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Do microwaves pose a hazard to mind and body?

by Gerald Silverberg

A BIOLOGICAL REVIEW would not be complete without consideration of one of the least obvious, but most important, physical influences on life: electromagnetic radiation. Consider for a moment the various natural sources—light waves, manifested in the images you see and the sunburn on your back; X-rays, penetrating your innards with silent stealth. We are surrounded by electromagnetism, winging through space invisibly and—in the main—imperceptibly.

Modern life has brought a plethora of additional man-made sources. Among the most subtle are those generated in the microwave spectrum, at frequencies from 30 Megahertz to 300 Gigahertz, nestled between radio and infrared waves at wavelengths from 1,000 to .1 cm. Microwaves carry television signals to dazzle or daze you, radar signals to guide the airplanes that transport you, oven heat to cook the meals you consume. And yet, in the 30 years that they have become an integral part of our lives, microwaves have garnered little public attention. Except in the Soviet Union.

The Russians have long maintained that microwaves can cause a wide range of psychological and physiological abnormalities, particularly the "asthenic" syndrome: irritability, fatigue, headache, loss of memory and indecisiveness. Soviet scientific faith in microwave-induced aberrations is based on several years' observation of workers in industrial microwave environments conducted by the Academy of Medical Sciences, Moscow, during the late 1950s and early 1960s; permissible microwave exposure levels in the Soviet Union are thus one-thousandth of the U.S. ASA Standard for continuous exposure in industrial and military situations.

Upsetting Ambassadors and Grandmasters

U.S. security agents, alert to Russian interest in electromagnetism, discovered in the early 1960s that the U.S. Embassy in Moscow was under high frequency bombardment from a neighboring building, according to columnist Jack Anderson. (*New York Post*, May 10, 1972) The exact purpose, presumably unsalutary, remains obscure after an intense CIA-sponsored investigation by several American scientists; still, the Russians were asked to remove this Cold War artifact at the 1967 Glassboro summit.

And as recently as last year, a Kremlin official ordered Efim Geller, Boris Spassky's second, to accuse Bobby Fischer of electronic underhandedness, i.e. planting some sort of radiating instrument in the auditorium. Could Spassky's listless showing in chess be attributed to the subtle asthenic syndrome of microwave radiation? What appeared to be ideological paranoia and/or poor sportsmanship to American observers was taken much more seriously in Moscow. (*Science*, September 2, 1972)

American scientists have remained generally skeptical about the potency of low-energy microwaves; it was not until the late 1960s that our researchers were able to replicate Soviet laboratory experiments. Thus, the U.S. project charged in 1957 by the three military services with determining microwave hazards mainly investigated large-scale thermal effects; it set a 10 milliwatt/cm² exposure ceiling which is still in widespread, though not mandatory, use in the United States. However, recent American findings indicate that microwaves *do* produce seemingly inexplicable physiological effects.

The Sound of Microwaves

Exploring low-power-induced biological responses for several years, Allan Frey of Randomline, Inc., Willow Grove, Pa., has shown that human beings can hear microwaves directly. He reports in *IEEE Transactions on Microwave Theory and Techniques* for 1971 that his subjects report a variety of sounds, including buzzing and humming, when they are irradiated with trace amounts of radio frequency energy in the UHF and VHF spectrum. However, according to Frey, the microwave beam must be amplitude modulated or pulsed at audible frequencies to produce the effect. He says that some researchers who failed to confirm the phenomenon used unmodulated microwaves.

The intensity of the sensation is a function not of the average energy of the pulsed waveform, Frey maintains, but of the peak energy. Those familiar with high fidelity equipment are aware of the controversy about "peak music power" versus the more reliable rms power ratings. Frey has shown that as far as hearing microwaves is concerned, peak power is a better measure than rms power. Since a microwave beam of low average power can be highly modulated, people can hear such low rms, high peak power beams; Frey reports a statistically significant threshold —about .3 mW/cm² average power—at which highly modulated signals become audible.

