

Objections against the current limits for microwave radiation

Josef Lutz, Franz Adlkofer

Abstract—Current safety limits for microwave radiation (RF-EMF) are presented as RMS values and based on thermal effects. But there are organs/tissues with relatively little blood flow to carry away excess heat, and interferences as well as non-thermal effects of RF-EMF are not taken into account. A risk to the health of people below the current safety limits is in no way excluded. Therefore, a considerable reduction of the presently valid power flux density is recommended.

Index Terms—Electromagnetic radiation, biological effects, mobile communication, safety limits, precautionary principle.

I. REMARK

The first author is a specialist for power semiconductor devices and their application. Electromagnetic compatibility in relation to biological organisms is only a secondary part of his research, and his learning did not finish yet. Nevertheless, some conclusions resulted. According to the rules of the German Research Society (DFG) for good scientific practice the author explains, that he has several connections and relations to industrial companies in the field of power devices and their application, especially in the automotive industry. There are no contracts and no relations to companies in the field of mobile telecommunications or to scientific institutions supported by them.

The second author is a medical doctor. As director of a non-profit research foundation, he has studied biological effects of electromagnetic fields in details for many years. The views presented here are based on the results of his independent research.

II. THE CURRENT LIMITS FOR RF EXPOSITION

The current safety limits in Germany for the exposure with high frequency electromagnetic radiation (RF-EMF) from the far field are published in the "26. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (26. BImSchV") from December 16, 1996. According to this regulation, the allowed electric field strength of the radiation from base stations is 27,5V/m for frequencies up to 400MHz. Between 400MHz and 2GHz it must be calculated with

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$E_{ii} = 1,375 \cdot \sqrt{f}$ [V/m] (f in MHz). Above 2GHz it is fixed at 61V/m. This value is the "root mean square value of the field strength averaged within intervals of 6 minutes" (RMS).

For occupational exposure the safety limits are published in the "Berufsgenossenschaftliche Vorschrift BGV 11". In the exposure area 1 - which needs no special signs - a 5-fold value is allowed. Even much higher values are permitted in especially marked areas, where the time of abidance is limited.

In high frequency electromagnetic waves the electric and magnetic field strength are coupled, and from energy density and spreading velocity the power flux density can be calculated (Fig. 1).

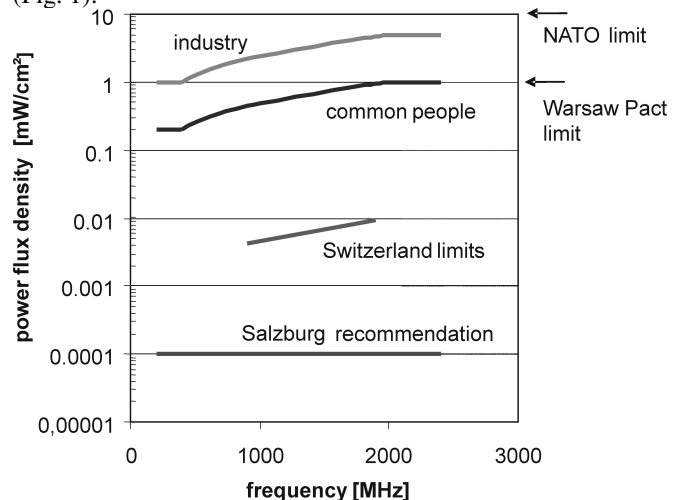


Fig. 1: Limits for power flux density during RF-EMF exposure

For the general population in Germany the actual safety limit is set to approx. 1mW/cm² which corresponds to the value allowed for the military in the Warsaw Pact. For NATO soldiers the safety limit was by a factor of 10 higher than that in the Warsaw Pact. Twenty and more years ago exposure to RF-EMF was essentially limited to the military and certain occupational settings. In the meantime the Swiss safety limit was reduced by a factor of 100 compared to that in Germany, but only put into force at places with "sensible using", e.g. schools and kindergartens. The so called Salzburg recommendation value is by a factor of 10 000 lower than the one in Germany.

