

Biophysical field interaction and their

Short report on the Workshop in Ft. Lauderdale/Florida March 22 to 23, 2004

by Roland Glaser

Can exposure limits for modulated and unmodulated radiofrequency fields be derived from scientifically based interaction mechanisms? What is the state of the art of research in this field? What relevance do biophysical radio-frequency field interaction mechanisms proposed by different authors have for frequencies, modulations and intensities actually used by mobile radio?

These related questions were the focus of a two-day workshop organized by Mobile Manufacturer Forum (MMF) and the FGF to which about a dozen of specialists, mainly from the USA, were invited for holding lectures and participating in discussion. This event was a continuation of a series of similar workshops that was begun in 2000 in Bad Münstereifel (see Newsletter 01/01) and continued in May 2001 in Washington (see Newsletter 02/01) resp. in December 2001 in Dresden (see Newsletter 02/02) where also biophysical mechanisms were discussed as an explanation of radiofrequency fields interaction in the intensity range of mobile radio. Discussion was based on lectures of attendees presenting the state of the art of theoretical research and its experimental basis.

The event began with a lecture of **A. Sheppard** and **Q. Balzano** titled: „A thermodynamic approach for determining the amplitude & frequency of possible nonlinear RF interactions on biological preparations“, based on their recent publications (Bioelectromagnetics 2002; 23, 278-287, and: 2003; 24, 473-482; see also “News from Science“ in Newsletter 1, 2004). The authors explained that amplitude modulated RF





action mechanisms relevance

fields would have to split into several resonant frequencies at absorption by nonlinear reactions within the system. These frequencies result from the modulation frequency and its multiple, as well as the sums from the RF carrier frequency plus the LF modulation frequency and their multiples. It should be possible to derive these oscillations of known frequencies capacitively and to measure them with a sensitive method, thus proving the nonlinear character of the field absorption mechanism. The authors hope to be able to detect – e.g. at irradiation of 900 MHz on the system – the first higher-mode oscillation, i.e. 1800 MHz, with a sensitivity of 10 to 100 photons per second and cell in a sample comprised of about 10^6 cells.

It was discussed – as had been done before in the remarks on the aforementioned publications – whether the proposed method was really adequate to recognize the weak signals with background noise, especially in cases of weak field application, i.e. in the range of legally prescribed exposure limits. According to the authors, at least the threshold values for nonlinear reactions of cells to amplitude modulated RF fields could be determined in case that there would be successful measurements only at higher field strengths.

R. Glaser spoke on the issue „Are thermoreceptors responsible for ‘non-thermal’ effects of RF fields?“ Mostly, biological reactions to RF fields that are not associated with a measurable heating of the tissue are called “non-thermal“. Given measurement accuracy is maximally +/- 0.1 degrees; measurement probes that are very large compared to cellular dimensions are applied. However, research groups investigating field effects largely ignored the progress made in recent years regarding thermoreception. Although it has been known for a long time that various animals have thermosensitive organs responding to a heating of one hundredth of a degree and below, transport proteins with an extreme thermosensitivity

in temperature ranges of very few degrees have only been found in recent years. Even more surprising is the fact that these proteins do not only occur in specific nerve endings but also in various other cells, like e.g. in the keratinocytes of skin. Thus local regulatory mechanisms beyond possible heat sensations can be activated that may not even express neuronally. Research in this field is progressing rapidly and should be carefully observed. Are these rough temperature measurements acquired in experiment really sufficient to speak of “non-thermal“ effects? Could some “non-thermal“ effects perhaps be explained by local changes in blood flow? Are measured effects ultimately “quasi-thermal“? Are they distinguishable from reactions of the body-inherent thermoregulatory system at temperature variations in daily life?

During discussion, it was emphasized that there are, naturally, “non-thermal“ interaction mechanisms in the sense of direct field effects on permanent or induced dipoles. Well-known examples of this are electrorotation and dielectrophoresis. However, these reactions secondarily lead to considerable heating since they require field strengths of several orders of magnitude above legal exposure limits. These mechanisms consequently have no relevance to the issue discussed here.

In his lecture “‘Selective’ heating of biological structures by Rf energy, revisited“, **R. Foster** pointed to the impossibility of hot spots in the microscopic range. He emphasized that this was already proven by Schäfer and Schwan in a publication from the year 1943 („Selective heating of small particles in the ultra-short wave condensator field“ – “Zur Frage der selektiven Erhitzung kleiner Teilchen im Ultrakurzwellen-Kondensatorfeld“, *Annalen der Physik* 43, 99-135). According to them, the characteristic time of the heating of a sphere in a cooling fluid is proportional to the square of its radius. For a sphere of $R=10\mu\text{m}$ it would reach an order of magnitude of 0.3 ms. Stationary heatings of local character in cellular dimensions and below

thus are physically impossible. Basically, this does not even change if the shape of bodies deviate from the sphere geometry. The calculation of the time course at application of pulsed or amplitude modulated fields showed that occurring local temperature variations in the microscopic range can be neglected for the same reason.

In discussion, the publication of Hamad-Schifferli et al. was addressed (Nature 2002; 415, 152-155; see "News from Science", Newsletter 1, 2003). A 1.4 nanometer gold particle adhered to a synthetic DNA sequence was thermally activated by irradiation of a 1 GHz field. Such extreme conditions of course are not comparable to dielectric inhomogeneities within biological systems.


