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Comments on "Human Exposure to Nonionizing Radiant Energy—Potential Hazards and Safety Standards"

Dr. Michaelson should be complimented highly on the above encyclopedic paper[1] concerning human exposure to nonionizing radiation.

Since much of my professional experience has involved microwaves, I read with particular interest the section entitled "Microwaves" (pp. 406–413), and with concern the sentence (p. 410): "To date, there is very little information on injury other than burns, and possibly cataracts in man from exposure to microwaves. . . ."

For the benefit of my fellow engineers who may be occupationally (or otherwise) exposed to high-power microwaves, I would like to complement Dr. Michaelson's references by offering the following.

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REFERENCES

Human Eye Injury

[1] F. G. Hirsch and J. T. Parker, "Bilateral lenticular opacities occurring in a technician operating a microwave generator," *Amer. Med. Ass. Arch. Ind. Hyg.*, vol. 6, pp. 512–517, Dec. 1952.

[2] I. S. Shimkovich and V. G. Shilyayev, "Cataract of both eyes which developed as a result of repeated short exposures to an electromagnetic field of high density," *Vestn. Oftalmol.*, vol. 72, pp. 12–16, 1959.

[3] L. P. LaRoche, M. M. Zaret, and A. F. Braun, "An operational safety program for ophthalmic hazards of microwaves," *Arch. Environ. Health*, vol. 20, pp. 350–355, Mar. 1970. (Report of positive findings of ophthalmic microwave injury in 33 employees at Patrick AFB, Fla. These people were involved in incidents during the period 1963–1968.)

[4] M. M. Zaret, I. T. Kaplan, and A. M. Kay, "Clinical microwave cataracts," in *Biological Effects and Health Implications of Microwave Radiation, Symp. Proc.* USDHEW, PHS, BRH/DBE 70-2, 1970. (Case history of Mr. Kay's ophthalmic microwave injury.)

[5] F. G. Hirsch, "Microwave cataracts—A case report reevaluated," in *Electronic Product Radiation and the Health Physicist.* USDHEW, BRH/DEP 70-26, Oct. 1970, pp. 111–140. (Follow-up report on the case history in [1].)

Human Testicular Inury

[6] D. S. Rosenthal and S. C. Beering, "Hypogonadism after microwave irradiation," *J. Amer. Med. Ass.*, vol. 205, pp. 245–248, July 22, 1968.

Relevant Animal Experiments

[7] L. Birenbaum, G. M. Grosof, S. W. Rosenthal, and M. M. Zaret, "Effect of microwaves on the eye," *IEEE Trans. Bio-Med. Eng.*, vol. BME-16, pp. 7–14, Jan. 1969. (Effects of CW versus pulsed 5.5 GHz microwaves on cataractogenic thresholds in rabbits.)

[8] L. Birenbaum *et al.*, "Effect of microwaves on the rabbit eye," *J. Microwave Power*, vol. 4, pp. 232–243, Dec. 1969. (Extension of work in [7] to find frequency dependence of thresholds.)

Author's Reply[2]

I appreciate Mr. Birenbaum's concern, but I should point out at the outset that, as in so many other comments on microwave bioeffects and hazards, there is a certain lack of perspective.

My statement on page 410—"To date, there is very little information on injury other than burns, and possibly cataracts in man from exposure to microwaves . . ."—is still incontrovertible. This statement should be understood in the context of the earlier statement on page 407 of the same paper:

> The extensive investigations into microwave bioeffects . . . conclusively show that for frequencies between 1200 MHz and 24 500 MHz, exposure to power density of 100 mW/cm² for 1 h or more could have pathophysiologic manifestations of a thermal nature. At power densities below 100 mW/cm², however, evidence of pathologic change is nonexistent or equivocal. It is important, therefore, to assess the possible biologic effects of power densities below 100 mW/cm².

This is germane to the entire paper. I could have reviewed the entire area of microwave bioeffects, which would have increased the size of the present paper by an order of magnitude. This was not the purpose of the present paper. Each of the references mentioned, however, has been previously reviewed and analyzed by me (or my associates) in other publications [9]–[16].

To respond adequately to Mr. Birenbaum's letter would require a paper probably as long as the present one. Nevertheless, I should like to comment briefly on the references noted by Mr. Birenbaum. Of the eight references noted, seven refer to cataractogenesis. In my paper, on page 410, I do point out that the lens of the eye can be considered the critical organ for microwave cataractogenesis and potential hazard.

