PROBLEMS WITH REGULATING RADIOFREQUENCY (RF) RADIATION EXPOSURE.

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Many concerns have been raised, both by the scientific community and in the press, that quite divergent opinions exist in industrialized countries on the nature and degree of hazard from exposure to RF radiation. This divergence of opinion is reflected in widely differing national exposure standards. In response to this, there has been intense activity, both at the international and national level, on the evaluation of biological effects literature and assessment of health hazards of human exposure to RF radiation. It has been only recently that our understanding of some of the factors influencing RF absorption in biological systems has reached a stage that it can be usefully employed in the development of human exposure limits.

IRPA's International Non-Ionizing Radiation Committee (INIRC) recognised the problems associated with RF exposure and, in collaboration with the United Nations Environment Programme and the World Health Organization, developed a health criteria document on radiofrequency radiation (1). This document incorporates a review of RF sources, characteristics of RF fields, measurement instruments, RF energy absorption in biological systems, and a thorough review of reports on biological effects in animals and health effects in man. An outline of existing national and international standards and their rationale is also included. The criteria document provided a scientific basis for the development of an exposure standard for the IRPA/INIRC.

The INIRC has composed interim guidelines on limits of exposure to electromagnetic fields in the frequency range from 100 kHz to 300 GHz (2). Following approval by the IRPA Executive Council, a draft was distributed to Member Societies of IRPA, and to various Institutions and individual scientists for comments. Many helpful comments and criticisms were taken into account to form the present guidelines. The Committee recognized that when exposure limits are drafted, various value judgements are made. The validity of scientific reports has to be considered, and extrapolations from animal experiments to effects in humans have to be made. Cost versus benefit analyses are necessary, including the economic impact of such controls. However, the limits in these guidelines were based on scientific data and no consideration was given to economic impact or other non-scientific priorities.

In summerized form the guidelines state that occupational exposure to RF radiation at frequencies at or above 10 MHz should not exceed a specific absorption rate (SAR) of 0.4 W/kg when averaged over the whole body in any 6 minute period, or 4 W/kg when averaged over any one gram of tissue in any 6 minute period. For RF radiation exposure at frequencies below 10 MHz, the levels of unperturbed root mean square (RMS) electric or magnetic field strength should not exceed the values given in Table 1.

The limits of occupational exposure given in Table 1 for the frequencies between 10-300,000 MHz are the working limits derived from the SAR value of 0.4 W/kg. They represent a practical approximation of the incident plane wave power density needed to produce the whole body average specific absorption rate of 0.4 W/kg. These limits apply to exposure from either continuous or modulated electromagnetic fields from one or more sources, averaged over any 6 minute period during the working day (8h per 24h).

Although little information is presently available on the relationship between biological effects and peak values of pulsed RF fields, it is suggested that the instantaneous peak values for all frequencies not exceed 100 times the limits in Table 1 for the frequency concerned.

Table 1: Limits for whole and partial body occupational RF exposure

Frequency Range	Unperturbed RMS Electric Field Strength	Unperturbed RMS Magnetic Field Strength	Equivalent Plane Wave Power Density	
MHz	V/m	A/m	W/m^2	mW/cm^2
0.1-1	194	0.51	*100	*10
1-10	$194/f^{1/2}$	$0.51/f^{1/2}$	*100/f	*10/f
10-400	61	0.16	10	1
400-2000	$3f^{1/2}$	$0.008f^{1/2}$	f/40	f/400
2000-300,000	137	0.36	50	5

* These values are not for determining compliance.

Note: (i) f = frequency in MHz

(ii) The limits in the frequency ranges above 10 MHz may be exceeded for specific applications provided the SAR remains below 0.4W/kg when averaged over the whole body and below 4W/kg when averaged over any one gram of tissue. The limits for frequencies at or below 10 MHz may be exceeded (up to 615 V/m or 1.6 A/m) provided workers take the necessary precautions to prevent potentially severe RF burns.

