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Rapporteur´s Report from the Workshop:

Mechanisms for the Interaction of RF-Signals with Living Matter- Demodulation in Biological Systems

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Rostock, 11. – 13. September 2006

A Workshop was held in Rostock, Germany (11 - 13 September 2006) on "Proposed mechanisms for the interaction of RF-signals with living matter. Demodulation in biological systems." It was organized by FGF, COST281, the University of Rostock, and EMF-Net.

This workshop came as the "concluding event" of a series of eight workshops or seminars which had been held in the last six years addressing the issue of RF fields interaction with biological matter (see the list below).

The main objective of that workshop was to reach a consensus among the scientists working in this field.

The meeting took place at the University of Rostock and was attended by 45 scientists from Europe, the USA, and Japan. Along with talks and visit of the laboratories, much time was devoted to lively discussions. Talks about experimental work and not directly relevant to modulation mechanisms are not summarized in this report.

As the advancement of bioelectromagnetics must be based on both experiments and theory, FGF has built a database of published experimental works in which the comparison is made of the effects of continuous waves (CW, i.e. unmodulated signals) with those of pulsed or amplitude modulated waves (PW or AM-RF). This database was presented by **Margarita Simeonova** of the University of Rostock (info@fgf.de). It contains 163 papers published between 1967 and 2006. The carrier frequencies are 0.9, 1.8, and 2.45 GHz. One can learn from the database that (i) there is a lack of temperature control in half of the studies! (ii) there are no papers showing differences in effects of CW and PW in stress and cancer studies, while there are 4 papers in genotoxicity and 14 dealing with the nervous system showing differences. In conclusion, there is only a small percentage of the studies that is relevant (29%) and the differences occur more often under acute exposure, and more often in Europe! This most awaited database will soon be available on CD from FGF.

The main discussion topic of the meeting was demodulation of AM-RF. The need for definitions became at once obvious as physicists, engineers and biologists do not understand demodulation in the same way! **Tobias Weber** of the University of Rostock (tobias.weber@uni-rostock.de) gave an historical overview of RF modulation and demodulation and gave his views about the future of the techniques that are being developed and will be implemented.
An RF signal (s(t) = A(t) sin(2 f(t) + (t)) can be modulated in three ways: amplitude (A(t)), frequency (f) or phase ((t)). Prof. Weber explained the different ways this can be achieved and how demodulation at the receiver end can be done. Modulators must be nonlinear or time variant. Future signals will be modulated in the space and time domains (e.g., MIMO[1]).

[1] Multiple-input multiple-output

Another approach to demodulation was given by **Ken Foster** (kfoster@seas.upenn.edu) who reminded the audience that there is no low frequency component in the field spectrum of amplitude-modulated RF signals. However, the power spectrum of such signals contains low frequency components. It is known that demodulation can occur in biological systems if nonlinear elements are present which is the case in the membrane, but only up to the MHz range and not in the GHz range used in mobile communication.

Within the MTHR research programme led in the UK by **Lawrie Challis** (lawriechallis@aol.com), 15 human studies aimed at detecting possible effects of modulation (10 with GSM phones, 5 with TETRA and one on base stations), 4 animal studies including replications of the de Pomerai study on nematodes and of the Bawin and Adey findings on calcium efflux.
The conclusion so far from the data obtained within the MTHR programme is that there is no evidence of effects. However, the question remains of the nature of the mechanism of effects due to chronic exposure, if they exist.
One of the key ongoing project on demodulation is the one led by **Quirino Balzano** (qbalzano@glue.umd.edu) of the University of Maryland, USA, and **Peter Excell** (p.s.excell@bradford.ac.uk) of the University of Bradford, UK, as part of the MTHR programme. The objective is to detect emission at 1800 MHz (TE113 mode) from cells exposed at 900 MHz (TE111 mode) inside a cavity. Storing the energy in a double cavity will increase the chance of detection. The system should be able to detect emission if there are at least 6×10^3 nonlinear oscillators in the cavity (one million cells are exposed in a Petri dish with a small amount of medium). The experiment is in progress in the UK, with results expected within a few months.

One of the organizers, **Lutz Haberland** (lutz.haberland@uni-rostock.de) from the University of Rostock gave an overview of the previous 8 workshops.