The regulations use the RMS value. The RMS value of a variable $E(t)$ which is periodic with the time T is calculated according

$$E_{eff} = \left[\frac{1}{T} \int_0^T E(t)^2 dt \right]^{\frac{1}{2}}$$

For a signal in sinus form the RMS value results to $E_{eff} = 1/\sqrt{2}$ of the amplitude (Fig. 2 top).

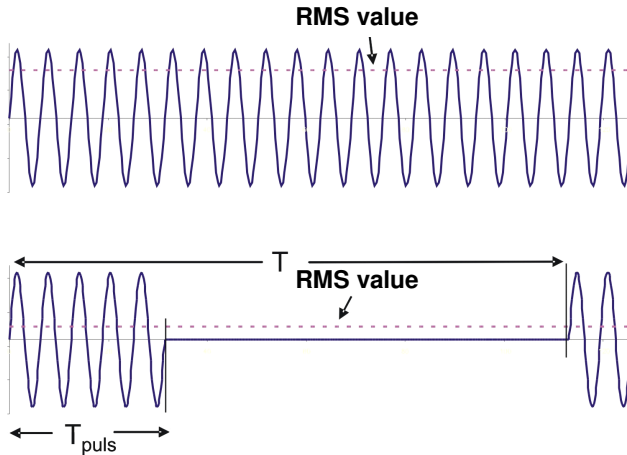


Fig 2: RMS value of a sinus form function (top) and of a pulsed sinus form function (bottom)

If the variable E is pulsed, the pulses are repeated with the period T, during T_{puls} the signal is on, during $T - T_{puls}$ the signal is off, then follows with

$$a = \frac{T_{puls}}{T} \quad \text{with } 0 \leq a \leq 1$$

for the RMS value of the pulsed signal

$$E_{eff}(pulsed) = \left[\frac{1}{T} \left(\int_0^{a \cdot T} E(t)^2 dt + \int_{a \cdot T}^T 0^2 dt \right) \right]^{\frac{1}{2}}$$

The result of the second integral is 0, then holds for a constant signal during T_{puls}

$$E_{eff}(pulsed) = \sqrt{a} \cdot E_{eff}(unpulsed)$$

If E is the electric field strength, then the transmitted power is proportional to E^2 , and then results

$$P(pulsed) = a \cdot P(unpulsed)$$

The transmitted power is reduced by the factor a at constant peak value of E.

These equations are used for the calculation of a heater, but also for a human body which was obviously put by the regulators on the same level.

Engineers measuring microwave exposition by mobile phone base stations usually use the maximum value. But the regulations do not. They use RMS

III. OBJECTIONS

Objection 1: Due to inhomogeneous blood flow excess heat is not carried away from all organs/tissues equally effectively

The current safety limits are solely based on thermal effects. For example, Hermann Schwan, proposed in the early fifties of the last century a safety limit of 10mW/cm^2 which was set in the NATO. He justified this with the deliberation, that the human body is emitting a thermal radiation with a heat flux of 5mW/cm^2 . Therefore, heating of the body through an isotropic radiation of 10mW/cm^2 should easily be controlled for by the blood circulation [1]. Our present safety limit of 1mW/m^2 , which is recommended by the World Health Organisation (WHO) and valid for the general population, too, is solely based on thermal reflections [2].

But the blood circulation is reduced in some organs/tissues of the human body, e. g. eyes, testes and fatty tissue, and, therefore, a homogeneous temperature is not ensured in all its parts. The eyes and the testes are particularly vulnerable to RF-EMF heating, because excess heat is carried away less effectively as compared to other organs.

Furthermore, it is known, that different parts of the human body - muscles, bones, fat, brain, etc - have different microwave properties. Therefore reflections and diffractions must be taken into account which means that no homogenous microwave absorption can be expected.

This is not considered in the current safety limits.

Objection 2: Interferences are not taken into account

Electromagnetic waves are partially reflected at walls etc., and by superimposition with reflected and multiple reflected waves interferences can occur. Consequently, there will be places in rooms with increased intensity and such with decreased intensity.

