

Disharmony in Radiofrequency Exposure Limits

Kenneth R. Foster

Abstract—This commentary discusses the reasons for the very large variation in exposure limits for radiofrequency energy that are in effect throughout the world, which reflect deep philosophical differences about managing risk. There are important practical and philosophical reasons to harmonize exposure limits, but this goal will not be easily achieved.

Index Terms—Radiofrequency energy, exposure limits

I. INTRODUCTION

MANY engineers, reading the accompanying article by Cavdar and Ozguner [1], will be surprised at the wide range in limits for human exposure to radiofrequency (RF) energy at different places around the world.

For example, at the frequency used by many mobile telephones (1800 MHz), the maximum allowable exposure to the general public is 9 W/m² incident power density (58 V/m electric field strength) in the ICNIRP guidelines [2], which are widely adopted throughout much of the world. Limits in Russia, China, and some Eastern European countries are much lower, 0.1 W/m². Recently, Switzerland and Italy have adopted even lower limits (0.09 W/m² or 6 volts/m).

How can such variation be possible? The short answer is that risk research is hardly an exact science, and human issues come into play, including a widespread fear of “radiation” among the public. This situation is hardly new: since at least the 1960s Russia and the former Soviet Union have had much lower limits for public exposure to RF energy than the West. This has been a longstanding cause of controversy among citizens in the West, who ask why citizens in the (former) Soviet Union are so much better protected against RF hazards than their Western neighbors.

The guidelines mentioned by Cavdar and Ozguner fall into two broad groups: science based limits, and precautionary measures [3]. The former try to identify and avoid hazards based on expert reviews of the scientific literature, and the latter try to offer protection against poorly understood hazards even though the necessary scientific data may be lacking, as described by the English phrase “better safe than sorry”.

Two of the most influential Western limits, IEEE C95.1-1999 [4] and the ICNIRP guidelines, are science-based. They were both developed by expert committees after a critical review of numerous (nearly 2000, in the ongoing revision of the IEEE standards) scientific papers in search of confirmed effects that are relevant to setting exposure guidelines. The committees both restricted their study to papers in peer-reviewed journals, and placed great weight on appropriate dosimetry and other aspects of study design.

Both the IEEE and ICNIRP limits were based on the

conclusion that “behavioral disruption” is the confirmed effect that occurs at the lowest exposure level and relevant for setting human exposure guidelines. This well-confirmed effect has been reported in several species. It occurs at whole-body exposure levels that are considerably higher than the animal’s natural rate of heat generation. For example, a rat might be taught to push a lever for food while being exposed to RF energy. After sufficient exposure, the animal will stop pressing the lever and begin spreading saliva on its tail – a normal thermoregulatory behavior in rats but a disruption in the assigned task. The guidelines were developed to exclude such exposures with safety factors of 10 (for occupational exposures) to 50 (general public). These calculations assumed worst-case exposure conditions, for example assuming that the subject is oriented with respect to the incident field to maximize the absorption of energy.

Behavioral disruption is clearly a thermal phenomenon, and thus ICNIRP and IEEE limits might be termed “thermal” limits. However, the committees evaluated all relevant literature and failed to find persuasive evidence for “nonthermal” hazards at the lower exposure levels. Other expert committees in the West have come to similar conclusions [5]–[7].

The rationale for the Russian limits is much less clear, and is not described in the standard itself [8]. The guidelines obviously reflect the conviction that long-term exposure at levels far below ICNIRP guidelines causes health problems. Indeed, the Russian scientific literature has reports of problems such as “microwave illness” in workers in factories exposed to unknown (but presumably very low) levels of RF energy – an illness not recognized by Western medicine. These studies typically provide sketchy (or no) information about exposure, and often lack elementary information such as the frequency of the field. Many suffer from obvious and severe defects in study design as well, or are available only in the form of brief abstracts that cannot be evaluated at all. Consequently, this literature has had very little impact in Western standards setting committees.

II. PRECAUTIONARY LIMITS

In the past few years, Italy, Switzerland, and a few other countries have adopted exposure limits based on a totally different approach, the precautionary principle [9], to a large extent in response to public concerns about the safety of emissions from wireless base stations. In contrast to science-based limits, the precautionary limits were not designed to exclude any identified hazard but were intended (as stated in the Swiss limits) “to minimize the yet unknown risks” of RF fields. The Swiss set their limits at the lowest levels that were considered to be technically and economically feasible, by simply dividing the ICNIRP limits by a factor of 10 in field strength or 100 in power

The author is with the Department of Bioengineering, University of Pennsylvania, Philadelphia PA 19104 US (e-mail: kfoster@seas.upenn.edu).

Publisher Item Identifier S 1682-0053(03)0181c

density. Precautionary limits have also been a source of controversy.

Laypeople (and also Cavdar and Ozguner) commonly fail to distinguish between exposure limits and risk, which is defined as the probability of an adverse effect. Clearly, the relation between the two is complex and indirect. The relation is most direct in Western science-based limits (ICNIRP, IEEE), which are designed to avoid a specific and well documented effect in animals, behavioral disruption. However, the safety factors that were built into these limits were calculated under worst-case exposure conditions (a human subject in a fixed position, oriented to absorb the maximum power from the incident field) that do not accurately reflect real-world exposure conditions. They are more conservative (against thermal hazards) than their safety factors would suggest. The hazards against which the Russian limits are designed to protect are not recognized by Western health agencies. And the precautionary limits of Switzerland and other countries are not designed to avoid any identified hazards at all.