1. Biological and Biophysical Research at Extremely Low- and Radio-Frequencies: (1) Application of Research Results across the Frequencies and Modulation Schemes of Present and Future Wireless Technologies, and (2) Demodulation in Biological Systems. Bad Münstereifel, Germany, 4th – 5th December 2000 (FGF)
2. Mechanisms for Interactions of Radiofrequency Energy with Biological Systems . Washington, D.C., USA, May 22-23, 2001 (MMF)
3. Physical Effects of Pulsed RF Fields at Microscopic and Molecular Dimensions (Microdosimetry). Dresden (Germany), 17th-19th December 2001 (FGF)
4. Review of Progress in Research on Interaction Mechanisms for RF Energy and Biological Systems. Rockville, USA, 30 & 31 October 2002 (MMF)
5. Subtle Temperature effects of RF-EMF . London, UK, November 12 - 13, 2002 (COST 281)
6. Quantifying Biophysical Mechanisms for RF Interactions. Plantation, Florida, USA, 22–23 March 2004 (MMF)
7. Do sinusoidal versus non-sinusoidal waveforms make a difference? Zurich, Switzerland, February 17-18, 2005 (COST 281)
8. Subtle Thermal Effects of RF-Fields *in vitro* and *in vivo*. Stuttgart, Germany, 21.-23. November 2005 (FGF)

Lutz Haberland reminded the audience that resonant absorption of RF fields by macromolecules is expected to occur only at frequencies above several hundreds of GHz. He also quoted key review papers including that of Foster and Glaser (2006 Health Physics, submitted) dealing with thermal and micro-thermal effects.

Friedemann Kaiser from Darmstadt (friedemann.kaiser@physik.tu-darmstadt.de) gave a talk on nonlinear dynamics, signal amplification, and the work of Prof. Fröhlich which has been often quoted and commented as a basis for mechanisms of bioeffects of RF. Friedemann Kaiser said that Prof. Fröhlich never said that his theories or models could explain bioeffects. That was not their purpose.

Cells are not lasers! There is no resonant absorption by DNA: these were the main messages of Prof. Kaiser.

More on the dielectric properties of cells came from Prof. **Jan Gimsa** of the University of Rostock (jan.gimsa@uni-rostock.de) who showed that the model of cell polarization charges is related to forces and movements or deformations of the cells. In the electromagnetic field, cells can behave – in a simplified view - as air bubbles or water droplets! At low frequency, there is no electric field inside the cytosol while at high frequency, the membrane is “transparent”. Using the proper fields, one can deform, orient, attract, trap, rotate, or move cells!

Other approaches were described by Prof. **Guglielmo D'Inzeo (**dinzeo@die.uniroma1.it) from the University of Rome “La Sapienza” in his talk entitled “from Molecular Dynamics to Cellular Networks”. The main idea behind his work is to
- integrate the interaction of electromagnetic fields with structures at different levels of scale and complexity.
- use various methods to describe the interaction and its consequences (quantum chemistry, molecular dynamics, neuron network modelling, etc.).
In parallel, experimental evidence is sought to support the theoretical approach.

The last talk was given by **Roland Glaser** (roland.glaser@rz.hu-berlin.de, Humboldt University, Berlin) on thermoreceptors and what he calls subtle thermal effects. Prof. Glaser showed that certain species have a high temperature sensitivity (e.g., the boa which can detect 3 mK in the infrared!). All thermoreceptors are based on changes in the macromolecular structure:
- RNA thermometers, which are ribo-switches involving cis-trans isomerisation leading e.g. to heat shock protein (HSP) expression,
- TRP (transient receptor potential) channels.[2]
There is a need for more research into the role these thermoreceptors can play in the detection of RF signals.

In conclusion, some consensus was reached (at least among the scientists present at the meeting) on the fact that the only established mechanism is the thermal one, i.e. effects are caused by increases in temperature of the living system. However, several other models and hypotheses deserve further elaboration and investigation.

[2] Benham, C. D.; Gunthorpe, M. J., and Davis, J. B. *TRPV channels as temperature sensors* Cell Calcium. 2003; 33(5-6)479-487