

News from Science


The following articles refer to recent original scientific studies investigating effects of mobile radio frequency fields. Publications were selected by the author, Prof. Roland Glaser, due to his personal judgement of relevance.

by Roland Glaser


Can radio frequency effects be explained by direct coupling with charges of biological macromolecules?

This directly relates to the much discussed question of potential non-thermal effects of radio frequency fields, provided that actual effects without thermal impacts are referred to, and not simply effects without measurable temperature increases. From the perspective of molecular mechanics, the definition must be even more exact. Thus, we must distinguish first between *intermolecular* motion, i.e. interchanging molecular thrusts, and *intramolecular* motion, i.e. vibrations or rotations of nuclear bindings within a molecule. Only the latter can actually become biological-

ly relevant by changing the characteristics of proteins or nucleic acids. Such intramolecular vibrations are the basis of processes of biological energy transfer. An influence on these would be „non-thermal“ in the narrower sense of the word. Is this conceivable as a result of mobile radio electromagnetic field radiation in the frequency range around 1 GHz? This is the subject of an extensive theoretical study of Earl Prohofsky. Firstly, we can assume that there are sufficient charges and dipoles in biological macromolecules, which can be caused to vibrate by alternating fields. The question is, however: Are resonances conceivable, and can such vibrations affect biologically



relevant processes? The vibration of a string can e.g. only be affected if the excitation frequency has at least the same size as the inherent resonance frequency. The afore mentioned processes of energy transfer in biological systems though take place in the frequency range of several hundred to thousand GHz. Direct coupling through the frequency of mobile radio, i.e. two powers of ten below, thus is extremely unlikely. But could these “low” frequencies perhaps provoke other molecular changes in macromolecules, which affect their functions? Prohofsky examines two macromolecules, representative of others, for which there are sufficient physical data for calculation: myoglobin – as a representative of a globular protein – and double-stranded DNA. If size, density, elastic properties of these molecules are known, sound velocity and, eventually, the acoustic resonance frequency can be calculated. Although these calculations cannot be described in detail here – the interested reader may find further information in the original study – the author has derived internal acoustic resonances around 240 GHz in the protein, and not far below in the DNA. In addition, it has to be considered that vibrations are strongly attenuated by water molecules in their hydrate layer, especially in the extended DNA molecule. Absorption means, however, that any induced motion is immediately transformed into bulk modes of thermal motion, or, as is said in thermodynamics, “thermally dissipates”. Therefore, Prohofsky concludes that, theoretically, non-thermal effects of mobile radio fields are extremely unlikely. The term “impossible” does not exist in statistical mechanics! The author also considers special cases of huge protein complexes, such as membrane pores, but finds no solution here either. Any influences of mobile radio GHz frequencies on higher-frequency vibrational modi not only are extremely ineffective but are also “thermalized” at once, being absorbed by the ubiquitous water molecules (Prohofsky, E.W.: RF absorption involving biological macromolecules. *Bioelectromagnetics* **25**, 441-445. 2004).



Are there non-thermal effects of radio frequency fields on nerves and brain functions?

Limits are well established on the basis of thermal considerations and corresponding safety factors, and also basically supported by epidemiological studies. Nevertheless, there are repeated single case reports on persons who are neurologically affected by field exposure below limits. Following occupational exposure, or even longer use of mobile phones, there are complaints about headache, visual disorders, effects on cognition and other things. Mostly, these symptoms are reversible, but can extend over several hours. Similar symptoms are reported in particular cases also for hyperthermic treatment. Do these persons have a particular disposition, or can their sensitivity be seen simply as the extreme edge of a Gaussian distribution? How can these effects be explained neurophysiologically? Must limits be changed?

The authors attempt to approach these questions by giving a survey from a neurologist’s perspective. They also cite own individual case studies that have already been published (Hocking and Westerman: *Occup. Med.* **50**, 366. 2000; **52**, 410. 2001; **52**, 413. 2002). Exposure is below limits in these cases. Though “only” individual observations, mostly not double-blinded tests and, as yet, without replication, they are remarkable nonetheless. Unfortunately, in attempting explanation the authors use findings the relevance of which has since been declared as highly doubtful (e.g. the eternal story of the alleged calcium release in the brain by Bawin and Adey, from the years 1976 to 1978). The conclusion is as usual: further research is required (Westerman, R. and Hocking, B.: Diseases of modern living – neurological changes associated with mobile phones and radiofrequency radiation in humans. *Neuroscience Letters* **361**, 13-16. 2004).