Once a set of exposure limits is in place, serious and unforeseen legal consequences may occur (whatever the health risks or nonrisks may be). As is clear from Cavdar and Ozguner's article, low-powered mobile base stations can easily exceed "precautionary" limits in some jurisdictions. But modern society has many radiofrequency transmitters, some operating at very high power levels. In the past two years a major controversy developed in Italy, concerning a radio transmitter operated by the Vatican that operated within international (ICNIRP) limits but failed to meet the precautionary Italian limits [10]. Criminal charges have been filed in the matter.

In November 1998, the EMF Project in the World Health Organization commenced a project aimed at "harmonizing" exposure standards around the world [11]. This can be justified on both philosophical grounds – there should be a consistent level of health risk protection to peoples around the world – as well as practical grounds related to the globalization of trade.

Managing technological risk involves a combination of approaches, both regulatory (e.g. setting mandatory exposure limits) and nonregulatory (e.g. encouraging effective risk communication, and encouraging industry to establish good practices that avoid risk and minimize controversy). Exposure guidelines, as with electrical safety rules, are best suited to addressing defined hazards of technology. I believe that exposure guidelines should be based on scientific evidence for hazard. If a real hazard exists that is not adequately addressed by IEEE or ICNIRP exposure limits, scientists from different countries should sit down and discuss the matter, and spend more time trying to understand each other's scientific positions than they have until now. If the problem to be addressed is public fear about "radiation", more effective approaches may be possible than arbitrary reduction in exposure limits.

III. CONCLUSIONS

The wide variations in exposure limits for RF energy that are in effect in different places throughout the world reflect deep philosophical differences and approaches to dealing with uncertainty. There are important practical and

philosophical reasons to harmonize limits. But, as one would infer from Cavdar and Ozguner's paper, there is a long way to go before such harmonization will be achieved.

REFERENCES

- [1] I. H. Cavdar and N. E. Ozguner, "Electromagnetic field measurements at 900 MHz to obtain the effects of mobile communication on risk probabilities for the human health," *Iranian Journal of Electrical and Computer Engineering*, vol. 2, no. 2, pp. 119-124, Summer-Fall 2003.
- [2] A. Ahlbom, et al., "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)," *Health Phys.*, vol. 74, no. 4, pp. 494-522, Apr. 1998.
- [3] K. R. Foster, "Limiting technology: Issues in setting exposure guidelines for radiofrequency energy," in *3rd Generation Mobile Communication Systems: Future Developments and Advanced Topics*, M. Jian-Guo, Ed., New York: Springer, to appear Fall 2003.
- [4] *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, IEEE, 1999.
- [5] W. Stewart, "Mobile phones and health," *Chilton, Didcot, Oxon: Natl. Radiological Protection Board (UK)* (available at <http://www.iegmp.org.uk/report/text.htm>), 2000.
- [6] P. Aubineau, A. Bardou, G. Dixsaut, M. Goldberg, R. de Seze, B. Veyret, and D. Zmirou, "Mobile telephones, their base stations and health: state of knowledge and recommendations" ["Les telephones mobiles, leurs stations de base et la sante: etat des connaissances et recommandations"]. *Report to the Director General of Health, French Government. Paris: Direction Generale de la Sante*, 2001, (available http://www.sante.gouv.fr/htm/dossiers/telephon_mobil/index.htm)
- [7] J. A. Knottnerus, "Mobile telephones: an evaluation of health effects," *The Hague: Health Council of the Netherlands*, 2002
- [8] Ministry of Public Health, Russian Federation, "Sanitary Rules and Norms (SanPin 2.2.4/2.1.8.055-96) Radiofrequency electromagnetic radiations (2.2.4. physical factors of industrial surroundings. 2.1.8. Physical factors of the environment)," 1966.
- [9] K. R. Foster, P. Vecchia, M. H. Repacholi, "Science and the precautionary principle," *Science*, vol. 288, no. 5468, pp. 979-980, 2000.
- [10] P. Vecchia and K. R. Foster, "Precaution and controversies—Regulating radiofrequency fields in Italy," *IEEE Technol. Soc. Mag.*, vol. 22, no. 4, pp. 23-27, Winter 2002.
- [11] <http://www.who.int/peh-emf/standards/framework/en/>

Kenneth R. Foster received the Ph.D. in physics from Indiana University, Bloomington Indiana USA in 1971.

Since 1976 he has been with the Department of Bioengineering, University of Pennsylvania, where he is Professor of Bioengineering and Electrical Engineering. Since receipt of the Ph.D., Dr. Foster has been engaged in studies on the interaction of nonionizing radiation and biological systems, including studies on mechanisms of interaction and biomedical applications of radiofrequency and microwave energy. In addition he has written widely about scientific issues related to possible health effects of electromagnetic fields. He has published approximately 100 technical papers in peer reviewed journals, numerous other articles, and is the author of two books related to technological risk. His latest book, *Judging Science*, was published by MIT Press in April 1997.

Dr. Foster is Fellow of the Institute of Electrical and Electronics Engineers (IEEE). From 1997-9 he served as Chair of the IEEE EMBS Committee of Man and Radiation, and from 1997-8 he served as President of the IEEE Society on Social Implications of Technology. He is a member of the IEEE Standards Committee ICES that sets the IEEE exposure limits for RF energy. He has been a consultant to industry, as well as to several government and international agencies related to health and safety of electromagnetic fields, including the World Health Organization during a sabbatical leave (2000).