UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

APRIL 25, 1984

OFFICE OF
THE ADMINISTRATOR

Mr. William D. Ruckelshaus
Administrator
Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Ruckelshaus:

The Science Advisory Board (SAB) has completed its review of the Office of Research and Development's assessment document entitled Biological Effects of Radiofrequency Radiation and is pleased to transmit its report to you. An SAB Subcommittee, chaired by Dr. Charles Susskind of the University of California at Berkeley, twice reviewed the draft document and unanimously concluded that it represents an adequate statement of the current scientific literature and can serve as a scientifically defensible basis for the Agency's development of radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation.

The enclosed report summarizes the Subcommittee's review process and presents its major findings and recommendations. The SAB Executive Committee, at its recent meeting of April 11-12, fully endorsed the Subcommittee's report and authorized its transmittal to you. Should you wish any further SAB review of the radiofrequency issue, I am sure that the Board would be pleased to address your request.

Sincerely,

Norton Nelson, Chairman
Executive Committee
Science Advisory Board

Enclosure

The following is general background information on radiofrequency (RF) radiation and, with only minor changes, is a re-issue of the material prepared for Mr. Ruckelshaus in advance of his July meeting with Mr. Ancil Payne of King Broadcasting.

Radiofrequency Radiation
Background Information for Mr. Ruckelshaus

Index

Radiofrequency Radiation Background for Mr. Ruckelshaus

I. Why is Guidance being prepared?

a. To respond to needs of Federal agencies and the private sector -- see list in notebook, Section 1
b. To protect public health
c. To allow effective planning/siting by industry and Federal agencies
d. To preempt a variety of conflicting local standards
e. Other
    1. Congressional interest
    2. High degree of public apprehension

II. Why is EPA involved?

a. No Federal exposure guides or standards
    1. OSHA occupational standard is advisory only
b. Voluntary industrial advisory standards only
c. Other agencies and industry have asked EPA to use its Atomic Energy Act/Federal Radiation Guidance authorities
d. Longstanding programs -- OAR and ORD

III. Nature of the environmental problem -- see notebook, Section 4

IV. EPA approach

a. Developed scientific/technical basis
    1. Measured national environmental levels
    2. Developed cost/impact data
    3. Developed credible health assessment document
        a. reviewed by SAB and found to be adequate basis for setting Guidance -- see closure letters in notebook, Section 2

b. Developed draft Guidance in cooperation with
    1. Interagency Work Group -- listed in notebook, Section 2
        a. Other Federal agencies
        b. State representation
        c. NCRP
    2. EPA Work Group
        a. Regional representation - target focal point for public concerns
        b. OPPE, OGC, ORD (OFA kept up-to-date)

V. Impact of Guidance

a. Allows rational planning of new source sites by industry and government
b. Protects property values of local residents/communities
c. Corrective measures relatively inexpensive
d. Impact on EPA budget small
    1. Implementation by other agencies
    2. EPA technical advice/oversight

VI. Status of RF Guidance
a. Steering Committee met, OPPE non-concurrence

REQUESTS FOR EPA ACTION

Department of Commerce, National Telecommunications and Information Administration (NTIA)--(Provides frequency assignments to Government-owned and operated sources.)	
- August 1981. Letter from the Electromagnetic Radiation Management Advisory Council (ERMAC) to Secretary of Commerce.	Encourages development of Federal standard.
- October 1981. Letter from National Assocation of Broadcasters (NAB) to Secretary of Commerce.	Indicates NAB support and encourages DOC support of issuing EPA standard. "... the Executive branch must not lose sight of the potentially crippling costs to industry of not regulating exposure standards at the Federal level."
- March 1982. Letter from Assistant Secretary of Commerce to Administrator, EPA.	EPA should promulgate guidelines as soon as possible.
- November 1982. Meeting among Deputy Secretary of Commerce, Assistant Secretary of Commerce, and Administrator, EPA.	Commerce urges EPA to rapidly issue guidelines.
- March 1984. Letter from Assistant Secretary of Commerce to Administrator, EPA.	"I want to underscore my support of EPA's efforts in this regard (proposed guidance) ..."

Federal Communications Commission (FCC)--(Issues licenses to to privately-owned sources.)	
- February 1982. Notice of Proposed Rulemaking, Responsibility of the FCC to Consider Biological Effects of Radiofrequency Radiation When Authorizing the Use of Radiofrequency Devites.	"... until EPA, the responsible Federal agency, establishes a standard for general population exposure, ... (FCC will use) ... the radiation level established by OSHA for workers as the trigger for reviewing the environmental impact of general public exposure levels under our NEPA procedures. When EPA ... establishes a general public exposure standard, that will become the trigger.
- June 1982. Letter from Director, EPA's Office of Federal Activities to Secretary, FCC.	"EPA recognizes its broad authority to issue Federal Radiation Guidance for limiting exposures of the general public to nonionizing radiation. Until such time (as EPA guidance is issued) FCC should consider using a more conservative approach to evaluating public exposure than that provided in the OSHA standard."
- February 1983. Letter from Chairman Fowler, FCC, to Administrator, EPA.	"... we believe that a definitive Federal standard is imperative. Therefore, we would like to make clear our support for your guidance development. We encourage the EPA to complete this process as expeditiously as possible so that a uniform Federal standard will be available for use by the FCC and other affected agencies."

Industry.	
- 1982. Response to FCC Notice of Proposed Rulemaking (see above).	Companies and Trade Associations asked FCC to adopt interim guidelines for assessing radiation hazards while work on a Federal standard continues at other agencies. FCC has made a policy decision to leave standard setting to other Government agencies such as EPA.
- 1983. American Satellite Co., AT&T, GTE, NAB, TV Broadcasters All Industry Committee, Ford, Motor Vehicle Manufacturers Association, Motorola.	All support issuance of Federal Guidance in response to EPA's Advance Notice of Proposed Recommendations for Controlling Radiofrequency Exposure of the Public, December 1982
- February 1984. Electromagnetic Energy Policy Alliance established.	Purpose is to push for Federal safety standards for nonionizing radiation because of concern over State and local standards and costly siting disputes. Founded by 3 trade associations and 7 industrial companies with initial budget of $100K.
Other.	
1983. States (Massachusetts, New Jersey, and New York).	Support national environmental exposure exposure standard in response to RF ANPR.
March 1984. American Radio Relay League, the National Association of Amateur Radio Operators.	Petitions FCC to issue a status report on preparations for the eventual adoption of RF protection guidelines by EPA.

A 81-43
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FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D. C. 20554

February 22, 1983

OFFICE OF
THE CHAIRMAN

Anne M. Burford
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

In re: Docket A-81-43

Dear Mrs. Burford:

This letter is in response to the Environmental Protection Agency's Advance Notice of Proposed Recommendations in Docket A-81-43, Federal Radiation Protection Guidance for Public Exposure to Radiofrequency Radiation (47 Fed. Reg. 57338, December 23, 1982).

The Federal Communications Commission (FCC) is responsible for licensing facilities and authorizing equipment, not operated by the federal government, that utilize radiofrequency (RF) energy. In carrying out these responsibilities the FCC must comply with the requirements of the National Environmental Policy Act of 1969 (NEPA) to consider the environmental impact of its "major actions...significantly affecting the quality of the human environment"[42 U.S.C. §4332(2)(c), 1976].

In 1979, the Commission issued a <u>Notice of Inquiry</u> (44 Fed. Reg. 37008, 1979) to gather information to help us determine the extent to which RF radiation hazards should be considered by us in our licensing and authorization procedures. As a result of that inquiry and an assessment of our statutory obligations under NEPA, the Commission issued a <u>Notice of Proposed Rule Making</u> (<u>NPRM</u>) (47 Fed. Reg. 8214, 1982) in February of last year. A copy is enclosed.