It is not clear how microwaves produce the sensation of sound, but Frey has ruled out one possibility: fluctuations in external air pressure impinging on the eardrum. In the hope of learning something about the mechanism, he looked for the periodicity pitch phenomenon associated with ordinary hearing: perception of tone from a pair of conventional acoustic pulses is related to the time delay between them. No relationship between delay and perceived frequency was observed for microwave hearing. In fact, trained musicians, irradiated with low-level UHF energy carrying a 200 Hertz signal, reported hearing a mixture of higher frequencies, including harmonics of the original tone. Thus, Frey concludes that microwaves do not act directly and exclusively by a simple linkage with the ear-brain network.

Straight to the Nerves?

Another possibility is that microwave electric fields trigger nerves directly; nerves transmit pulses electrochemically, the balance of sodium and potassium ions on either side of a nerve cell membrane being critical to the hearing process. Hermann P. Schwan of the Moore School of Electrical Engineering, University of Pennsylvania, has argued against direct stimulation of nerve tissue. Using a theoretical model of nerve action, he has shown that the electric field strength required across the boundary of a nerve cell is about 500 kilovolts per centimeter; a microwave beam of such intensity would burn a living organism to cinders. Frey, however, says that very intense microwave beams may not be required for nerve tissue stimulation; he suggests that the imperfect state of knowledge of nerve operation is sufficient reason for not rejecting out of hand a possibly delicate and subtle interaction between microwaves and flow of information to the brain.

In experiments with cats, Frey has evoked brain stem electroencephalographic activity with microwave pulses as small as 30 microwatts/cm^2 average energy with 60 milliwatts/cm^2 peaks. Different neural phenomena associated with microwaves have been observed by other researchers: G. E. Hearn has shown that microwaves influence the frequency at which a flashing light is seen as a continuous image—an accepted indication of neural dysfunction; A. E. Bourgeois, Jr. has found that the sound threshold required for auditory perception decreases during microwave irradiation.

