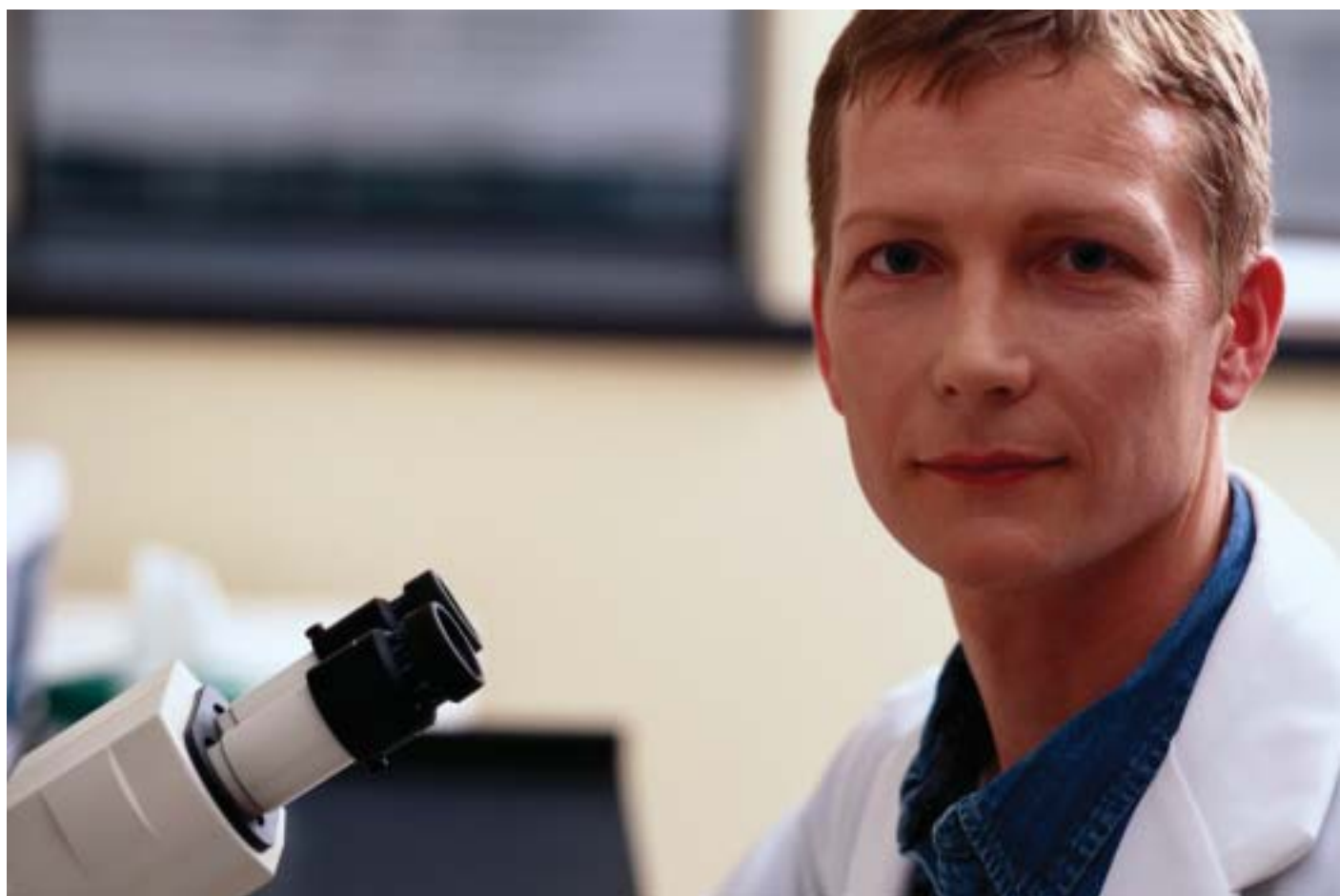


Insights from experimental

by Alexander Lerchl

The question whether high-frequency electromagnetic fields are health-relevant or not, is still controversially discussed. Since the introduction of mobile communication by private persons this discussion has expanded considerably. Huge parts of the population think that health hazards exist and are critical of mobile radio operators and manufacturers of end devices. The only way to react to the fears in the population is to initiate scientific investigations that are cleanly performed and which examine possible dangers on all relevant levels. Besides biophysical investigations on membranes, especially investigations in cells, animals and humans are necessary to assess both possible mechanism and consequences for the whole organism.





EMCE research

In principle, high-frequency electromagnetic fields (HF-EMF) in the frequency range of mobile communication are not able to ionize and thus cause direct changes in molecules or atoms. They are therefore fundamentally different from ionizing radiation, which provokes damages already at smallest radiation doses. The only established effect of HF-EMF is thermal, i.e. tissue is more or less heated by the absorption of these fields. This fact on one hand is the basis for the setting of limits, on the other hand the focus of discussions about **non-thermal effects** of HF-EMF, repeatedly postulated and seemingly confirmed by single studies.

To investigate health effects of HF-EMF, biological experiments in cells and whole organism have to be conducted in order to examine both possible interaction mechanisms and effects which cannot be determined in single cells alone, e.g. tumour initiation or promotion. Investigations in cells are oriented to processes, which e.g. comprise the expression of certain genes or physiological responses that can be examined by light microscopy. At any rate, possible HF-EMF effects should be examined both in cells and in whole organisms to compare possible effects. Without this basic research, epidemiological studies lack the fundamental prerequisite to see results, if there is a damaging effect, in relation to the overall context.