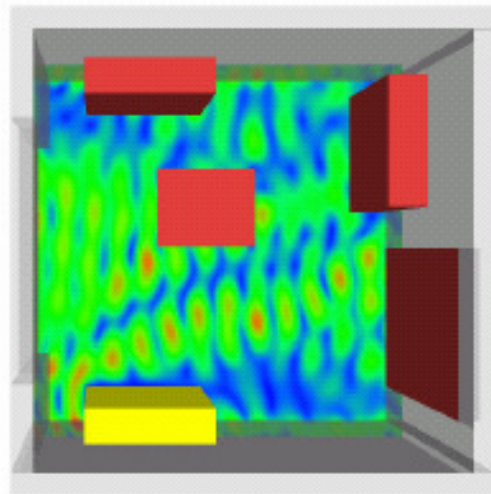


Fig 3: Interferences of electromagnetic waves (900MHz) in a room. Taken from "Forschungsbericht der IMST GmbH an das BfS", March 2005. Reprint with kind permission of IMST GmbH

Fig. 2 shows the results of an investigation with the simulation program "Empire" by the IMST GmbH. Assumed is a room with furniture, in which the radiation enters from the left through the window. Typical minima (blue) and maxima (red) are generated. Quite obviously, the interferences are very sensitive to modifications [3].

An investigation at the Chemnitz University of Technology by Geromiller and Farschtschi [4] resulted in a similar outcome. Assuming certain reflection- and absorption characteristics of the walls, it was found that the highest interference maxima occurred when radiation comes in transversely in an angle of 20°. Maxima of the intensity of the electric field strength as high as $E_{\max} \approx 2,5E_{\text{in}}$ (incoming radiation) were found. Since the power is proportional to E^2 , this corresponds to an increased power flux density by a factor of 6 at interference maxima.

Interferences are insufficiently considered with regard to the current safety limits. The German 26. BImSchV requires measurements at the "location of impact with the strongest exposition". However, these measurements are not simple. Interference patterns and places of interference maxima are influenced even by the presence of a person in the room. The incoming radiation is obviously variable. A maximum can quite easily be overlooked. Experienced engineers who measure the exposure to RF-EMF might detect it, but in the regulation 26. BImSchV a procedure how to ensure this is not described.

But there is a further even more important shortcoming. Calculations of the minimal distance to mobile phone base station antennas, which constitute the basis of the permission certification by the issuing authority, do not take into account interferences at all. The interferences would correctly be considered only if they were calculated in advance. But this is indeed not the case. This weakness of the regulation alone would be important enough to justify a considerable reduction of the current safety limits.

Objection 3: There are non-thermal effects

That RF-EMF radiation causes other effects except heating is highly controversial. This claim is regularly rejected as "not proven" [5]. Or it is argued e.g. as follows:

"The used frequencies ... are in the range 10Hz to 10GHz and far below the typical ionization energy of molecules (min 800THz, more than thousand fold) ... therefore gene defects by electromagnetic environmental stress can be excluded" (Wikipedia, "Elektromog") [6].

It is correct to say that the quantum energy e.g. for UMTS radiation is in the range $9 \cdot 10^{-6} \text{eV}$ and, therefore, many decades below the energy needed for the ionization of molecules. However, this deliberation may only hold for not-living matters and can certainly be used if one radiates a piece of wood, a piece of plastic, etc. In living organisms biological processes take place such as cell division, cell differentiation, etc., that

render the molecules, especially the DNA and the RNA, very vulnerable. Chemical bonds are opened and new bonds are formed. DNA chains are opened, copied, and new cells are formed. Much lower threshold energies may be sufficient for a disturbance of the cellular processes. It is certainly very difficult to define a minimum energy level to exclude perturbations in vital processes for which molecular instability is a genuine prerequisite.

Very alarming are the results of the REFLEX project, with the full name "Risk Evaluation of Potential Environmental Hazards From Low Energy Electromagnetic Field (EMF) Exposure Using Sensitive *in vitro* Methods" (QLK4-CT-1999-01574). This project was funded by the EU Commission under the 5th Framework Programme (FP5), planned and coordinated by the Verum Foundation in Munich, and carried out by 12 research groups from 7 European countries from Feb 2000 to May 2004. The aim of the study was to search in isolated cells *in vitro* for biological effects of RF-EMF below the present safety limit of 2.0W/kg for mobile telephones, and to show that there are no biological effects which might be of importance in the pathogenesis of chronic diseases. The outcome of the study showed exactly the opposite.