When simultaneous exposure occurs from radiations emitted from sources operating at different frequencies, the exposure should be measured at each frequency and expressed as a fraction of the power density limit or the square of the electric or magnetic field limit for each frequency range (in Table 1). Then the sum of these fractions should not exceed unity. Exposure to radiofrequency radiation emitted from low power devices, such as citizen's band radios, land mobile and marine transmitters, and walkie-talkies can be excluded from consideration in assessing compliance with the prescribed limits provided the radiofrequency output power of the device is seven watts or less. Such devices only generate very localized fields.

Limits of RF exposure for the general public were set at one-fifth of the occupational exposure limit in the appropriate frequency range. Lower exposure limits for the general public were recommended for a number of reasons:

(i) exposure could occur for 24h/day

(ii) broader spectrum of health sensitivities in the general public than the working population (sick, disabled, infirmed, babies, children); and

(iii) our lack of knowledge of possible health effects from long term chronic exposure suggested that an additional safety factor was necessary.

When developing the IRPA guidelines, a number of questions had to be addressed:

(i) What are the populations being protected and are there any differences that should be considered (occupational verses general public exposure)?

(ii) In view of our incomplete understanding of the interaction mechanisms underlying biological effects of RF exposure, and there presently being no predictive theory possible for non thermal effects, what allowances must be given to these effects?

(iii) From the information available on the absorption of RF energy in humans, and the fact that most experimental data were accummulated at frequencies above 1 GHz, how should the frequency ranges be divided to provided the same degree of protection from 100 kHz to 300 GHz?

(iv) How valid is it to extrapolate results of animal experiment to possible effects in humans?

(v) Should the exposure standard take account of indirect or secondary effects such as RF shocks and burns?

(vi) How should one overcome the lack of knowledge of relating peak SAR to observed biological effects?

(vii) Environmental conditions - should the exposure limits be protective under the most adverse conditions of temperature, humidity and air movement?

(viii) Is there an altered response of humans taking medicines while being exposed to electromagnetic fields?

(ix) Are there possible combined effects of RF electromagnetic energy with drugs, chemicals or physical agents?

(x) What are the implications of effects reported with modulated microwave fields on the central nervous system and the possible existance of "power" and "frequency" windows for effects?

(xi) Is there sufficient data on effects from long term, low level RF exposure? If not, is it reasonable to require an increased safety factor?

Effects on behaviour (convulsion, work stoppage, work decrement, decreased endurance, perception and aversion of the exposing field) seem to be the most sensitive indicator of human health hazard from exposure to RF fields giving SAR's above 4 W/kg (an implied "dose threshold") (3). Using this and the data on human absorption of RF energy, a set of exposure limits can be developed which incorporates an "apparent" constant safety factor. The frequency ranges in the exposure limits were determined taking into account RF energy absorption for all possible human sizes (including babies), partial body resonances (e.g. head) and the "hot spots" that can occur up to 2 GHz.

The IRPA/INIRC felt that a clear distinction was necessary between occupational and general public exposure. Safety factors should incorporate: some allowance for "non-thermal" effects (especially for the general public); the fact that most bioeffects data were obtain in animals at frequencies above 1 GHz and results are extrapolated to possible effects in human exposured at lower frequencies; and our poor knowledge of potential effects from long term, low level exposure. It was also felt that exposure standards should be "safe" in the most adverse environment (temperature, humidity etc) and working conditions (RF shocks and burns).

References

1. "Radiofrequency and microwaves", Environmental Health Criteria 16, United Nations Environment Programme, World Health Organization, International Radiation Protection Association, WHO, Geneva, 1981.

2. "Interim guidelines on limits of exposure to radiofrequency electromagnetic fields in the frequency range from 100 kHz to 300 GHz", International Radiation Protection Association, Health Physics (in press).

3. "Safety levels with respect to human exposure to radiofrequency electromagnetic fields, 300 kHz to 100 GHz", American National Standards Insitute, ANSI Committee C95.1, IEEE, New York, NY, 1982.