Can weak mobile radio fields affect the short-term memory and learning capacities of rats?

Based on their behavioural tests performed with rats, Lai et al. thought they could give an affirmative answer to this question. The respective experiments were published between 1987 and 1994 and received a lot of attention. A 45 min. whole-body exposure of the animals to pulsed 2.45 GHz fields (0.6 W/kg) was seen as sufficient to reach a significant increase in the number of search errors that occurred in a 12-arm food maze. The rats more often searched arms of the maze repeatedly for food that they had previously learnt were empty. In the meantime, other authors have dealt with this question, but could find an effect only in cases where the animals were thermally influenced by strong fields and therefore were stressed (Mickley et al.: *Physiology & Behavior* **55**, 1029. 1994; Sienkiewicz et al.: *Bioelectromagnetics* **21**, 151. 2000; Dubreuil et al.: *Behavioural Brain Research* **145**, 51. 2003; Yamaguchi et al.: *Bioelectromagnetics* **24**, 223. 2003). However, these experiments slightly differ from those of Lai in frequency and application conditions. As yet, there has been only one attempt to reproduce the experiments of Lai under the same conditions. These experiments failed to show any field influence (Cobb et al., *Bioelectromagnetics* **25**, 49. 2004; see also "News from Science", issue 2, 2004). Recently, another group published experiments with exact dosimetry and statistics, which were performed under conditions as similar as possible to those of Lai et al. As already in the study of Cobb et al., there was no evidence of effects this time. The authors discussed a number of possible methodological error sources in test set-up, performance and evaluation of Lai to clarify the contradiction (Cassel, J.C.; Cosquer, B.; Galani, R.; Kuster, N.: Whole-body exposure to 2.45 GHz electromagnetic fields does not alter radial-maze performance in rats. *Behavioral Brain Research* **155**, 37-43. 2004).

In the meantime, a new study has been published by Henry Lai. This time, he did not use a multi-arm maze

for the behavioural test where the animals had to find the food reservoir, but he used a 2.5 m water pool with a small landing that was only 5 cm deep under water. The animals were meant to learn to quickly find it in the murky water, by orientation to the surroundings of the pool during swimming. Further, based on an older (never verified!) hypothesis of Litovitz, the additional influence of a noise-added low-frequency field (60 mG) was examined. The conditions of radio frequency field exposure (1 hour at 2.45 GHz, 2 mW/cm²) were identical to those of the preceding experiments. Lai thinks he has found confirmation of his earlier findings with these experiments, according to which field exposure prior to the behavioural test provokes a decrease in learning capacity. The additional exposure to the low-frequency interferential field neutralizes this effect. If this publication is read by an unprepared reader, he/she will be convinced by the results, because Henry Lai, similar to T.A. Litovitz (see Glaser: *Bioelectrochem. Bioenerget.* **46**, 301.1998), does not think much of the necessity of citing studies in the chapter "Discussion" that contradict his own findings in order to identify the causes of potential differences (Lai, H.: Interaction of microwaves and a temporally incoherent magnetic field on spatial learning in the rat. *Physiology & Behavior* **82**, 785-789. 2004).



Do mobile phones affect human short-term memory?

After the Finnish working group around Mika Koivisto reported an increase in vigilance and influences on short-term memory of test persons in psychological tests (*Neuroreport* **11**, 413 and 1641. 2000), last year he failed in his attempt to reproduce results in cooperation with the Swedish working group around Christian Haarala (*Bioelectromagnetics* **24**, 283. 2003; see also: "News from Science", issue 2, 2003). In the meantime, another result of this Swedish-Finnish cooperation has been published. In both countries, 32 test-persons each were again subjected to