The FCC's <u>NPRM</u> proposes to amend Section 1.1305 of the Commission's Rules, 47 C.F.R. §1.1305, for assessing the environmental consequences of FCC actions by adding a new subsection to address the matter of potential hazards of RF and microwave radiation. Pursuant to this proposal, the Commission would treat grants of construction permits or licenses to transmit as "major actions" subject to its NEPA processing requirements (47 C.F.R. §1.1301-1.1319) if the proposed operations would result in exposure of workers or the general public to levels of RF radiation in excess of those established by federal agencies having jurisdiction thereover.

To determine whether an action should be treated as a "major action" the Commission plans to rely on standards for exposure to RF radiation established by federal agencies such as EPA. The FCC lacks the necessary expertise and statutory authority to promulgate its own health and safety standards and, therefore, must look to EPA and other responsible agencies for guidance in this area.

There is presently no standard set by the federal government for exposure of the general public to RF radiation. However, several state and local governments are establishing their own standards in this area. We cannot judge whether an applicant's failure to comply with one of these non-federal standards constitutes an environmental impact issue. In addition, the Commission and its regulatees are concerned about safe exposure levels and the possibility of a confusing and costly proliferation of inconsistent state and local standards. For these reasons, we believe that a definitive federal standard is imperative.

Therefore, we would like to make clear our support for your guidance development. We encourage the EPA to complete this process as expeditiously as possible so that a uniform federal standard will be available for use by the FCC and other affected agencies.

We will be happy to cooperate in any way possible in this effort. Our Office of Science and Technology will be responsible for coordinating further activities with EPA's Office of Radiation Programs.

Sincerely,

Mark S. Fowler
Chairman

Enclosure

cc: Ms. Kathleen M. Bennett,
Assistant Administrator for
Air, Noise, and Radiation, EPA

Norbert N. Hankin,
Office of Radiation Programs, EPA

Central Docket Section, EPA

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Communications and Information
Washington, D.C. 20230

March 23, 1984

Honorable William D. Ruckelshaus
Administrator
Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Ruckelshaus:

I am writing with regard to the Environmental Protection Agency's (EPA) development of proposed Federal Radiation Protection Guidance for Public Exposure to Radiofrequency Radiation.

The National Telecommunications and Information Administration's (NTIA) interest stems from its responsibilities for authorizing and managing Federal Government use of the radio frequency spectrum and our role as the principal Executive branch adviser on telecommunications matters. As part of these responsibilities, I am concerned that the spectrum is used safely and also that essential and beneficial services in both the Government and private sector are not unnecessarily curtailed.

This agency and its predecessors have long encouraged Federal efforts to develop a sound scientific basis for national policy that would afford necessary protection and permit continued development and innovation in the telecommunications industry.

I want to underscore my support for EPA's efforts in this regard and also to express my concern that the functional and economic impact of such guidance on telecommunications and related services, including but not limited to mobile platforms and certain low frequency systems, be carefully identified and evaluated prior to promulgation in order to avoid or minimize any unnecessary dislocation or disruption. I am particularly interested in seeing EPA's Background Information and Cost Estimate documents in this regard. I am also concerned that any criteria be operationally practical in terms of methods for determining compliance and that institutional roles in implementation, compliance, and enforcement be clearly delineated, including Federal-State relationships insofar as possible.

We have just received EPA's March 8 revised draft guidance and Notice of Proposed Recommendation (NPR). We plan to bring this to the attention of the Interdepartment Radio Advisory Committee (IRAC), which advises on spectrum use and management matters, for their review and comments. My staff will continue to work with EPA and, in addition to views and comments provided previously, we will provide further comments on this and other matters as appropriate.

Please be assured of our continuing cooperation in your efforts to develop sound national guidelines in this area of mutual interest.

Sincerely,

David J. Markey

Received in Radiation Office
Environmental Protection Agency
Date MAR 30 1984

Background Notes on the EPA Radiofrequency Radiation Guidance Program

In April 1979, the Agency initiated a program to develop Federal Radiation Protection Guides to protect the public from excessive exposure to radiofrequency radiation (Start Action Notice 1525). The Development Plan was approved in September 1982, and an Advance Notice of Proposed Recommendations (ANPR) was published in the Federal Register in December 1982. The ANPR states, "We intend to develop guidance for Federal agencies to limit exposure of the public to radiofrequency (RF) radiation" and to publish a Notice of Proposed Recommendations (NPR) "in late 1983." The current schedule for publication of the NPR is listed as June 1984 in the Regulatory Agenda published in the April 19, 1984 Federal Register.

The Agency has been asked to develop this Guidance by private citizens, State and local Governments, industry, trade associations, and Federal agencies. Federal Communications Commission (FCC) Chairman Fowler in a February 1983 letter to the Administrator, states, "... we believe that a definitive Federal standard is imperative. Therefore, we would like to make clear our support for your guidance development. We encourage the EPA to complete this process as expeditiously as possible so that a uniform Federal standard will be available for use by the FCC and other affected agencies." The FCC licenses privately-owned and not for profit owned radiofrequency sources. The National Telecommunications and Information Administration (NTIA) within the Department of Commerce assigns frequencies to Federally-owned and operated sources. In November 1982, the Deputy Secretary for Commerce met with former Administrator Gorsuch to encourage EPA to promulgate guidance as soon as possible. More recently, March 1984, the Assistant Secretary of Commerce wrote the Administrator to "underscore my support of EPA's efforts in this regard (proposed guidance.)"

In developing the Guidance, the Agency (1) established an Interagency Work Group consisting of representatives from 16 Federal agencies to review the proposed guidance and how it is to be implemented, (2) established an Interagency Agreement with the Lawrence Livermore National Laboratory (LLNL) to develop and apply a methodology to determine economic impact of the proposed Guidance, (3) conducted an indepth review of the biological effects, and (4) conducted a national measurements program to define exposure.

The final draft of the economic impact report by LLNL is now completed. The 500 plus page comprehensive review of the biological effects was transmitted to the Administrator April 25, 1984, with a letter from Dr. Norton Nelson, Chairman of EPA's Science Advisory Board (SAB) stating that the review, Biological Effects of Radiofrequency Radiation is "an adequate statement of the current scientific literature and can serve as a scientifically defensible basis for the Agency's development of radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation." The studies of radiofrequency environmental exposures have been published in the open literature and have been summarized in a Background Information Document (BID) that is complete except for revising the economic impact section to conform to the final version of the LLNL economic analysis report.

On March 15, 1984, the Draft Notice of Proposed Recommendations for Controlling Public Exposure to Radiofrequency Radiation was entered into the Steering Committee review process. The Steering Committee met on April 6, 1984 and the only objections to the proposal were raised by the Office of Policy, Planning, and Evaluation (OPPE). Though there are a number of points detailed in the May 9, 1984 memo from the Chairman of the Steering Committee on closure of this issue, the two principal objections are: (1) Should EPA propose guidance? and (2) If guidance is to be proposed, what specific rate of absorption (SAR) value is appropriate? (Note: SAR is the rate at which energy is absorbed per unit body mass). These two points are also contained in an OPPE options paper transmitted to Assistant Administrators Cannon and Goldstein by Deputy Assistant Administrator Campbell on May 11, 1984. This options paper is being reviewed in the Office of Air and Radiation (OAR).

The issue of whether guidance should be proposed will need to be resolved in the context of whether the Administrator decides to respond to the requests of FCC and NTIA to exercise his Atomic Energy Act Guidance Authority. The levels proposed by the Office of Radiation Programs are within a factor of two of those enacted by the State of Massachusetts and proposed by the National Council of Radiation Protection and Measurements and the International Radiation Protection Association. The proposed levels are a factor of ten less than the present American National Standards Institute's voluntary standard, which is principally a standard for occupational exposure and at best is only an upper limit for public exposure.