It is no doubt appropriate to comment briefly on the specific references that Mr. Birenbaum lists.

References [1], [5]; Hirsch [17], [18]: This report concerns a 32-year-old man who operated a microwave test bench for a period of 1 year. The frequency was apparently 4000–5000 MHz (6–7.5 cm) with a peak power of 500 W and average power of 250 W. It is calculated that the power density to which the man was exposed ranged from 40–380 mW/cm² and up to as much as 1160 mW/cm² for exposures in the Fresnel zone which extended about 1 ft in front of the antenna, within which distance the subject frequently worked. There is the possibility that the patient had a recurrent uveitis and chorioretinitis associated with vitreous opacities and secondary cataracts. The case, therefore, would appear to be suggestive but not conclusive of a cataractogenic effect of long-term high-level microwave radiation exposure.

Reference [3]; LaRoche *et al.* [19]: This paper reports "ophthalmic microwave injury" in 33 employees at Patrick AFB, 1963–1968. It is important to note, however, that as the authors themselves state, ". . . however, since preemployment examinations do not normally include examination specifically for microwave injury, there is either limited or no information available concerning the prior condition of the lens." Also, of these 33 individuals, only four were negative at the initial examination. One therefore has no means of relating the results of the examination to previous history. Most important, the authors state, ". . . it is not certain if those persons showing evidence of microwave injury on first examination actually received the exposure while working on the Air Force Eastern Test Range."

Reference [4]; Zaret *et al.* [20]: This paper describes a case of cataracts in an individual who ". . . had many exposures to power densities of about 1 W/cm²."

Manuscript received July 6, 1972.

[1] S. M. Michaelson, *Proc. IEEE*, vol. 60, pp. 389–421, Apr. 1972.

[2] Manuscript received July 14, 1972.

References [7], [8]; Birenbaum *et al.* [21], [22]: These authors studied cataract production in rabbits exposed to CW and pulsed microwaves at 5500 MHz. The average power causing an observable loss of transparency (in at least a portion of the lens) in 50 percent of the animals was defined as the "threshold value." Logarithmic time–threshold curves were obtained when the exposure times for cataract production were plotted against the corresponding "threshold" values in both CW and pulsed experiments. This study indicates the 1-h threshold to be well above 600 mW/cm² for this frequency.

Reference [2]; Shimkovich and Shilyayev [23]: These authors reported a cataract in a technician exposed to "high levels" of 10–12-cm microwaves in 1959. It is noteworthy that Shilyayev [24], in a publication approved and recommended for printing by the Editorial Council in the USSR Academy of Medical Sciences, states:

> On the basis of our present knowledge of the conditions under which experimental 'microwave cataract' arises and of its diagnosis and treatment, it must be acknowledged that none of the cases described in the literature is fully verified. . . . Under normal working conditions, personnel are exposed at levels representing several orders of magnitude below the level with which the various changes in the lens are produced experimentally. It appears that damage to the lens from exposure to microwave may occur very seldom (if at all), and then only under unusual circumstances. Exposure to a rotating radar antenna is no practical threat to the lens even at rather high power densities such as 100 mW/cm² or higher. There are no experimental data demonstrating cataract formation associated with whole-animal exposure.
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> . . . as a rule, the development or detection of cataract coincide only accidentally in time with the exposure to microwaves and was actually due to other causes such as uveitis, congenital cataracts, etc.
>
> Lenticular opacities have also been noted to appear at the positions of existing microscopic congenital changes and, on reaching a certain magnitude, progress no further even when there is no change in the occupational setting. Such studies are only qualitative and do not give any relation between the actual power level and pathology. It should also be recognized that individuals studied in such surveys could have been exposed to ionizing radiation just as well as to microwaves.
>
> It should be noted that in actual radar or microwave-communication operation, it is rare that a technician is exposed to high-intensity microwaves for a time that can prove harmful, since he would probably feel the heat due to energy absorption which would serve as a warning.
>
> The results of experimental study of the action of microwaves on the lens suggest a potential for lens damage in personnel exposed to microwaves. The treatment given such potential injury in the public press has led many radar and electronics industry workers to associate a wide variety of eye diseases with exposure to microwaves. This circumstance may give rise to certain difficulties in medical-legal litigation and have an unfavorable psychological effect on persons working with microwave sources.