An Aversive Response

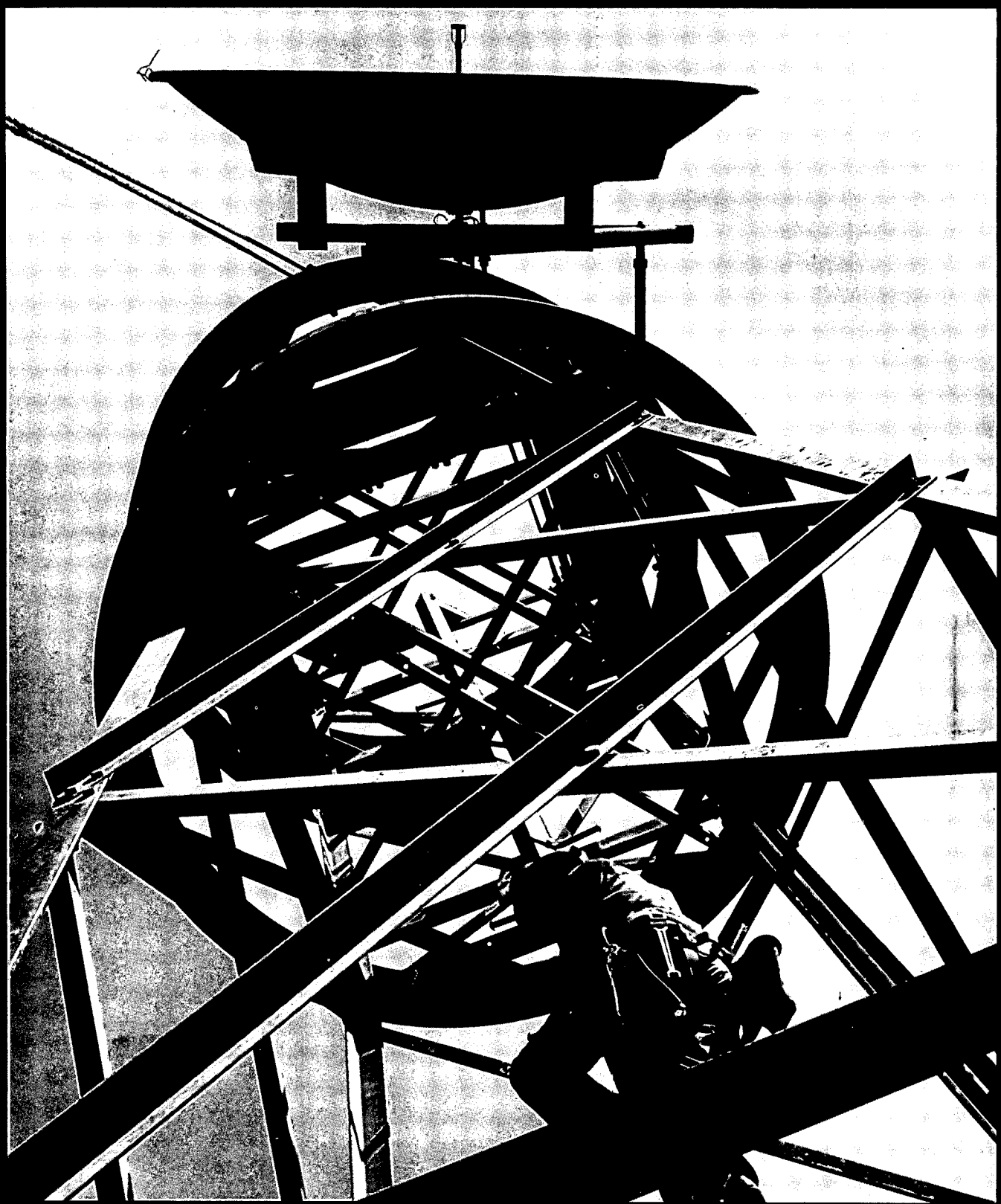
There is also evidence from American scientists that low-level microwaves can affect behavior. In 1965, for example, Dr. Susan Korbel and W. D. Thompson, University of Arkansas psychologists, reported increased activity from rats irradiated with 1 mW/cm^2 rf energy. Allan Frey has constructed a shuttle box—a miniature room divided into two compartments by a low barrier; when he illuminated one side of the box with .1 mW/cm^2 UHF microwaves, lab rats distinctly avoided the irradiated side, spending only 30 per cent of their time there. Microwaves are clearly responsible for this behavior, Frey concludes, although he has no explanation for how the rats sense the radiation—at such low power levels, body temperature rise is insignificant—or why they dislike it.

Drs. Don R. Justesen and Nancy Williams King of the Neuropsychology Research Laboratories, U.S. Veterans Administration Hospital, Kansas City, Mo., and Rex L. Clarke, University of Kansas, have pursued microwaves' aversive effects further. In a conditioned suppression environment, they found that the radiation stimulates an aversive response in rats—the cessation of licking associated with a photoelectrically triggered sugar solution reward —by warning the animals of impending electric shock. The conditioning of aversive behavior is impressive because the subjects have no natural inclination to make such responses, as they would with appetitive behavior; in situations where the biophysical mechanisms are mysterious and conclusions based on statistical analysis of behavior, it is absolutely essential to exorcise artifactual uncertainty.

These researchers suggest that modulated microwave cues suppress licking almost as efficiently as do audible tone cues. The subjects reacted to microwave signals as low as 1.2 milliwatts/gram of body weight, and one rat was able to sense .6 mW/gm—equivalent to about 1 mW/cm^2. The team writes in *Science* for April 23, 1971, "We offer our data as evidence that confirms and extends the generality of Frey's findings; mammals are sensitive to something that inheres in or accompanies illumination by microwaves at low levels of available power."

Although U.S. scientific findings of specific low power biological effects are growing in number, the only microwave health hazard officially recognized in our country is

Unreasoning Radiation



ues—and along come these wonks with slide rules sewn into their sports jackets, these *utilitarians* with their impersonal instruments, their college board exams, weighing us as though each of us weren't *unique*. "They" are telling "us" that they can measure our merriment and our desperation and that we don't deviate very much from the norm.