As a related issue, FCC Chairman Fowler in a February 14, 1984 letter wrote to the Administrator and requested EPA assistance in measuring radiofrequency radiation levels in Honolulu, Hawaii. The Administrator agreed to help in his March 12, 1984 letter and a field study was conducted in Honolulu from May 15-24. The EPA News Release announcing the study states "When the measurements in Honolulu and their analysis are complete, the results will be provided to the FCC for action. The results will be made public at that time." We can anticipate that FCC will ask for an interpretation of the health significance of the fields measured in Honolulu. Since the NPR has not yet completed the Steering Committee process, the Agency has not yet reached conclusions on the health significance of various exposure levels.

There has been a continuing media interest in radiofrequency radiation problems in general and in the Agency's program. Of recent note, Spectrum, the journal of the Institute of Electrical and Electronics Engineers, featured articles on "The Drive to Regulate Electromagnetic Fields" and "Biological Effects of Electromagnetic Fields," in its March and May 1984 issues, respectively. The Honolulu study generated mostly local coverage and West Coast coverage. The most recent coverage is an article that appeared in the June 7, 1984 New York Times. As a spinoff, many articles appeared nationally after June 7. Electromagnetic radiation exposure was also the subject of a Times article by Philip Boffey, August 2, 1983. An article by Marjorie Sun also appeared in the July 6, 1984, issue of Science Magazine on the Honolulu study and the development of guidance.

Significant Events, EPA Radiofrequency Radiation Guidance Program

- 1979, April 30 — Start Action Notice 1525, "Federal Radiation Protection Guides will be developed to protect the public from excessive exposure to radiofrequency radiation through specification of maximum allowable environmental radiofrequency intensities as a function of radiation frequency at locations accessible to the public. Instrumentation and measurement techniques appropriate to guidance compliance activities will be recommended."

- 1981, July 23 — Interagency Agreement negotiated with Lawrence Livermore National Laboratories to "develop and apply a methodology to determine the economic impact of Federal Radiofrequency Radiation Guidance" (IAG-AD-89-F-1-803-0).

- 1982, March 11 — Assistant Secretary of Communications, U.S. Department of Commerce (B.J. Wunder, Jr.) writes Administrator Gorsuch: "...I understand that EPA has prepared a work plan and is carrying out studies to support the development and issuance of guidelines for public exposure to nonionizing electromagnetic radiation. NTIA (National Telecommunications and Information Administration, DOC) thoroughly supports EPA's initiative in this area and believes EPA should devote all resources necessary to promulgate these guidelienes (sic) as soon as possible.

- 1982, September 13 — Development Plan for Federal Radiation Protection Guidance for Controlling Public Exposure to Radiofrequency Radiation completed Steering Committee Consent Calendar review.

- 1982, November 5 — Department of Commerce Deputy Secretary Fiske and Assistant Secretary for Communications Wunder met with Administrator Gorsuch to reemphasize DOC interest in the Guidance and request that the scheduled date for the availability of Guidance, September 1984, be greatly advanced so the guidance would be available to meet NTIA needs as early as September 1983. (January 10, 1983 letter from EPA Assistant Administrator Bennett to Deputy Secretary Fiske.)

- 1982, December 23 — Advance Notice of Proposed Recommendations, "We intend to develop radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation.... The Agency plans to publish a Notice of Proposed Recommendations in late 1983..." Federal Register 47 (247): 57338.

- 1982, December 29 — Assistant Administrator Bennett signs letters to 15 Federal agencies reactivating Interagency Work Group and asking that each Agency designate an individual to work with EPA in the Guidance development process.

- 1983, March 28 — Questions from Senate Appropriations Subcommittee on 1984 Budget.

Question: Your budget request indicates that the nonionizing health effects program has been eliminated in FY 84 due to the completion of health research needed for publication of a guidance document. When will the guidance material be available?

Answer: The Agency published a notice in the Federal Register on December 23, 1982, which stated our intention to develop guidance for Federal agencies to limit exposure of the public to radiofrequency radiation (nonionizing). The Agency plans to publish a Notice of Proposed Recommendations in late 1983 and will announce a schedule of public of public hearings. Coincident with the Notice of Proposed Recommendations, the Agency will publish a Background Information Document that summarizes the health effects and environmental levels of radiofrequency radiation. The Background Information Document will also examine the economic impact of guidance and methods of implementation.

The Agency is preparing a critical and comprehensive review of the literature on the biological effects of radiofrequency radiation. This literature review will be submitted to an ad hoc panel of the Agency's Science Advisory Board. The Science Advisory Board panel will critique the literature review in an open meeting in late spring or early summer 1983; the date and place of the meeting will be announced in the Federal Register.

The final guidance should be issued within one year of the proposed guidance, i.e., in Fiscal Year 1984.

- 1983, April 14 — First Interagency Work Group meeting.

- 1983, June 21 — Department of Commerce established Ad Hoc 189 Committee to "...accurately assess the potential impact of the (EPA) proposed guideline for exposure of the general public to electromagnetic radiation from telecommunication transmitters..."

- 1983, July 21 — Request for public comment on Biological Effects of Radiofrequency Radiation, a health effects assessment document prepared by ORD staff in the Experimental Biology Division, Health Effects Research Laboratory, Research Triangle Park, NC. Federal Register 48 (141): 33345.

- 1983, August 25 — Office of Management and Budget Approved Information Collection Request, Survey of Economic Costs of Guidance for Nonionizing Radiation, OMB No. 2060-0045.

- 1983, September 21 — EPA offers assistance to other agencies in analyzing impact of Guidance on specific sources.

- 1983, September 22-23 — First meeting of the Science Advisory Board (SAB) Subcommittee to review the Biological Effects of Radiofrequency Radiation, Washington, D.C. Federal Register 48 (171): 39688.

- 1983, October 18 — Nonionizing radiation briefing for Assistant Administrator Cannon.

- 1984, January 10 — EPA Radiofrequency Work Group meeting.

- 1984, January 24-25 — Second meeting of the SAB Subcommittee on the Biological Effects of Radiofrequency Radiation, Research Triangle Park, North Carolina.

- 1984, January 31 — SAB Subcommittee on the Biological Effects of Radiofrequency Radiation concludes that the health effects assessment document..." is an adequate review of the scientific literature and can serve as the basis for the development of radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation" (letter from Professor Charles Susskind, Subcommittee Chairman to Dr. Norton, Chairman, SAB).

- 1984, April 25 — SAB closure on health assessment document, Biological Effects of Radiofrequency Radiation, transmitted by letter from SAB Chairman Dr. Norton to Administrator Ruckelshaus.

FEDERAL RADIATION PROTECTION GUIDANCE FOR CONTROLLING PUBLIC EXPOSURE TO RADIOFREQUENCY RADIATION

PURPOSE: TO LIMIT EXPOSURE OF THE PUBLIC TO RADIOFREQUENCY RADIATION

COMPLIANCE BY SOURCES INCLUDING:

- AM AND FM RADIO
- VHF AND UHF TELEVISION
- COMMUNICATIONS
- RADAR

<u>NOT</u> APPLICABLE TO:

- OCCUPATIONAL EXPOSURE
- CONSUMER PRODUCTS CONTROLLED MORE EASILY BY PRODUCT PERFORMANCE STANDARDS

IMPLEMENTATION BY: ALL FEDERAL AGENCIES, INCLUDING

- FCC AND NTIA
- DOD
- DOT
- DOE
- NASA

RF GUIDANCE INTERAGENCY WORK GROUP

FEDERAL COMMUNICATIONS COMMISSION

DEPARTMENT OF COMMERCE

- NATIONAL TELECOMMUNICATIONS & INFORMATION ADMINISTRATION
- NATIONAL BUREAU OF STANDARDS

DEPARTMENT OF HEALTH AND HUMAN SERVICES

- NATIONAL CENTER FOR DEVICES AND RADIOLOGICAL HEALTH, FDA

DEPARTMENT OF LABOR

- OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

DEPARTMENT OF DEFENSE

DEPARTMENT OF TRANSPORTATION

- FEDERAL AVIATION ADMINISTRATION
- U.S. COAST GUARD

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DEPARTMENT OF ENERGY

DEPARTMENT OF STATE

DEPARTMENT OF AGRICULTURE

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VETERANS ADMINISTRATION

NATIONAL SCIENCE FOUNDATION

CENTRAL INTELLIGENCE AGENCY

NATIONAL ACADEMY OF SCIENCES

NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

CONFERENCE OF RADIATION CONTROL PROGRAM DIRECTORS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460
APRIL 23, 1984

OFFICE OF
THE ADMINISTRATOR

Mr. William D. Ruckelshaus
Administrator
Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Ruckelshaus:

The Science Advisory Board (SAB) has completed its review of the Office of Research and Development's assessment document entitled _Biological Effects of Radiofrequency Radiation_ and is pleased to transmit its report to you. An SAB Subcommittee, chaired by Dr. Charles Susskind of the University of California at Berkeley, twice reviewed the draft document and unanimously concluded that it represents an adequate statement of the current scientific literature and can serve as a scientifically defensible basis for the Agency's development of radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation.

The enclosed report summarizes the Subcommittee's review process and presents its major findings and recommendations. The SAB Executive Committee, at its recent meeting of April 11-12, fully endorsed the Subcommittee's report and authorized its transmittal to you. Should you wish any further SAB review of the radiofrequency issue, I am sure that the Board would be pleased to address your request.

Sincerely,

Norton Nelson, Chairman
Executive Committee
Science Advisory Board

Enclosure

UNIVERSITY OF CALIFORNIA, BERKELEY

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PROF. CHARLES SÜSSKIND
U.C. COLLEGE OF ENGINEERING
BERKELEY, CA 94720

31 January 1984

Dr. Norton Nelson, Chairman, SAB
Environmental Protection Agency
WASHINGTON DC 20460

Dear Dr. Nelson:

The SAB Subcommittee on the Biological Effects of Radiofrequency Radiation met on 22-23 September 1983 and on 24-25 January 1984 to review the report on Biological Effects of Radiofrequency Radiation produced by a team led by J. A. Elder and D. F. Cahill at EPA's Health Effects Research Laboratory in Research Triangle Park, N.C. The Subcommittee asked for changes in the organization and wording of the report, virtually all of which have been accommodated in the final version. Accordingly, the Subcommittee concludes that the report is an adequate review of the scientific literature and can serve as the basis for the development of radiation protection guidance for use by Federal agencies to limit exposure of the general public to radiofrequency radiation. The Subcommittee also concludes that the EPA team has done a splendid job in producing the report and in responding to the Subcommittee's requests for amendments; its members, and especially team leader Joe A. Elder, are to be commended.

The Subcommittee has asked me to make clear that its conclusion is limited to the review of the scientific literature; it does not extend to prior approval of any standards EPA may base on this material. In addition, the Subcommittee wishes to make the following recommendations.

1. The process of reviewing the scientific literature should go on within EPA, so that there is at least one government agency that uses its own professional staff to keep abreast of developments in this field. That is not to say that the agency should not avail itself of outside advice from time to time, for instance by periodically constituting a review committee to monitor its own efforts.

2. If significant new results appear between such periodic reviews (which could be scheduled, say, every two years), they should be evaluated for pertinence and used for revision of exposure standards as appropriate. It is most unlikely that any standard based on the present effort will remain appropriate for all time; a standard is inherently dynamic, since it reflects knowledge at the time of promulgation.

3. EPA should continue and strengthen its program of extramural research, and also its in-house research on the health effects of radiofrequency radiation, not only to keep abreast of the field (Item 1 above) but also because the research itself is invaluable to the nation, as attested by the fact that a considerable part of the scientific results reported in the present review derives from work done at EPA's own laboratories.

4. The agency should provide technical support to other government agencies to help them in assuring compliance with EPA standards.

5. The agency should continue its unique and valuable service in monitoring ambient levels (and studying population exposures) throughout the USA, and in characterizing the environment, including such problems as may arise from modes of modulation imposed on radiofrequency sources; the rapidly changing picture in telecommunications and data transmission alone would warrant continuation of this service.

6. The Subcommittee draws special attention to certain research topics that may not have progressed far enough to be of use in rule making at present but may become significant in the near future. Among them are the following:

a. Effects of modulation imposed on radiofrequency carriers, particularly modulation at very low frequencies, on biological specimens exposed to very low power densities.

b. Effects of chronic vs acute exposures, and of partial-body vs whole-body exposures.

c. Effects of exposure to pulsed sources of very high peak power vs sources that are adequately characterized by average power.

d. Synergistic effects of radiofrequency energy with other physical and chemical agents.

e. Validation of recent results with regard to mutagenic and similar effects observed at low power densities.

f. Evaluation of the thermoregulatory capability and concomitant physiological processes of various populations exposed under extreme environmental conditions.

Sincerely,

C. Susskind

Charles Susskind, Chairman
SAE Subcommittee on the
Biological Effects of RF Radiation

cc: Subcommittee members
Drs. Elder, Sahm, Toste
Mr. James

CS:c

INDUSTRY COST - TOTAL BROADCAST AM, FM, & TV (Millions of Dollars)

	Total Net Present Value (Constant Dollars)			Average Annual Cash Flow (Current Year Dollars)		
	Low	Med.	High	Low	Med.	High
100 uW/cm^2 (Opt.5)	23.5	41.5	55.3	2.6	4.7	6.3
200 uW/cm^2 (Opt.4)	17.4	29.9	40.0	1.9	3.4	4.5
1,000 uW/cm^2 (Opt.3)	10.1	15.1	19.6	1.0	1.6	2.1

The three columns represent the low, medium, and high cost scenarios evaluated in the Study. Subtract approximately $12.5 M from all TNPV dollars above since many stations will not have to conduct a survey. In addition costs can be reduced by approximately 10-20 percent by permitting posting which was not allowed in study numbers

AVERAGE STATION COSTS (Medium Costs) (Thousands of Dollars)

		Annual Net Cash Flow (5 yrs.)	Total Net Present Value	Average Profit Drop (percent)
100 uW/cm^2	AM	0.4	2.1	0.5
(Opt.5)	FM	4.0	20.4	4.2
	TV	16.3	81.9	1.2
200 uW/cm^2	AM	0.4	2.1	0.5
(Opt.4)	FM	4.0	20.1	4.2
	TV	11.7	59.0	0.9
1,000 uW/cm^2	AM	0.4	2.0	0.5
(Opt.3)	FM	3.4	17.4	3.6
	TV	7.8	39.5	0.6

Compliance costs are reduced by approximately 20 percent for FM and 8 percent for entire industry if posting is allowed.

NUMBER OF STATIONS AFFECTED

	AM (4622)	FM (4374)	TV (1080)
100 uW/cm^2 (Opt.5)	2,253	1400 (32%)	60 (6%)
200 uW/cm^2 (Opt.4)	1,031	962 (22%)	30 (3%)
1,000 uW/cm^2 (Opt.3)	946	262 (6%)	2 (0.2%)

A COMPARISON OF STANDARDS

LEVEL $\mu W/cm^2$ (W/kg)	ORGANIZATION	REMARKS	REFERENCE
1000 (0.4)	American National Standards Institute (ANSI)	"Because of the limitations of the biological effects data base, these guides are offered as upper limits of exposure, particularly for the population at large."	1
less than 100 to 1000	World Health Organization (WHO) and International Radiation Protection Association (IRPA)	Occupational Exposure Limit. "Exposure of the general population should be kept as low as reasonably achieveable and exposure limits should generally be lower than those for occupational exposure."	2
200 (0.08)	Massachusetts	Divided ANSI recommendations by 5 for application to general population.	3
200 (0.08)	National Council on Radiation Protection and Measurements (NCRP)	"... it is recommended that there be an exposure criterion for the general public that is set at a level equal to one-fifth of that of occupationally exposed individuals."	4
100 (0.04)	Environmental Protection Agency (EPA) Recommendation	Based on eliminating temperature-dependent effects and on protecting against other effects.	5

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A COMPARISON OF STANDARDS

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2. World Health Organization/International Radiation Protection Association Task Group on Environmental Health Criteria for Radiofrequency and Microwaves (1981). Environmental Health Criteria 16, Radiofrequency and Microwaves, World Health Organization, Geneva, Switzerland.