E. Prohofsky in his lecture titled: "Looking for possible RF effects in biomolecules", dealt with the question of whether a direct energy transfer of GHz oscillations into the system of bioenergetic processes is possible. In his view, this would be an authentic "non-thermal" reaction. Exemplarily, he calculates resonant frequencies of the nuclear oscillation of globular proteins such as myoglobin and hemoglobin, and more or less linear macromolecules like DNA and RNA. While, in proteins, the smallest resonant frequency is 720 GHz, in less rigid DNA molecules, the frequency range could get down to 182 GHz. With respect to the publications of R. K. Adair (Bioelectromagnetics 2003; 24, 39-48, see "News from Science", Newsletter 1, 2003), who recently showed the impossibility of non-thermal reactions within the small intensity ranges of RF fields by means of calculations based on continuum physics, Prohofsky emphasized that in the frequency ranges above 100 GHz only quantum physical estimates can be made. However, he thinks that his calculations confirm the concept he already expressed in his Washington lecture: that the efficacy of energy transfer of mobile radio frequencies compared to those of nuclear energy transfer systems is exceptionally small. Despite their differences in their

theoretical approach, Prohofsky thus, just as Adair, reaches the conclusion that biological effects of these fields are possible only via normal heating.

Discussion became heated following the lecture of **D. Astumian** on the topic, "Do membranes multiply and biomolecules add?" As he has expressed in several publications, Astumian thinks that effects from fields with arbitrarily small intensities are possible, even below thermal noise. Ultimately, the occurrence of an effect is a matter of the time that is required to separate the signals from noise in a statistically significant way. This concept is based on a ratchet mechanism model according to which the movement, independent of vibrations, occurs due to the functioning of this ratchet and is even promoted by the noise. Unfortunately, the presented models were not sufficiently quantified and thus difficult to apply.

The most important objection to this raised in discussion was that this theoretically unlimited integration time for achieving a possible effect is contradicted by repair processes and time constants of real biological effects. Neither could Astumian present a proposal as to the validation of his model in experiment. The effects from electromagnetic fields in the Na-K-ATPase of human blood cells discussed by him (e.g. Tsong, Astumian: Bioelectrochem. Bioenerg. 1986; 15, 457-476; Tsong, Liu, Chauvin, Astumian: Bioscience Reports 1989; 9, 13-26) have not yet been confirmed in experiment and moreover refer to a frequency range below 1 MHz.

J. Weaver spoke about "Microdosimetry, chemical noise and implications for RF effects". He presented a model based on known impedance properties of cells and their components that allows calculation of field distribution across the tissue over a broad frequency range. For this, he used the method of "internodal segments", a series of very small RC circuits. For simpler structures three-dimensional models were developed, for more complicated ones two-dimensional models. So he could prove that an increase in the



SAR can occur in specific tissue folds. However, this is the case only in the frequency ranges below those used in mobile radio communications.

It was discussed whether an amplifying effect of the membrane is also possible in the UHF range, although the membrane is capacitively bridged beginning at approx. 1 MHz. It is conceivable, albeit not yet proven, that field amplification in the membrane by up to a factor 10 could also occur in a higher frequency range due to specific dielectric properties of adhered water molecules. Discussion evolved around the extent to which the models calculated by Weaver could be used for real tissue.

In the lecture “A theoretical study of the effects of RF fields in the vicinity of membranes“, **F. Barnes** and **Y. Kwong** presented assessments of a possible dielectrophoretic movement of small particles in the vicinity of cells. The calculations referred to a very abstract and extremely simplified model of a membrane border plane with the concept of two strictly separated phases of different dielectricity constants. An applied RF field then should lead to a field gradient which would exert a dielectrophoretic attraction upon adjacent particles. This hypothesis however was strongly doubted in discussion, since this would lead to a physically inexplicable symmetry break. Moreover, dielectrophoresis as a non-thermal mechanism was addressed once again. This mechanism is physically well-understood and biotechnologically used, but is not relevant for the setting of exposure limits in the range of mobile radio, due to the required high field strengths.

In his contribution titled “Field gradients near resonant short wire RF sources“, **Q. Balzano** demonstrated interesting dosimetric calculations on near-field situations which were not related to possible interaction mechanisms, though.

In the following, **A. Sheppard** made the difficult attempt to summarize possible non-thermal interaction mechanisms of radiofrequency fields into a table.

The agenda item was called “Creation of summary table, frequency, amplitude of mechanisms reviewed“. The result was a long list, partially prepared by him during the meeting, partially added to and revised by others in discussion. He tried to classify the many mechanisms of possible effects from radiofrequency fields due to frequency range and threshold values. Moreover, the aim was to find out whether an interaction mechanism was merely assumed, theoretically founded or even experimentally proven. However, basically all mentioned mechanisms referred to field strengths more or less far above currently valid exposure limits.

Not only due to the lack of time but also to controversial opinions, it was not feasible to make this list during the workshop. In truth, discussion did not succeed in finding new ways to understand how “non-thermal“ effects, i.e. direct interactions of weak radiofrequency electromagnetic fields with the molecular structure of biological systems, could be possible without heating.

Sheppard also overtook the difficult task to write a consent report of this meeting. At present – when this short report was written – a first draft is available which will have to be thoroughly revised, though.

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