tests examining short-term memory and, in part, were exposed to a mobile phone that was fixed to the head (GSM field: 902 MHz, 217 Hz pulse frequency). Field exposure intensity was slightly above that applied in the Koivisto study (10 g SAR 0.990, instead of 0.683 W/kg). The task of the test persons was to recognize 2 to 5 sequences of letters shown on a screen. The entire test was controlled by a computer program and thus was double-blinded. In the case of field exposure, a temperature increase from 35.6° C to 36° C was measured on the skin, which, in the opinion of the authors, could not be perceived by the test person. Data evaluation showed learning effects as well as gender- and country-specific differences, demonstrating the sensitivity of methodology. Influences of the radio frequency field were not determined though. Referring to previous studies reaching positive results in similar tests, the authors conclude that, due to then applied statistics, results could have been incidental, in spite of the significance of single data. Moreover, such tests obviously included a great number of difficult to control variables easily leading to wrong conclusions. In summary, the authors state that mobile phone use has no effect on human short-term memory, unless effects are so small that they can be detected only sporadically. At the same time, they emphasize that their study only involved short-term experiments which do not allow to draw conclusions on long-term effects (Haarala, C.; Ek, M.; Bjornberg, L.; Laine, M.; Revonsuo, A.; Koivisto, M., and Hamalainen, H.: 902 MHz mobile phone does not affect short term memory in humans. *Bioelectromagnetics* **25**, 452-456. 2004).



Is there an influence of weak modulated RF fields on the EEG of volunteers? Mostly, there has been a negative answer to this often-posed question. The group from the Technical University of Tallinn (Estonia) reported on the influence of 450 MHz fields, 7 Hz pulsed, on the human EEG already in 1999 (Med.

Biol. Eng. Comp. **37**, 105) and 2002 (Int. J. Radiat. Biol. **78**, 937). Besides the alpha rhythm, this time the other frequencies of the EEG were included in the evaluation. The result is summarized by the authors as follows: "Although results are not statistically significant, we can conclude from experiment results and the aforementioned discussion, that low-frequency modulated radiation provokes changes in the energy level of the EEG rhythm." The authors' peculiar perspective on statistics characterizes the entire study. Aside from the slightly problematic technology (no absorption chamber, uncertain dosimetry), the application was blinded only for the test persons. Speaking of "tendencies" under these conditions, of "single cases", and drawing statistically unfounded conclusions it will be difficult to convince readers. At least, the authors are aware of the uncertainty, several times emphasizing the difficulty to identify small effects in the EEG that depends on many physiological factors and therefore fluctuates greatly (Hinrikus, H.; Parts, M.; Lass, J., and Tuulik, V.: Changes in human EEG caused by low level modulated microwave stimulation. *Bioelectromagnetics* **25**, 431-440. 2004).



Is there an influence of mobile radio fields on protein folding? Already last year a publication of the Dipartimento di Biochimica e Biofisica of the University of Naples (Eur. Bioph. J. **32**, 628. 2003) dealt with this issue. The authors found out that a 1.95 GHz field, even after 2.5 hours, at a SAR of 51 W/kg, is not capable to exert an influence on the native structure of the globular protein myoglobin. But could the field perhaps interfere with processes for the repair of this molecule? To answer this question, a follow-up study observes kinetics during refolding of this protein after denaturation in an acidic medium (pH3), when it is again subject to physiological conditions. The process was shown to become significantly, albeit slightly, slower after field exposure. On the

other hand, 51 W/kg does not qualify as “non-thermal”. In fact, the solution heats up by 5 degrees to 30° C. Heating up the control solution conventionally to the same temperature is not necessarily comparable. The reader would at least have appreciated measurements casting light on the temperature dependency of this process enabling assessment of methodological errors. The conclusion of the authors that results reveal a potential health risk, at least demands discussion considering that a SAR 500 times above the limit was applied (Mancinelli, F.; Caraglia, M.; Abbruzzese, A.; d’Ambrosio, G.; Massa, R., and Bismuto, E.: Non-thermal effects of electromagnetic fields at mobile phone frequency on the refolding of an intracellular protein Myoglobin. *J. Cell. Biochem.* **93**, 188-196. 2004).



Is there an increase in cancer incidence in the vicinity of South Korean broadcasting transmitters?