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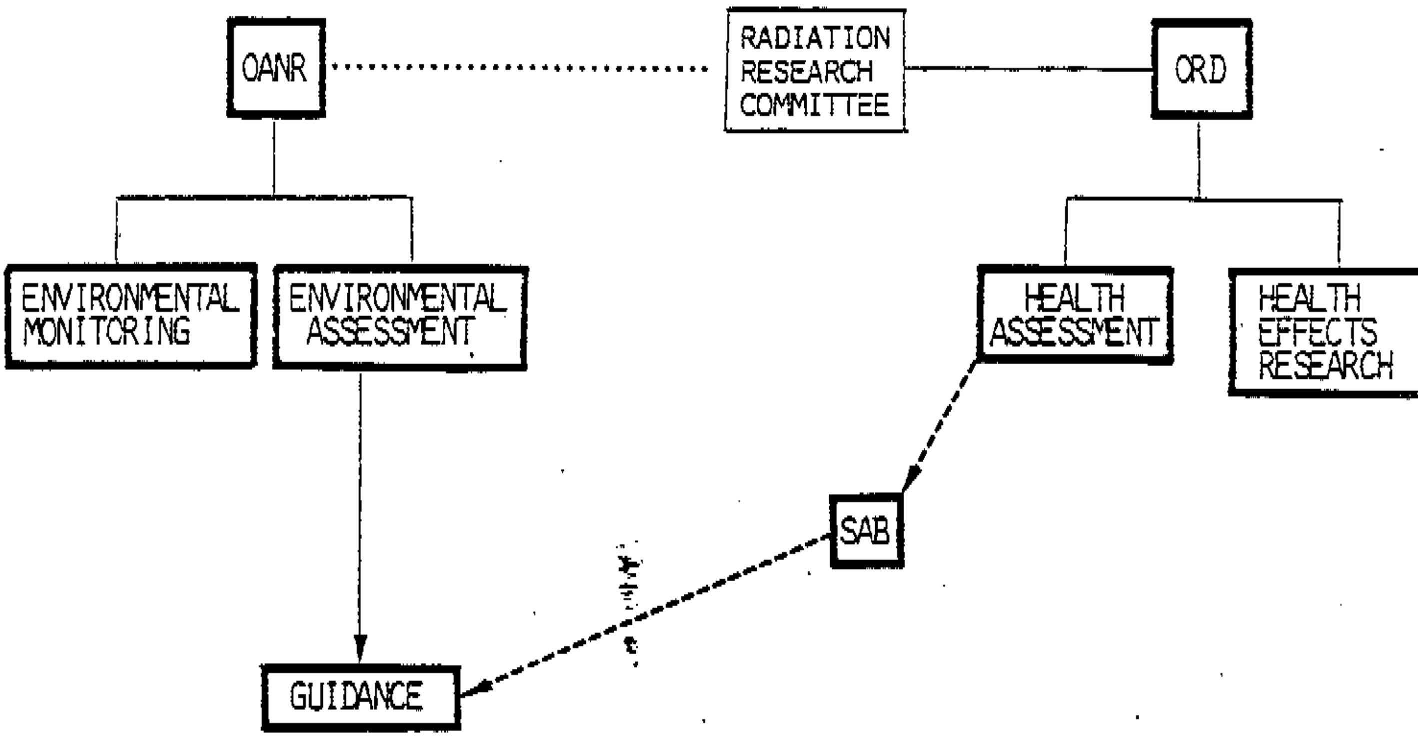
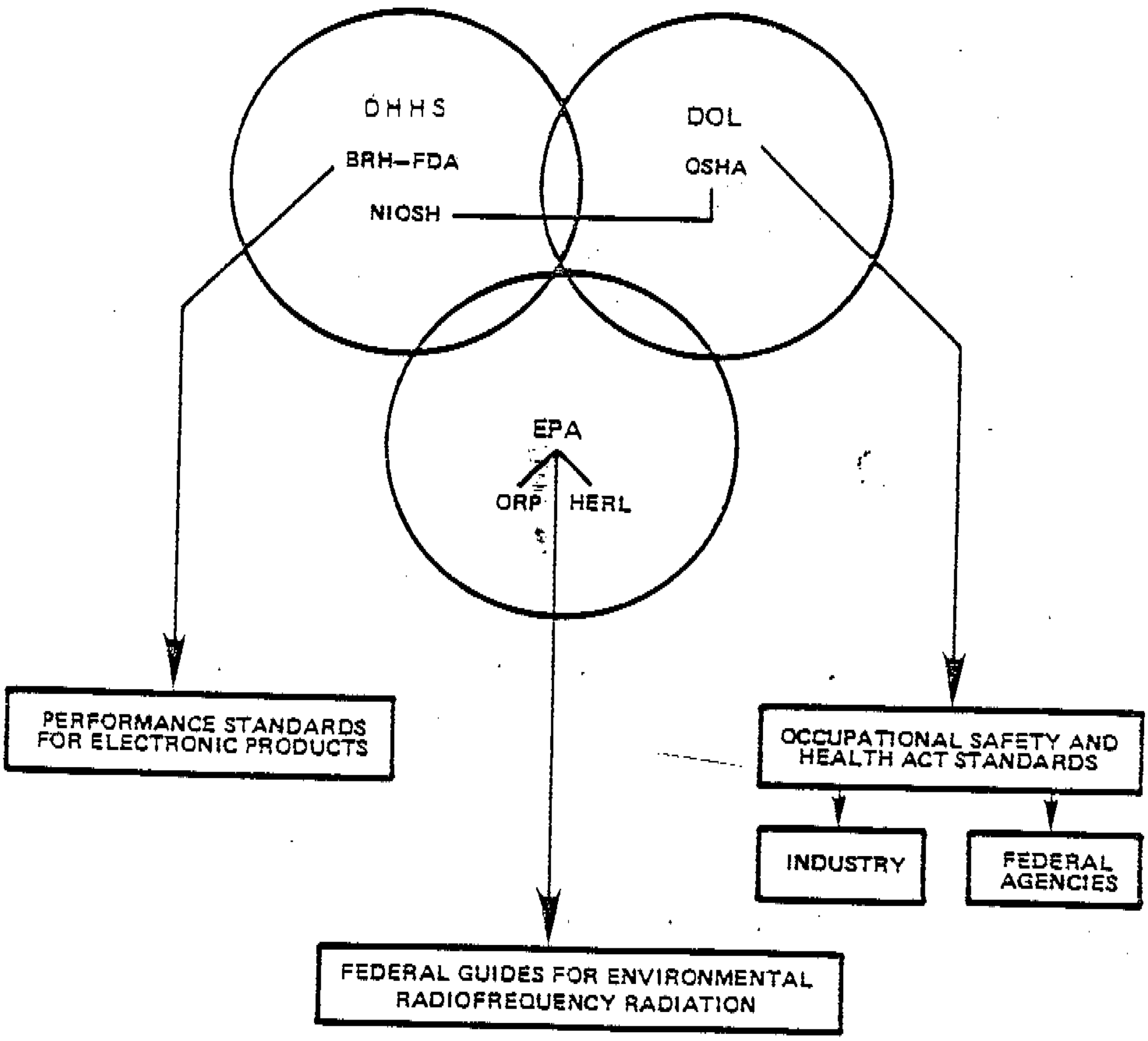
5. Environmental Protection Agency, March 9, 1984, Federal Radiation Protection Guidance for Public Exposure to Radiofrequency Radiation, Draft Notice of Proposed Recommendations.