Reference [6]; Rosenthal and Beering [25]: This is a case of oligospermia in a 31-year-old male. It is not necessary to comment on this reference in great detail. First, there was no preexposure examination of this individual, so any causal relationship is very tenuous. It should be mentioned that at best one must be extremely careful in interpreting such reports. In man, especially, obtaining adequate testicular biopsies imposes considerable practical difficulties and skillful cytological analysis is required to study cellular changes in the testes. Highly relevant are the comments of the authors. Evidence of testicular damage in man is lacking, although extrapolation of results from animal studies has led to the general belief that extreme exposure may lead to injury. . . . The patient was a repairman at a weather radar installation where he had been employed for four years. He frequently performed maintenance on the radar antenna while the equipment was in operation. He did not wear protective clothing. On occasion, while working near the microwave beam, the patient noted a sensation of warmth. . . . (the) patient was exposed repeatedly to microwave power densities more than 3,000 times the currently accepted safe level established by the US Air Force . . . and, furthermore, wore no protective garments. . . . The ordinary precautions currently in use near microwave transmitters appear adequate to preclude excessive exposures such as this patient experienced.

I sincerely regret this lengthy discussion, but such analysis of the published reports is essential to bring order and perspective in this very controversial and greatly misunderstood area of microwave bioeffects. Certainly, excessive or irrational utilization of the good things in life such as eating, sunbathing, lifesaving drugs, etc., can prove harmful. There is no reason why nonionizing radiant energy should be any different. If used judiciously, great benefits can be derived from these energies. On the other hand, either through lack of knowledge or perspective, utilization and future development of these energies can be hampered.

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[10] ——, "Biomedical aspects of microwave exposure," *Amer. Ind. Hyg. Ass. J.*, vol. 32, pp. 338–345, 1971.

[11] W. C. Milroy and S. M. Michaelson, "Biological effects of microwave radiation," *Health Phys.*, vol. 20, pp. 567–575, 1971.

[12] S. M. Michaelson, "Biological effects of microwave exposure—An overview," *J. Microwave Power*, vol. 6, pp. 259–267, 1971.

[13] W. C. Milroy and S. M. Michaelson, "Microwave cataractogenesis—A critical review of the literature," *Aerosp. Med.*, vol. 43, pp. 67–75, 1972.

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[15] ——, "Microwave exposure safety standards—Physiologic and philosophic aspects," *Amer. Ind. Hyg. Ass. J.*, in press.

[16] ——, "The relevancy of experimental studies of microwave-induced cataracts to man," submitted for publication.

[17] F. G. Hirsch and J. T. Parker, "Bilateral lenticular opacities occurring in a technician operating a microwave generator," *Amer. Med. Ass. Arch. Ind. Hyg.*, vol. 6, pp. 512–517, 1952.

[18] F. G. Hirsch, "Microwave cataracts—A case report reevaluated," in *Electronic Product Radiation and the Health Physicist*, USDHEW, BRH/DEP 70-26, 1970, pp. 111–140.

[19] L. P. LaRoche, M. M. Zaret, and A. F. Braun, "An operational safety program for ophthalmic hazards of microwaves," *Arch. Environ. Health*, vol. 20, pp. 350–355, 1970.

[20] M. M. Zaret, I. T. Kaplan, and A. M. Kay, "Clinical microwave cataracts," in *Biological Effects and Health Implications of Microwave Radiation, Symp. Proc.* USDHEW, PHS, BRH/DBE 70-2, 1970.

[21] L. Birenbaum, G. M. Grosof, S. W. Rosenthal, and M. M. Zaret, "Effect of microwaves on the eye," *IEEE Trans. Bio-Med. Eng.*, vol. BME-16, pp. 7–14, Jan. 1969.

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[24] V. G. Shilyayev, "Effects of microwave radiation on the visual organ," in *Influence of Microwave Radiation on the Organism of Man and Animals*, I. R. Petrov, Ed. Leningrad, USSR: Academy of Medical Sciences of the USSR, Meditsina Press, 1970 (Transl. of *Viliyaniye SVCh-Izlucheniya na Organizm Cheloveka i Zhivotnykh*, Nat. Aeron. and Space Admin., Washington, D. C., NASA TT F-708, Nov. 1971, p. 142).

[25] D. S. Rosenthal and S. C. Beering, "Hypogonadism after microwave irradiation," *J. Amer. Med. Ass.*, vol. 205, pp. 245–248, 1968.

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