An epidemiological survey comparing registered cancer fatalities in the years 1994 to 1995 in a group of 1,234,123 persons living in areas surrounding base stations (2 km radius) with a control group of 6,881,783 persons is available. 10 out of 107 AM transmitters in Korea were selected, with power levels of 100; 250; 500 and 1500 kW. The data originating from the official death registers were analyzed according to cancer type, gender, age group and power of the nearby transmitter. Summarizing all data, the average number of cancer fatalities per 100,000 persons living in the vicinity of transmission towers in this period amounted to 113.07, whereas the number in a comparable population was only 87.32. This is a significant increase by a factor 1.29; the 95%-confidence interval was between 1.12 to 1.49. Aside from differences in this factor for different cancer types (maximum for rarer diseases such as leukaemia and pancreas cancer, no significant difference for stomach cancer, the most frequent cancer type in Korea), correlations to the transmission power levels

were also determined. Values are seen as noteworthy by the authors, but not as evidence for a causal relation. Various error sources are listed: The address given in the death register is not necessarily identical with that of residence, since it is the custom in Korea to die at one’s place of origin. The selected regions did not exactly match with the 2 km radius around the transmission mast; instead, administrative regions prevailed. Interviews that would have shed light on sociological or other conditions (confounders) could not be performed. Misdiagnoses given on the death certificate could not be excluded. However, this would also affect control cases to the same extent. Here, as in all epidemiological surveys, small numbers result in limited certainty. Thus, as usual, the conclusion is: “Further studies are needed!” (Park, S.K.; Ha, M., and Im, H.J.: Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death. Preliminary observations in Korea. *Intern. Arch. Occupat. Environm. Health* **77**, 387-394. 2004)



Are there non-thermal influences of 2.45 GHz fields on blood and bone marrow cancer?

This question has been controversially discussed by several publications, mainly giving negative results. Now, the results of the experiment performed by a working group from Zagreb is available, who again dealt with the issue. For this purpose 40 Wistar rats were daily exposed over 2 hours to a 2-10 mW/cm² field, equivalent to a SAR of 1.25+/-0.36 W/kg (why such small SAR deviations, if the power flux density varies by a factor 5?). A change in the body temperature of the animals could not be measured after exposure. Exposure to the far field was performed in special cages where the animals were unconstrained (8*17 cm, 30 cm high). After 2, 8, 15 and 30 days, the animals (10 per group exposed, 6 controls) were sacrificed and samples taken from bone marrow and peripheral blood. For exposed animals, an increase in the num-



ber of polychromatic erythrocytes, i.e. red blood cells with disturbed differentiation, was found in the 8- and 15-day samples (not after 30 days!). However, the significance of the difference was small ($p < 0.05$), and the effect was obviously reversible. A slight decrease in lymphoblasts, immature white blood cells, was also found. In the view of the authors, this finding rather suggests adjustment than a syndrome (Trosic, I.; Busljeta, I.; Modlic, B.: Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells *in vivo* exposure. *Mutagenesis* **19**, 361-364. 2004; Trosic I.; Busljeta, I.; Pavicic, I.: Blood-forming system in rats after whole-body microwave exposure; reference to the lymphocytes. *Toxicology Letters* **144**, 125-132. 2004).



How should present publications on possible cytogenetic effects of radio frequency fields be assessed? What are the reasons for controversial results? Two geneticists with profound experience in such studies have made the effort to critically review and evaluate all available scientific publications on this topic from the years 1990 to 2003. Though the topic has been dealt with for more than 40 years, 53 studies have appeared in this period alone. 31 failed to find any effect; 12 studies claimed to have found evidence; the rest failed to reach clear results. Science is not politics, majority does not decide! One single conclusive study possibly revealing the mistakes made by others could do the trick! But the reverse was true: When taking a look at methodological reliability, and this includes exact dosimetry, reliable temperature control, as well as professional animal and cell cultivation and methods of cytological evaluation, then the black sheep among those who speak of a proven field effect are found out quite easily. The assessment of published experiments presented by the two authors is very diligent, also taking into account critique and discussion that have in part already been published. The main reason behind positive findings