NON-IONIZING RADIATION

EPA PROGRAM STRUCTURE




DHHS
BRH—FDA
NIOSH
DOL
OSHA
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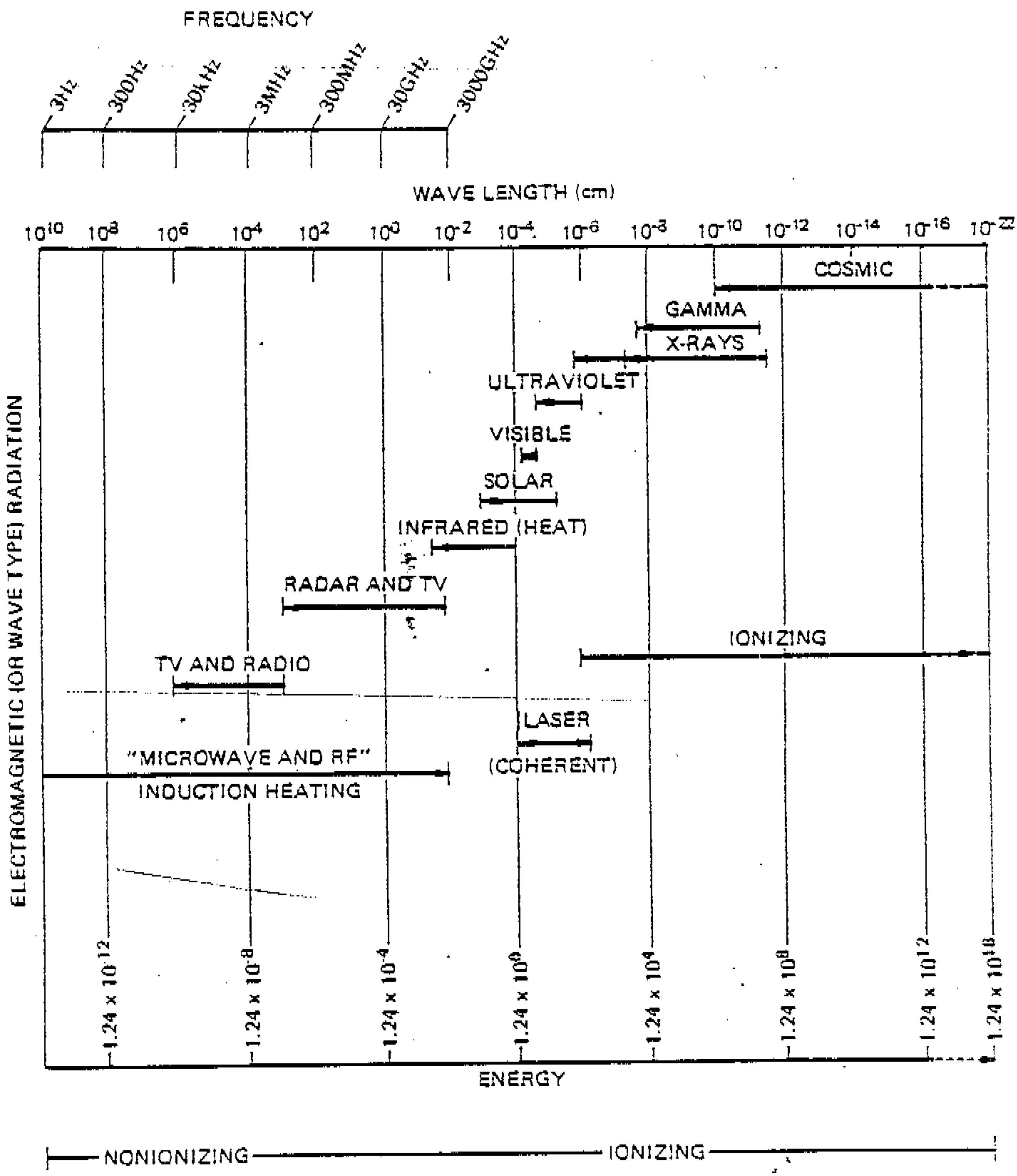
HERL
PERFORMANCE STANDARDS FOR ELECTRONIC PRODUCTS
OCCUPATIONAL SAFETY AND HEALTH ACT STANDARDS
INDUSTRY
FEDERAL AGENCIES
FEDERAL GUIDES FOR ENVIRONMENTAL RADIOFREQUENCY RADIATION

SIMPLIFIED ELECTROMAGNETIC ENERGY SPECTRUM



SOURCE: EPA

RADIOFREQUENCY RADIATION IN THE ENVIRONMENT

SOURCES

AM & FM RADIO

VHF & UHF TELEVISION

RADAR

SATELLITE COMMUNICATIONS

MICROWAVE RADIO

LAND-MOBILE RADIO

AMATEUR RADIO

APPLICATIONS

BROADCAST

COMMUNICATIONS

MILITARY

TRANSPORTATION

MEDICINE

SCIENCE

CRIME PREVENTION

CONSUMER PRODUCTS

BIOLOGICAL EFFECTS OF RADIOFREQUENCY (RF) RADIATION*

Dose Rate - Specific Rate of Energy Absorption (SAR) (W/kg)	Effect/Activity	Relevant Benchmark/Standard
25	• Heat exhaustion - death (humans)	
10	• Maximum sustained exercise (humans)	
8	• Teratologic effects (animals)	
7	• Increase core temperature to 40°C; e.g., about 3°C above normal (humans) (433 MHz) - increases of 2°C or more believed to be associated with fetal loss)	
4-8	• Lethality (animals including dogs) • Severe heat stress, +3°C increase in core temperature (animals including dogs) • Fetotoxicity - low birth weight (animals); 6+: acute exposure, <u>4.8: chronic exposure</u>	
5.6	• Temporary infertility in rats	
4	• Behavioral effects (work stoppage) - animals refuse food	• Old OSHA standard • <u>"Adverse Effects Level"</u> - EPA, Draft NPR (OAR) - ANSI - NCRP - ACGIH- - IRPA/WHO
3	• Changes in heart rate (animals)	
2.3	• Tumor promotion (mice)(1 study) • Severe heat stress in monkeys (predicted to be fatal with continued exposure)	
2	• Decrease in number of Purkinje cells in brain (rat)	• <u>"Adverse Effects Level"</u> - NIOSH proposed
1-4	• Increase in core temperature (0.5-1°C), human models • Various changes in clinical chemistry, hormone levels, and metabolism (animals)	
1	• Resting metabolic rate (humans) • Behavioral effects (work stoppage) with high temperature and humidity (animals)	• <u>"Adverse Effects Level"</u> under conditions of environmental stress - EPA health document (ORD) - SAB
.7 est.	• Heart disease in men (exploratory data - rough SAR estimate). Birth defects aspect of study in review at FDA.	
.5	• Various hematologic and immunologic changes	
.4 - 1	• Onset of thermoregulatory processes (humans)	
.4	• Increase in primary malignant neoplasms and enlarged adrenal-glands in rats exposed throughout their lifetime (one study).	• ANSI voluntary standard • FDA - probable heat sealer performance standard
.29	• Calcium ion efflux from cat brain <u>in vivo</u>	
.2 est.	• Poor pregnancy outcome (women) (one study - rough SAR estimate)	• NIOSH - probable recommended occupational level
.1	• Alterations in brain energy metabolism (rats)	
.08		• Massachusetts population standard • NCRP population standard • IRPA population standard
.05	• Calcium ion efflux from human cells <u>in vitro</u> • Chromosomal translocations (mice) (from FDA-submitted for publication)	
.04		• EPA proposed Guidance
.001 est.	• Calcium ion efflux from chick brain <u>in vitro</u>	
.0001 est.	• RF hearing • Defects in developing chick embryos with pulse modulated, low-intensity magnetic fields (EPA is replicating)	

*Based on ORD health assessment document, NIOSH, ANSI, IEEE Spectrum, etc.