In other words, science tells us things that make us feel bad. It tells us that we aren't central, but peripheral, to the business of the universe; that we aren't created in the image of God, but are rather a lucky concert of atoms; that we aren't masters of our fate or captains of our soul, but puppets of our past, jerking on strings attached to prior causes—"Predestination without grace," someone called it. A gloomy truth. We complain that you have created a world in which we do things not because we want to, but simply because we know *how*. You will reply that the only definition of free will that makes any modern sense is our ability to postpone action while we scan the possibilities, and that you have made that postponement possible, speeded-up the scanning process.

I believe you. These are cartoons. But this is a nation that has lived and died by cartoons. The logic of this particular cartoon goes deeper. It would resolve the night-shrieks by apportioning different aspects of life to different groups of professionals. Let the scientists look after our health, our food, our communication, our convenience and our physical survival. Let the humanists make all the political decisions; look after our souls, our notions of decency, mercy, justice, our order of priorities. Power from the one, values from the other, institutions to do the mediating between them.

It won't work, and it shouldn't . For one thing, I don't see the humanists, the writers and artists, being very busy on the value front, tackling social realities, evolving much of anything at all. It's been a long, long time since literature was what Matthew Arnold thought it ought to be—a criticism of life, addressing itself to moral consciousness. We have novels about writing novels. We have critical monographs about novels about writing novels. We have history written as though it were a review of a movie. We have a theater of personal abuse. We have a sensibility, in the words of Irving Howe, that "seeks to charge itself into dazzling sentience through chemicals and the rhetoric of violence"; that "*ordains* life's simplicity," choosing surfaces as against relationships, the skim of texture rather than the weaving of pattern. We have a psychology of unobstructed need.

And so I turn to you, to the working scientists. You are going through a bad period. The money faucets have been turned off in Washington. Your basic research is bound to suffer. But for three decades you have been pampered. Almost anything you wanted to do would be funded. Many of you didn't care what happened to the knowledge you discovered after you had discovered it; it seemed enough that you were paid to do what you liked. It wasn't enough. The garbage around us testifies to that.

You now have the enforced leisure not only to think about your own priorities in research, but also about your responsibilities for what is done with your knowledge and the way you might actively intervene in the political process. I know that Aristotle made idle basic research respectable. "Evidently, then," he said, "we do not seek knowledge for the sake of any other advantage; but as the man is free, we say, who exists for his own sake and not for another's, so we pursue this as the only free science, for it alone exists for its own sake." But I prefer Francis Bacon. "Knowledge," said Bacon, "that tendeth but to satisfaction is but as a courtesan, which is for pleasure and not for fruit or generation . . . The sure and lawful goal of the sciences is none other than this: that human life be endowed with new discoveries and power . . . As in religion we were warned to show our faith by works, so in philosophy by the same rule the system should be judged of by its fruits, and pronounced frivolous if it be barren." In other words, you have to decide what knowledge is worth having.

Nobody can or should tell you what you are supposed to be interested in, any more than anybody can or should tell an artist what he should be doing. But there are two reasons why I think you should consider it. The first is obvious: if your work is to be federally funded, all of us are helping to pay for it, and all of us have in the past helped to pay for the cleaning up afterward. We have a right to ask about the social merit of what we sponsor, as well as the scientific merit.

The second reason is that you have something unique to contribute. You experience in your working lives a viable idea of society in which progress depends on cooperation and trust. Professionally, you *live* the social contract. Politically, you are capable of redeeming it. Knowledge and values come together at the nexus of *policy*. Policy can have to do with abortion, with blood donations, with the medical definition of death, with the environmental afterbirth of the supersonic transport, or with *anything* that matters. Your history accumulates values as well as facts. It suggests, indeed it insists on, accommodating new ethical notions to social reality.