presented by some authors is obviously a lack of exact temperature control. Experiments are referred to where already a temperature rise above 39° C leads to clear cytogenetic changes. The general conclusion of the authors, according to which radio frequency fields, at least in the non-thermal range, obviously are not to be seen as genotoxic, is supported by experimental and epidemiological studies, which have failed so far to provide any evidence of effects on carcinogenesis, though this would be the inevitable consequence of occurring genotoxic effects. Unfortunately, the study fails to put sufficient emphasis on the use of positive controls. When comparing clearly genotoxic effects, e.g. of gamma radiation, with seemingly “significant” RF effects some authors claim to have found, one begins to comprehend what “significant” actually means in the biological sense of the term, and under which type of methodological “noise” RF effects are looked for.- How to go on? In view of the great relevance of the issue, it should be further examined critically. A coordinated multicentric cooperative study with high statistical significance and highest-quality dosimetry and cytogenetic methodology would be required (Vijayalaxmi; Obe, G.: Controversial cytogenetic observations in mammalian somatic cells exposed to radiofrequency radiation. *Radiat. Res.* **162**, 481-496. 2004).



Are limits recommended by international expert bodies and made mandatory in more than 30 countries really too high? This question, repeatedly addressed by some authors, is again posed by Martin Blank and Reba Goodman in a “comment”. The authors criticize the reviews published last year in a supplement to “Bioelectromagnetics” on the effect of radio frequency fields. They claim that these do not adequately reflect the actual scientific progress made in this area. When considering available knowledge, it becomes clear that the SAR is inappropriate as a quantity and limits are much too high. Theoretically, this is

supported by the thesis that it is not the absorbed energy, but a vibrational force that triggers effects. This, in turn, calculated per oscillation cycle, is independent of frequency, since the quantum energy of an electromagnetic wave is proportional to frequency; oscillation length, however, is inversely proportional to it. ELF effects therefore are directly comparable to those in the RF range. With regard to radio frequency fields, it is already the first wave trains that trigger the effect which potentially is covered by thermal effects. The authors draw support for their hypothesis mainly from findings taken from own experiments, starting from the old studies investigating field influences on the Na-K pump (which, by the way, were then presented as proof of frequency-windows of the effect!), via the hypothesis on influences on electron conductivity of DNA molecules and electron transitions in the cytochrome system, destabilization of hydrogen bridge bindings up to the alleged detection of special field-sensitive DNA sequences. In his "reply", Ron Peterson correctly points out that these findings are based on experiments not yet replicated by anyone successfully, and that other, replicated findings of international science, contradict their concept. Also, it is physically incomprehensible that interaction mechanisms of electromagnetic fields should be independent of frequency. By the way – the concept of Blank and Goodman contradicts other theses – as unverified as theirs – which claim that experiments can never be replicated since the smallest deviations in test conditions generate incomparability of experiments, due to an alleged narrow and biologically regulated resonant behaviour.

– Thus, the answer to the above questions should be better based on the evaluation of internationally replicated scientific experimental data, even if errors and flawed decisions can never be fully excluded in science (Blank, M. and Goodman, R.: Comment: A biological guide for electromagnetic safety: The stress response. *Bioelectromagnetics* **25**, 642-646. 2004;

Petersen, R.: Reply to „A biological guide for electromagnetic safety: The stress response“ by M. Blank and R. Goodman, *Bioelectromagnetics* **25**, 647-648. 2004).

Are neuronal effects observed during mobile phoning caused by heating in the area of the head?

Such effects, i.e. changes in response time of test persons during psychological tests, are repeatedly reported, even though results were always difficult to reproduce. Now, the behaviour of 10 test persons each was examined, prior to and during exposure to a mobile phone fixed to the head (GSM 902.40 MHz, approx. 0.5 W/kg). Even though no changes occurred in speed and accuracy during visual psychological tests, a small ($p=0.02$) increase in response speed could be measured. This obviously correlated in time to the temperature increase in the ear (by approx. 0.15° Celsius). The authors conclude from this that there is possibly an effect on blood circulation, though data do not allow to draw conclusions on concrete physiological mechanisms (Curcio, G.; Ferrara, M.; DeGennaro, L.; Cristiani, R.; Dinzeo, G., and Bertini, M.: Time-course of electromagnetic field effects on human performance and tympanic temperature. *Neuroreport* **15**, 161-164. 2004).