Part of the work dealt with the RF-EMF radiation of human HL60 cells at a SAR value of 1.3 W/kg. The longer and brighter the comet-shaped tail is turning up, the more DNA damage happened [7] (Fig.4).

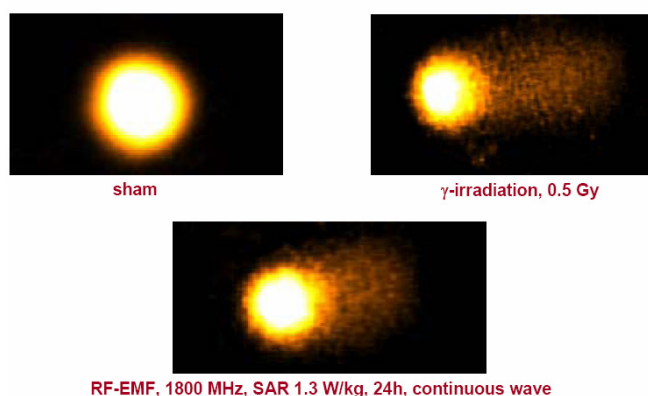


Fig. 4: "Comet Assay" of cell cultures from human HL60 cells. Left top: Unstressed. Right top: After radioactive irradiation with 0,5Gy. Bottom: After microwave irradiation with 1,3W/kg over 24 hours. Figure from [7].

In another experiment with GSM signals a similar effect was observed already at much lower SAR values. Fig. 5 shows the dose-effect-relationship between DNA damage and the strength of exposure. At a SAR value as low as 0.3W/kg a significant increase in DNA strand breaks is seen. For SAR values smaller than 0.6W/kg mobile phones can be featured with the sign "blue angel".

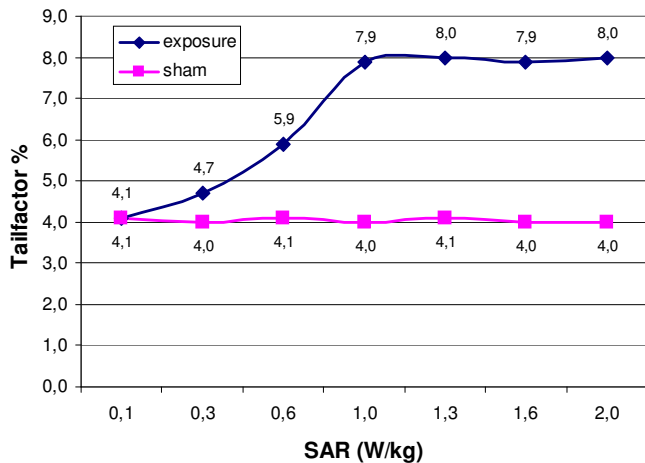


Fig. 5: Rate of DNA strand breaks in human fibroblasts Exposure: 24h, 5 min on / 10 min off. Figure from [7].

In the meantime, the *in vitro* effects of RF-EMF have been confirmed in a follow-up study of the REFLEX project. The results which were obtained most recently at the Vienna University with UMTS signals clearly demonstrate that RF-EMF is able to generate genotoxic effects in isolated human fibroblasts already at a SAR level of 0.05W/kg which is about 1/40 of the valid safety limit [8].

The human body has a complex system of repair mechanisms that detect and correct failures at the molecular and cellular level in any kind of cells. Damaged cells which cannot be repaired anymore are isolated and eliminated. But it may happen that defects are not detected or misrepaired. Furthermore, there is some suspicion that the repair mechanisms themselves may be impeded through RF-EMF. Under these conditions genetically damaged cell could easily survive, thus creating the prerequisite for the development of cancer and perhaps other chronic diseases, too.

The current safety limit of 2.0W/kg for mobile phones does not consider the already *in vitro* proven genotoxic effects of RF-EMF far below this value, and whether or not the safety limits for base stations protect from less significant biological effects such as alteration of the gene and protein expression can at present not be excluded with certainty. Should genotoxic effects be demonstrated one day in animal and in man *in vivo* as already done *in vitro*, science and society will face a serious problem.

In any way, the existence of non-thermal biological effects and their consideration in the establishment of reliable safety limits should no longer be denied.