Experiments on biological effects of HF-EMF necessarily are interdisciplinary. While earlier studies on this topic were performed with very simple technical means, exposure quality and dosimetry were considerably improved in recent years. The high technological standard of present investigations ensures that unintended "hot spots" are avoided, meaning areas of very high exposure falsifying the overall result. The study that is perhaps best known is by Repacholi and colleagues [1], where mice were exposed to a high-

frequency electromagnetic field at 900 MHz showed an increased leukemia rate. By the arrangement of antennas and the cages extremely high variations of the specific absorption rate (SAR) were reached, which varied by a factor of 500 across the animals. A replication study by Utteridge and colleagues with considerably improved exposure conditions and a much smaller variation of SARs could not confirm the results [2]. Other studies could find no evidence of HF-EMF accelerating leukemia development in mice either [3; 4].

Another criterium for the acknowledgement of a non-thermal effect of HF-EMF on biological systems is the replicability of results. Due to statistical laws and biological variances, random positive results can be expected which, per se, require no consequences. Only when single results can be reproduced independently, taking measures (e.g. the decrease of existing exposure limits) would be legitimized.

It should be standard today as well that experiments are conducted blinded and with adequate controls (sham exposure, perhaps cage controls). These requirements are not trivial technically, as the exposure systems (for exposure and non-exposure) must be optically identical and in each other respect, except for the existence of an electromagnetic field. Only under these conditions, and if the users do not know which animals and cells, respectively, are exposed, conscious or unconscious influences on results are excluded. Unfortunately, this standard is still not fully established. Repeatedly, studies are submitted and published, where the conditions under exposure and sham exposure considerably differ and effects other than those from HF-EMF cannot be excluded. It is e.g. technically and methodologically not acceptable, to irradiate rats with a rebuilt microwave oven, as it was done in 2006 by Trosic and colleagues [5]. The exposure conditions not only are less than

optimal, also other influential factors, especially noise, could have led to considerable effects. It is evident that the tests were not blinded.

But also negative results, i.e. lacking evidence of biological effects of HF-EMF should be viewed critically sometimes. Anane and colleagues e.g. could find no evidence of additional adverse effects in rats in which, by the application of a carcinogen, breast cancer was induced [6]. The group size of 16 animals was too small to provide evidence of effects. The statistical power of investigated parameters in such investigations has to be calculated prior to experiments so as to ensure sufficient power also when negative results are expected. Otherwise such studies are worthless.

Investigations of possible biological effects of HF-EMF require hypotheses, without which the experiments sometimes are like fishing in murky waters. The testing of all possible parameters in order to find effects, is not only doubtful scientifically, but causes a large statistical problem, namely that of the accumulation of significance. If e.g. 10 parameters are investigated, the probability that one or several factors differ "significantly" across exposed and non-exposed objects is very large. One can compensate such accumulated significance by correspondingly tightened statistical tests, but then one has the disadvantage to not discover actual differences. At any rate it is necessary to define the parameters to be investigated based on hypotheses prior to an experiment.

The great majority of investigations to-date performed on possible biological effects of non-thermal HF-EMF, which meet the mentioned qualitative criteria, could not show any damages. This is true for experiments performed, in part over long periods, with cells and animals. The investigations that at first showed ef-

fects, could not be confirmed in replication studies, or there are no such studies yet. Although it seems, mainly thanks to considerably improved quality standards, that non-thermal HF-EMF have no adverse health effects, research on this topic cannot be seen as finished, as new technologies (frequency bands, types of modulation) are emerging. Their possible biological effects should be tested before full area coverage is obtained.

References

- 1. Repacholi MH, Basten A, GebSKI V et al. Lymphomas in $\frac{1}{4}$ -Pim1 transgenic mice exposed to pulsed 900 Mhz electromagnetic fields. *Radiat. Res.* 1997; **147**:631-640.
- 2. Utteridge TD, GebSKI V, Finnie JW et al. Long-term exposure of E-mu-Pim1 transgenic mice to 898.4 MHz microwaves does not increase lymphoma incidence. *Radiat Res* 2002; **158**:357-364.
- 3. Sommer AM, Streckert J, Bitz AK et al. No effects of GSMmodulated 900 MHz electromagnetic fields on survival rate and spontaneous development of lymphoma in female AKR/J mice. *BMC Cancer* 2004; **4**:77.
- 4. Sommer AM, Bitz AK, Streckert J et al. Lymphoma development in mice chronically exposed to UMTS-radiofrequency electromagnetic fields. *Radiat Res* 2007; **168**:72-80.
- 5. Trosic I, Busljeta I. Erythropoietic dynamic equilibrium in rats maintained after microwave irradiation. *Exp Toxicol Pathol* 2006; **57**:247-251.
- 6. Anane R, Dulou PE, Taxile M et al. Effects of GSM-900 microwaves on DMBA-induced mammary gland tumors in female Sprague-Dawley rats. *Radiat Res* 2003; **160**:492-497.



Prof. Dr. Alexander Lerchl is Professor of Biology at the School of Engineering and Science, Jacobs University, Bremen. One focus of his work is the investigation of biological effects of magnetic fields and high-frequency electromagnetic fields. He is a member of the „Non-Ionizing Radiation“ Committee of the German Federal Commission for Radiation Protection.