It suggests to me that your knowledge extends to the moral as well as the material universe; that you must not only advise, and—God help us—dissent, but act boldly wherever policies are being formed. You may be able to teach the rest of us what a society means to millions of strangers. Our best and worst experiences occur inside ourselves, but we are at the beginning and at the end relying on others—for protection and education during the prolonged period of dependency after birth; for the unending flow of sensations and perceptions from the *outside*, without which there could be no integrity of the personality, no *coherence*; for the goods and services, the division of labor into bits and pieces of skills, the exchange of experiences abstracted into symbols and words, that allow us to adapt to the environment and to survive.

These transactions between individual and society are inevitable. So is conflict. And tension. But they might be for all of us, as they are for you, creative as well. Where the needs of the individual and the needs of society coincide is at the question of *What is the right thing to do?* I ask you to help me out with that question, because my side is really doing a lousy job of trying to answer it.

Readers are invited to contribute essays on any science-related subject that interests them. Contributions will be selected on the basis of content and will be edited for clarity of expression. You may first want to send a brief outline of your ideas to Point of View, The Sciences, 2 East 63rd Street, New York, New York 10021

general body heating. The present exposure tolerances appear to be more than adequate in safeguarding against known heating effects: heat prostration, testicular damage and the formation of cataracts. However, scientific opinion and government concern, partly engendered by the Radiation Control Act of 1968 and the Occupational Safety and Health Act of 1970, appear to be motivating much more comprehensive studies.

The Navy Investigates

Is there a clear and present microwave danger? If not, what is the precise nature of the phenomena? The Navy, in particular, has embarked on an extensive research program. One of their most ambitious experiments is being conducted by Dr. Dietrich Beischer at the Naval Aerospace Medical Institute, Pensacola, Florida. Beischer has constructed an 8x8x10-foot chamber in which Navy volunteers will live for several months at a time; they will be under uniform exposure to microwaves beamed from a 16-foot antenna outside their quarters. (*Microwaves*, April, 1972) Beischer will be looking for long-term effects of extremely low power microwaves, initially less than 1 mW/cm², on a gamut of physiological and psychological variables: body weight, temperature, EEG and ECG rhythms, decision making, reaction time, anxiety, etc.

Dr. Beischer was reluctant to tell me more; the Navy has become sensitive since the appearance of a Jack Anderson story about the project. The use of human guinea pigs is less shocking than it appears, however; communications technicians and plywood workers, who use microwave ovens to dry their products, are routinely exposed to the low level radiation that will be employed in the experiment. Except for cases of inadvertent overexposure, there have been no reports of microwave injury. The possibility of insidious long term damage exists, of course; high-power-microwave-induced cataracts have gone undetected for years. In any case, Beischer has had difficulty in procuring volunteers because of manpower shortages in the Navy, and it will be some time before any firm conclusions can be drawn from the project.

A microwave transmitter, one of more than 6 million in the U.S. Government agencies are undertaking a new look at the radiation hazards to man

A Different Kind of Heat

Animal experiments have highlighted phenomena which may represent clear hazards to man. Although these studies used not insubstantial amounts of microwave energy, the injuries they produced may not be of thermal origin in the usual sense. In 1961, for example, C.A. Van Ummersen, a Tufts University biologist, exposed chick embryos to microwaves for five hour periods, elevating their temperature only 3.5°C above the normal incubation temperature, but producing many abnormal embryos. Raising embryo temperature by other means had no serious consequences.

Dr. Russell Carpenter of HEW's Northeastern Radiological Health Laboratory and Elliot M. Livstone, Presbyterian University Hospital, Pittsburgh, reproduced Van Ummersen's results with the mealworm beetle. Irradiating 140 pupae in 80 mW or 20 mW waveguides for 20-30 minutes or 120 minutes, respectively, they found that only 36 developed into normal adults. Again, pupae exposed only to the equivalent temperature ambient were mostly normal. Speculating about the mechanisms responsible for microwave-stymied growth, the researchers write, "Successful development and metamorphosis depend upon a system of delicate chemical balances involving so many enzymes and hormones and

their interactions that there must indeed be almost countless targets for microwave radiation to strike." (*IEEE Transactions on Microwave Theory and Techniques*, February, 1971)