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VOLUME 21 NUMBER 5 MAY 1984

Biological effects of electromagnetic fields

New findings linking changes in organisms to irradiation by weak fields encourage researchers to posit theories, although research is incomplete

SPECIAL REPORT
HEALTH EFFECTS

In the past three years, the study of the biological effects of radio-frequency electromagnetic (EM) fields has taken a new turn. At the beginning of the 1980s, researchers still argued about whether all effects of fields on organisms were caused simply by the heating induced by intense radiation or if some effects also occurred at field strengths too low to produce even localized heating. Although laboratory results had by that time convinced some researchers that athermal effects—those that could not be explained by heating—did in fact occur, a vocal group of scientists still doubted that these laboratory results were valid and repeatable.

Now, a growing mass of evidence has virtually ended that debate. Few now question that some such weak-field effects exist. In fact, one such effect—the influence of weak, pulsed EM fields on bone growth—has now found widespread use as a treatment of bone fractures, with thousands of individuals treated successfully since the method won approval from the U.S. Food and Drug Administration in 1979.

But the study of the interaction of EM fields and organisms remains intensely controversial, with many questions not yet answered fully. For example, under what conditions and at what frequencies and field strengths do interactions with organisms occur? What are the mechanisms by which weak fields can influence organisms? Which biological effects are just harmless changes, which are beneficial, and which are harmful? How might weak-field effects be taken into account in setting safety standards for exposure to EM fields?

The outcome of these controversies has bearing as well on potential therapeutic uses of electromagnetic fields. In the view of some scientists, these studies can aid in the understanding of basic biological processes such as how growth is controlled, how cells communicate with one another, and how the nervous system works.

To examine this rapidly evolving field, *Spectrum* organized a panel discussion, held in conjunction with the annual meeting of the Bioelectromagnetics Society in Boulder, Colo., on June 16, 1983. The society is a multidisciplinary organization devoted to the study of the biological effects of radio-frequency EM fields. *Spectrum* invited to the meeting some of the outstanding researchers who have been looking at and observing evidence of weak-field effects. [An earlier panel meeting, also organized by *Spectrum* in Boulder, centered on the question of progress toward regulating exposure to radio-frequency EM fields. This meeting was reported in "The drive to regulate electromagnetic fields," March 1984, pp. 63–70.]

Spectrum's scientific panel focused on a number of key questions: What is the most recent evidence for the existence of genetic effects from electromagnetic fields—that is, effects on the nucleus of the cell? What new effects have been observed on the nervous system, and how do they relate to other effects on cell membranes (the outer covering of cells)? What progress is being made to tie experimental results to theoretical models? What new experiments, instrumentation, and approaches would aid in drawing firm conclusions?

The panelists reported a number of significant results that have appeared in recent work:

- Induction of chromosomal defects in mice spermatogenic (sperm-precursor) cells following microwave radiation in the gigahertz range.
- Changes in the calcium balance of living cats' brains exposed to microwaves modulated at extremely low frequencies.
- Alteration of nerve and bone cells exposed to extremely low-frequency fields.
- Decreased activity of the immune cells of mice exposed to modulated microwaves.
- Apparent increases in deformed fetuses among miniature swine exposed to intense power-line frequency fields.

These results are, in a number of cases, preliminary and subject to confirmation, entailing replication at different laboratories and further testing with increased numbers of specimens. Nevertheless, they all point to a need for a better understanding of the underlying mechanism of interaction between fields and organisms.

The study of EM-field interactions with organisms is wide-

Eric J. Lerner Contributing Editor

List of Participants

Chairman:

Frank Barnes, chairman, Department of Electrical Engineering, University of Colorado, Boulder.

Panelists:

W. Ross Adey, associate chief of staff for research, Veterans Administration Hospital, Loma Linda, Calif.

Larry E. Anderson, research scientist, Bioelectromagnetic Section, Battelle Pacific Northwest Laboratories, Richland, Wash.

Chung-Kwang Chou, associate director, Bioelectromagnetics Research Laboratory, School of Medicine, University of Washington, Seattle.

Friedrich Kremer, research scientist, Max-Planck Institute für Festkorperforschung (Solid State Research), Stuttgart, West Germany.

Shirley Motzkin, head, Biology Department, Polytechnic Institute of New York, New York.

Mays Swicord, research scientist, National Center for Devices and Radiological Health, U.S. Public Health Services, Rockville, Md.

Howard Wachtel, professor of electrical engineering, University of Colorado, Boulder.

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results obtained with extremely low-frequency fields.

Not only are the interactions with electromagnetic fields stud-ied over a wide frequency and power range, but the effects ob-served in experimental animals and biological preparations are also extremely varied. They range from subtle changes in body chemistry to possible gross deformations of fetuses. Broadly the effects are often grouped according to the parts of the living cells involved. Effects on the cell membrane are important in the nervous system, the immune system, and the endocrine system that produces hormones, while effects on cell nuclei (the part of the cell that contains genetic information) are important in the production of genetic changes.

Proceed with caution

The results that have accumulated must be interpreted with caution for a number of reasons. One limitation of nearly all the experiments is that they are performed at a very few frequencies widely spaced across the electromagnetic spectrum. In the United States, experiments typically take place at 27.12, 915, and 2450 MHz not because of their particular biological importance, but because they happen to be the frequencies that the Federal Communications Commission has allocated to industrial, scientific, and medical uses and thus are the frequencies generated by relatively inexpensive and readily available sources. Similar reasons dictate the selection of such higher frequencies as 9.4 or 64 Ghz. Extrapolation of the results obtained at one frequency to other frequencies not tested is thus risky.

Second, as in any biological investigation, many experiments are performed not on whole living animals (*in vivo*), but on laboratory preparations (*in vitro*), such as part of a chicken's brain or a cell culture. Effects obtained *in vitro* are not necessarily reflective of effects in a living organism. However, *in vitro* experiments, being generally capable of closer control than those performed *in vivo*, often help explain effects observed in whole animals or point the way to new animal tests.