Objection 4: There are impairments to health even within the current safety limits for mobile phones

Whether or not electro-sensitivity in a significant percentage of the population really exists, is still a matter of controversy. At one side, it is hard to believe that the many statements of physicians describing more or less serious symptoms or even diseases their patients are suffering from due to RF-EMF

through base stations are all wrong. On the other side, at present psychological reasons as the cause of these complaints cannot be excluded with certainty. The literature on this topic is confusing and full of contradiction.

With regard to the use of mobile phones, the most recent epidemiological studies, especially those carried out within the INTERPHONE study, shed some light on the validity of the respective safety limits. The INTERPHONE study, just as REFLEX funded since 2000 within the scope of FP5, is performed worldwide in 13 countries, and coordinated by the WHO International Agency for Research on Cancer in Lyon.

While studies on groups of people using the mobile phone less than ten years did not show a significant increase in brain tumors, studies on persons using the mobile phone more than ten years demonstrated [9,10] a slight and in some cases an even a significant increase [11,12] of such kind of tumors.

The multiple hints of a possibly increased brain tumour risk after a period of ten and more years might indeed be random, but could also be a first uncertain indication that RF-EMF below the current safety limits does cause cancer.

If one combines the epidemiological data with the genotoxic effects found *in vitro* (see objection 3) and if one considers that a latency period of many years - up to 20 and more - lies between the first damage of the cellular genome and the outbreak of diseases like cancer and Alzheimer, then the situation is alarming already now.

The current safety limits pretend to exclude effects on the health of people. In spite of this assumption, there is a recommendation of the president of the German Federal Office for Radiation Protection (BfS), Wolfram König, that children younger than 16 years should be kept away from mobile phones. In August 2007, the BfS repeated this recommendation [13]. In our opinion, there are at present more than enough reasons to take this warning seriously.

IV. RECOMMENDATIONS

The safety limits of the German 26. BImSchV do at present not correspond with the actual state of science in the respective area of research. In a discussion on student education at the International Seminar on Power Semiconductors, Prague 2004, the need of some kind of ethic codex for scientists and engineers regarding their responsibility in case of strong controversial opinions within the scientific community was recognized. As the chairman of this discussion, the first author summarized his position as follows:

- Be aware that life and safety in the modern world depends on technique. Never make solutions which cause harm to people, never accept solutions with lower safety because of economic interests or higher profits of companies.
- Never make solutions which are harmful to the environment. Scientists and engineers have a responsibility for the next generations.
- Resist work for weapons of mass destruction, for nuclear, biological and chemical weapons and for "conventional" ostracized weapons like mines and cluster bombs.

- Science and engineering is done in international cooperation. Use your international cooperation in the mind of friendship of this world's people and repel racism and bellicism.

This includes that the health of people is a higher value than economic interests. Therefore, actions are necessary already at the time when results of research in biomedicine and medicine are still controversial.

- 1) It is recommended to reduce the limit for the RF-EMF radiation in residential areas as near as possible to the value recommended in Salzburg in 1998 that considers, opposite to the limits set by WHO and ICNIRP, also the existence of non-thermal effects [14]: 10^{-4} mW/cm^2 (1 mW/m^2). This would be a decrease from valid limits by a factor 10 000. Furthermore, the limits for pulsed radiation should be based on the peak value.
In most recent measurements in residential areas a RF-EMF exposure in the range of 1 mW/m^2 to 10 mW/m^2 was already found. It should, therefore, be possible for the mobile communication industry to improve the technique further to achieve an exposure limit even below 1 mW/m^2 .
- 2) Typical mobile phone base stations (emitted radiation power of 13W) should keep a distance from residential areas of 300 m. At this distance, an exposure value of $< 1 \text{ mW/m}^2$ would be obtained for typical base stations, according to calculations in [15]. In case of a higher power emission the distance should be increased adequately.
- 3) Mobile communication transmitters should be installed sufficiently high over ground, i.e. 30 m can be recommended.

Beside these recommendations concerning mobile phone base stations, also the warnings on the use of mobile phones especially by children should strictly be considered in the risk communication efforts by government and industry.

ACKNOWLEDGMENT

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