PITFALLS IN THE ASSESSMENT OF MICROWAVE RADIATION AS A HAZARD

Russell L. Carpenter, Esther S. Ferri and Gary J. Hagan. Northeastern Radiological Health Laboratory, 109 Holton St., Winchester, Mass. 01890

ABSTRACT

The extent to which microwave radiation can constitute a health hazard is a question amenable to laboratory investigation, but the investigator must constantly be on guard against pitfalls peculiar to the investigation of this problem. Among them are: the reliability of power density measuring devices; near field and far field differences in field patterns and in perturbations of the microwave field by the experimental animal itself or by accessory supports or restrainers; whole body heating as a factor influencing results; determination of the relative roles of power density and duration of exposure as dose factors; and limitations on extrapolation to man of results from animal experiments. Attempts to define and to limit these problems will be described and illustrated.

. . . . . .

The question of whether microwave radiation can constitute a health hazard is easily answered by placing an animal in a microwave field. With sufficient energy absorption and duration of exposure, the animal's body temperature will rapidly rise to a lethal level and it will expire, death being due to hyperthermia. Although this demonstrates that microwaves can be hazardous to the animal's health, the same result may also be obtained by placing it in the oven of an operative gas or electric range. The question we really wish to have answered is how much - or how little - microwave radiation can cause damage to living tissue. This question is one to which we have directed our efforts for several years, with the lens of the rabbit eye as the target tissue. Damage becomes visible in the lens as small opacities in its otherwise transparent tissue. In the course of our research, we have encountered a number of pitfalls, some of which I shall here briefly describe.

In a series of 136 experiments, 2450 MHz radiation was directed primarily upon the target by positioning the rabbit with its eye two inches distant from the dipole antenna of the radiation source. The head was thus in the near zone of the microwave field. For eight different power settings, we found the shortest duration of exposure which would cause a lens opacity to develop, and expressed this information graphically as a curve showing time and power thresholds for opacity induction.[1] This curve was similar to one obtained in like manner by Williams, et al.,[2] but differed with respect to values for field power. They calculated field energy from measurements made with a dipole antenna and a tunable bolometer detector. Ours were done calorimetrically, the calorimeter being a fluid-filled plastic sphere placed in the same position in the microwave field as was occupied by the eye during irradiation. The sphere was filled with a saline solution having a dielectric constant similar to that of the eye. Temperature changes reflecting energy absorbed or lost were measured by a thermistor-bridge circuit, with the thermistor enclosed in the tip of a 24 gauge hypodermic needle inserted in the center of the sphere. Power density was then calculated employing the cross sectional area of the plastic sphere.

To assess microwave radiation as a hazard to the lens, it would have been most useful to know which of the two threshold curves represented the true state of affairs.

With the development of instruments for the direct measurement of power density in a microwave field, it appeared possible to re-evaluate our previous calorimetric measurements. Using a Narda Model 8110 Electromagnetic Radiation Survey Meter[3] and its Model 8122A probe having two crossed dipoles, we found that under identical conditions of geometry and power output, measurements were approximately 50 percent higher than when calculated from calorimetric measurements.

It should be noted at this time that the unit of mW/cm^2 as applied to the calorimetric measurement is conventional. However, when using an electromagnetic survey meter and probe as a measuring device in the near field, a meter reading in mW/cm^2 should not be considered a measure of the actual power density. The electromagnetic survey meter and probe measure, the electric field, and meter readings in the near field discussed in this paper are a measure of the electric field (E) and equal to $E^2/377 \times 1000$.

A few years later, it became possible to further evaluate the near field zone by means of an Electromagnetic Hazard Meter developed for the Bureau of Radiological Health by the National Bureau of Standards[4]. The probe of this instrument employs three crossed dipoles and, if desired, output of each can be read separately on the meter. This instrument gave readings which were an average of 34 percent higher than those of the Narda Model 8110 meter. This could be accounted for by the observation that there was a longitudinal and radial component of the field at the two-inch distance. This view was corroborated some months later when we acquired a Narda Model 8315A Broadband Electromagnetic Radiation Monitor[5] with its Model 8323 isotropic probe. Measurements made at the two-inch distance with this instrument averaged 41 percent greater than those made with the Narda Model 8110 instrument. Measurements with electric field sensors, such as the Narda and NBS probes, give an indication of the electric field strength; calorimetric devices measure absorbed energy. Therefore it would be inappropriate to compare measurements obtained by these different means.

There is a futility of attempting to define hazardous power levels on the basis of past reported experiments in the near zone field, if only because of the inability to measure the actual power density. The far field, on the other hand, exhibits a much more uniform and regular radiation pattern and permits a more reliable calculation of the power density from measurements of the E field.

One difficulty when performing experiments in the far field is that the entire body of the experimental subject is illuminated. The rabbit which, without anesthesia, will tolerate having its head subjected to a given exposure field for an hour in the near zone will strenuously seek escape after 15 minutes or will succumb from exposure to whole body radiation only one third of that tolerated in the near field.

Still another pitfall lies in the perturbation of the radiation field by the presence of the experimental subject itself. At a distance of 150 cm the field pattern of our standard gain horn at 2450 MHz is quite uniform in power density, being highest in the center of the field and falling off in a gradual manner along the x and y axes so that 50 cm from the center, it is reduced by 75 percent. However, a rabbit sitting quietly in the field perturbs the field in such an irregular manner that the power density may be either increased or decreased by as much as 50 percent in some areas. For example, in one instance we have found that the presence of the rabbit appears to reduce the power density at a location of the rabbit's eye by about 50 percent. Inasmuch as the pattern of field perturbation depends in part on the geometry of the perturbing factor, it is not surprising that there is a difference in perturbation of the field when the rabbit's ears are held erect or are down flat against the body. We have found that the eye is subjected to less radiation when the animal's ears are down than when they are up. Perturbation of the field also occurs from the presence of such experimental accessories as plastic cages or animal restraints.

The relationship of this perturnbed exposure field to an absorbed dose may be difficult to determine. However, a total absorbed dose would depend on a complex relationship between the exposure field (the magnitude, direction, and phase of the electric field at all points on the surface of the object), the dielectric constant or constants, geometry and surrounding media of the object of exposure.

REFERENCES

1. R. L. Carpenter, D. K. Biddle, and C. A. Van Ummersen: "Biological effects of microwave radiation, with particular references to the eye." Proc. Third Int. Conf. on Med. Electronics, London, pp. 404-408. (1960)

2. D. B. Williams, J. P. Monohan, W. J. Nicholson, and J. J. Aldrich: "Biologic effects of microwave radiation: Time and power thresholds for the production of lens opacities by 12.3 cm. microwaves." U.S.A.F. School of Aviation Medicine Report No. 55-94. (1955).

3. E. Aslan: "Electromagnetic leakage survey meter." Jour. Mic. Power, Vol. 6, No. 2, pp. 169-178. (1971)

4. R. R. Bowman: "Quantifying hazardous electromagnetic fields: Practical considerations." Biol. Effects and Health Implications of Microwave Radiation, Symposium Proceedings, Richmond, Va. (BRH/DBE-70-2) pp. 204-209 (1969).

5. E. Aslan: "Broadband isotropic electromagnetic radiation monitor." IEEE Trans. on Instrumentation and Measurements, Vol. IM-21, No. 4, pp. 421-424. (1972)

6. R. L. Carpenter and C. A. Van Ummersen: "The action of microwave power on the eye." Jour. Mic. Power, Vol. 3, No. 1, pp. 3 - 19. (1968)