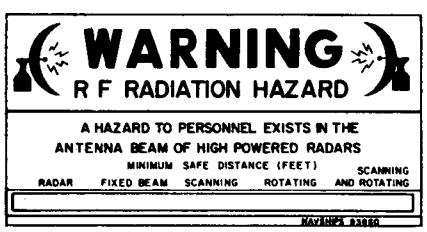
Carpenter has also attempted to understand how microwaves cause cataracts. The lens of the eye is particularly susceptible to microwave damage; Carpenter has shown that microwave injury is cumulative at subthreshold doses, i.e. repeated exposure to small amounts of microwave energy can create the same opacities produced by much larger single doses. Thus, cataract formation cannot be a purely temperature dependent phenomenon. In collaboration with Dr. Jin Kinoshita, Harvard Medical School, Carpenter detected a significant decline in ascorbic acid in rabbit lenses soon after irradiation. Drs. Van Ummersen and Frances Kogan found that DNA-synthesis-and-mitosis inhibition were also characteristic concomitants of microwave exposure.

The combination of microwaves with another stressor, such as physical restraint, can synergize, according to Dr. Justesen. Harnessed rats subjected to 10.5 mW/gm radiation showed rises in body temperature 1°C greater than those of unharnessed rats exposed to the same radiation. Indeed, a few of the restrained rats succumbed to hyperthermia at a deep colonic reading of 43.5°C, while their untrammeled peers sweated it out at a more comfortable 39°C for a full four hours. Justesen told me that the irritation of the restraint, coupled with the novel stress introduced by the microwaves, can lead to a potentially lethal endogenous release of heat. "The heat at the seat is a good reflection of an animal's emotional state," he said. Microwaves can precipitate an emotional upheaval.

Concern about the biological effects of microwave radiation has been slow in coming in the U.S. One reason, ironically, is the thoroughness of the earlier military research on the thermal hazard. For years, the vast Russian documentation on the subject has been relegated to the back rooms of this nation's scientific establishments, the catch basins for persistent irritations which do not conform to prevailing patterns of thought.

The explanation of this benign neglect is complex. Allan Frey has pointed to the generally inadequate quality of available translations from the Russian. But perhaps of greater importance is the great gap between the scientific traditions of the two nations. The Soviets are satisfied with subjective observations of behavioral changes, a practice going back to Pavlov; American scientists are more reductionist. They must have hard objective statistics on behavior and a microscopic understanding of the mechanism involved. Moreover, Russian experiments have frequently been reported without sufficient detail about experimental procedure. When American scientists have learned of these crucial fine points, they have often been able to confirm results which originally appeared to be dubious.

But a research effort of significant proportions is finally getting under way in this country. The Office of Telecommunications Policy, part of the Office of the President, is coordinating the research activities of various government agencies implicated in microwave safety: Defense, HEW, Environmental Protection Agency, FCC, FAA. The Electromagnetic Radiation Management Advisory Council (ERMAC) associated with the OTP has drawn up plans calling for an expansion of microwave study and an increase of funds from the presently allocated $4 million to an impressive $63 million.



In a report issued in December, 1971, ERMAC emphasized the uncertain safety of the 6,000,000 transmitting devices now in use and the 200,000 microwave ovens predicted for the seventies. Using such phrases as "increasing anxiety" and "an era of energy pollution," the report concludes on this note: "Thus, the consequences of undervaluing or misjudging the biological effects of long-term, low-level exposure could become a critical problem for the public health, especially if genetic effects are involved."

The document, which was prepared with the obviously tendentious purpose of obtaining a major increase in funds, may exaggerate the urgency of the situation. Allan Frey, who is a member of the U. S. Standards Institute committee on microwave safety, told me there is insufficient reason to tighten the present 10 mW/cm² limit, at least until more evidence is in. However, the pioneer in low level effects did say that he is still bothered by the sight of a major radio station opposite an elementary school.