this topic an FGF expert workshop titled „Are RF fields able to raise the risk of cancer?“ took place in 2004.

## Genotoxicity

The genotoxicity of EMF was considered during the first phase of the FGF’s research (1993-1996) as one of the first topics. On the molecular level possible genotoxic effects of mobile radio fields (GSM 900, 1800) on biological molecules (DNA and proteins), human cells as well as bacteria and viruses were examined. No clear, reproducible effects were observed. Own studies on this topic were not followed up. But the topic of genotoxicity was discussed during two workshops (2002, 2007) as well as – in a broader sense – in a literature study and two workshops on gene expression and heat shock proteins (HSP) (2003, 2004, 2005).

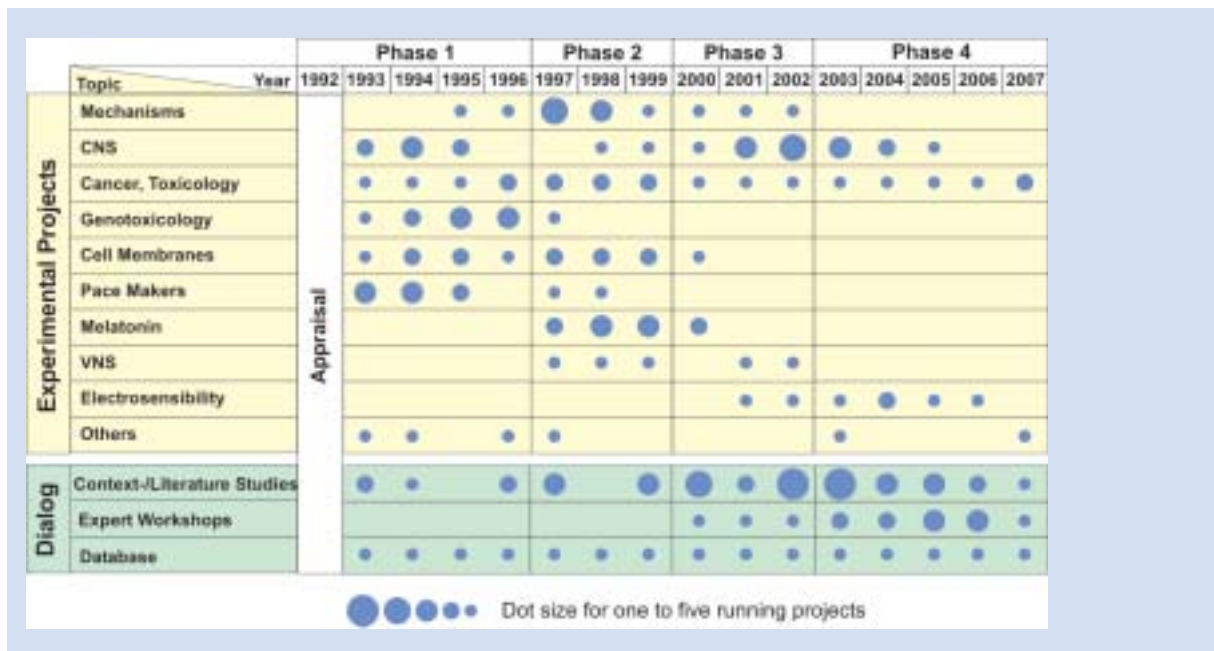
Contrary to the above-mentioned topics, the following five topics were observed over a shorter period:

- effects of EMF on cell membranes (1993-1997)
- impact of EMF on cardiac pacemakers (1993-1998)
- impact of EMF on the melatonin synthesis (1996-1999)
- effects of EMF on the autonomic nervous system (1997-2000)
- electrohypersensitivity (2001-2005)

Some of the first studies promoted by the FGF were devoted to the topic of a **possible effect of EMF on cell membranes**. This effect was examined via the measurement of ion concentrations (calcium), membrane currents and membrane potentials in cells of animals and humans. None of the studies observed field-specific effects.

On the level of medical devices calculations, measurements as well as computer simulations of interference voltages were conducted in a body model in the first five years of the FGF research programme. The question was whether there are interference effects of high frequency EMF as are emitted by mobile radio devices and television transmitters on cardiac **pacemakers**. In the 2<sup>nd</sup> phase the topic of “Effects of EMF on the **melatonin hypothesis**” was examined in form of theoretical considerations (literature study “The melatonin hypothesis”) and in three subsequent experimental investigations. The research plan was to examine the melatonin hypothesis in the selected object on three different biological levels, the level of cells, organs and the living animal. Final conclusions on these experiments are being prepared for scientific publication.

Possible effects of EMF on the autonomic nervous system (ANS, the part of the nervous system controlling involuntary, often unconscious body functions, e.g. digestion, heart rate, breathing, etc.) were closely inspected over a limited time period in three subsequent projects. The ANS had already been examined in the context of military applications, e.g. radar, but not in association with cm/mm waves, which were used in emerging technical applications in the civil sector (e.g. distance radar in vehicles). By promoting corresponding projects, the FGF responded to this gap of knowledge. Effects on the human ANS at



This table is an overview of the number of ongoing projects promoted by the FGF per year and focal topic. The length of some projects – sometimes several years – is correspondingly reflected in the number of points given to each project, i.e. the points symbolize either single one-year projects or a project of several years.

exposure to cm/mm waves could not be observed. A project just recently finished was devoted to **electrohypersensitivity**. It was the aim of this provocation study with volunteers performed under laboratory conditions to investigate electro sensitivity at exposure to simulated electromagnetic fields of a D net mobile radio base antenna. There was no statistically significant evidence that the volunteers sensed the electrical field used in the experiment under the selected laboratory conditions (completely shielded from external electrical fields).

In another study, mentioned in the paragraph on “Topics and the context of research work“, the development of a novel test approach (project EPROS: Electro-sensitive Protected Sleep) was promoted in a pilot study.

In view of the summary reports of different national and international research programmes (DMF, Interphone, WHO EMF-Project) that are soon to be expect-

ed, the FGF will increasingly devote resources to the review, evaluation and mediation of research results (science dialog, communication). Nevertheless it is planned at present to continue the promotion of own research (to a smaller extent) in order to maintain own scientific competence. Emerging technologies (e.g. RFID, WiMAX, etc.) may point the way. The European Research Advisory Board (EURAB) recently recommended that there be a conclusive exchange between science and society. The FGF will continue to make a valuable contribution to this.



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