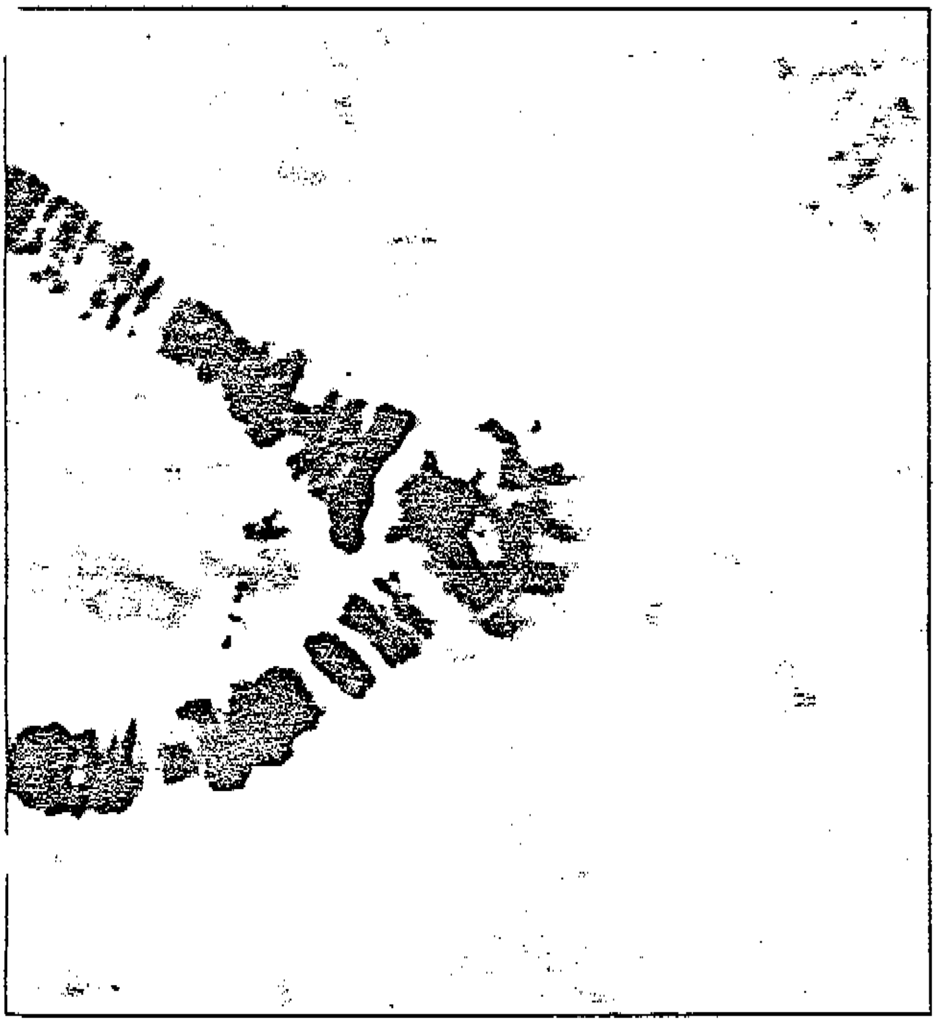
Mice cells with chromosomal defects

Dose rate mW/g	Total cells analyzed	Chromosomal translocations	
		Total	Percent
(Sham cells, not irradiated)	248	0	0
0.05	111	8	7.2
0.5	116	8	6.9
5	214	9	4.2
10	105	13	12.4
20	122	15	12.3

Chromosomal defects in animals subsequent to exposure to low-level microwave radiation is indicated in experiments performed by Ewa Manikowska-Czerska, Przemyslaw A. Czerski, and William M. Leach at the U.S. Food and Drug Administration's National Center for Devices and Radiological Health, Rockville, Md. In the data tabulated, the researchers found a significant number of chromosomal translocations (a class of defects) in sperm-precursor cells of mice after irradiation at 2.45 gigahertz. Moreover, the number of translocations does not increase smoothly with an increasing dose rate; a relative minimum value of translocations is indicated at 5 milliwatthours per gram.

Third, as in all research, initial results may not be confirmed by later research. Confirmation, however, may come not only as experiments are repeated, but also as results from different kinds of experiments pile up and consistently reinforce one another, resulting in a theoretical model of interaction.

Finally, it is important to realize that not all researchers are interested in the hazards of EM fields. Rather, the quest for basic knowledge of how biological systems work is the major motivation for many researchers, and such knowledge often has no direct bearing on health consequences. Thus, for example, some experiments cited by the panelists show effects on yeast cells of radiation in the 40-GHz range. The experiments are of great interest, because they appear to indicate that the cells' reaction to the radiation is heavily dependent on the exact frequency used. But such an experiment cannot reflect directly on human hazards, because 40-GHz radiation cannot penetrate beyond the outer layers of skin.



The panel members were chosen because of their expertise in the athermal effects of relatively weak fields that are believed to produce negligible heating. In general, fields are termed weak if they cannot produce temperature increases in animals outside the range of normal fluctuations. In most cases, power densities at or below 1 milliwatt per square centimeter, the limit set by the current American National Standards Institute (ANSI) safety standard for RF radiation in the frequency range from 30 to 300 MHz, are considered weak fields.

Indications of genetic effects

Perhaps the most dramatic findings discussed at the panel meeting were those indicating that microwaves may, in some circumstances, induce chromosomal damthose that other researchers had looked at and in that we used repeated exposures as well as a range of frequencies," Dr. Czerski commented. "Of course, none of the other experiments were identical to ours, and we would certainly welcome someone duplicating our results."

While the data of Dr. Czerski have not been repeated in other species, Friedrich Kremer of the Max-Planck Institut für Festkorperforschung (Solid State Studies), Stuttgart, West Germany, told the panel of related results at higher frequencies in a completely different organism. Dr. Kremer exposed the salivary glands of the larvae of an insect called the midge to radiation between 64 and 69 GHz for 2 hours. At a power density of 6 mW/cm^2, Dr. Kremer observed significant changes in larvae chromosomes [Fig. 1]. The experiments were carried out blind, which means that the examining biologist was not informed which gland was irradiated and which served as a control.

A key question is: Can the observed effects be caused by small microwave-induced rises in temperature? To answer that, Dr. Kremer examined the temperature sensitivity of the chromosomes. He warmed up a sham-exposed gland by 2.5 °C above the control, which is more than eightfold the microwave-induced temperature increase of 0.3 °C. No effect was observed, which in-

The link between weak fields and cell membranes

Much of the present research on the effects of weak electromagnetic fields (EM) on organisms has concentrated on possible interactions with cell membranes, the thin outer covering of cells. Interest in the possible interactions of cell membranes and weak fields was originally generated not by any concern with the potential hazards of artificial fields, but by efforts to understand how weak fields generated by the body itself could affect the body's cells.

In fact, research on EM effects on the brain was initially aimed at testing theories that gave weak fields in the brain a central role in coordinating the workings of the human brain's billions of neurons. Such theories, developed by E. Roy John, research professor in the Department of Psychiatry, New York University Medical Center, New York, myself, and others in the 1960s, rejected earlier ideas that attempted to explain all brain functions on the basis of the electrical impulse that traveled between individual neurons—the primitive analogies between the computer and the brain.

But there was a mystery here. The weak fields generated by the brain—electromagnetic waves called the electroencephalogram, or EEG—are only on the order of 50 millivolts per centimeter, far weaker than the 10^5 volts-per-centimeter fields of the nerve-cell membranes.

If the weak EEG fields could in fact affect brain function, then, researchers reasoned, imposed fields similar in strength and frequency to the EEG (between 1 and 100 hertz) should have measurable effects. By the early 1970s, such experiments demonstrated that not only do those fields alter brain function, but that even weaker fields, down to 10^{-7} and 10^{-8} V/cm, could also modify behavior and slowly recruit the EEG to match the frequency of the imposed field. The question then became: "How does the cell membrane behave as a powerful amplifier?"

In the mid-1970s, a number of scientists, including Leonard Kaczmarek, now professor of biochemistry at Yale University in New Haven, Conn., and Irwin Grodsky, then a professor of physics at Cleveland State University in Ohio, proposed that cell membranes could act as nonlinear resonators that could strongly amplify signals within a narrow range of frequencies. They developed models showing how such a biological amplifier might work.

It has long been known that calcium ions have a powerful effect on the cell membrane's function and, in particular, play a central role in the excitation of nerve impulses. Therefore, the theories that had been developed attempted to explain how the binding of calcium ions to proteins embedded in the membranes and protruding from its surface could modify the amplifying characteristics of the membranes.

If calcium ions bound to membranes could effect the interaction of cells with weak EM fields, then it was reasoned that extremely low-frequency (ELF) fields perhaps could knock calcium ions loose, like dust from a vibrating sheet of metal. In the 1970s Suzanne Bawin, then a research anatomist at the University of California at Los Angeles, and I showed that calcium efflux from brains *in vitro* could indeed be increased by exposure to microwave radiation that was sinusoidally modulated at ELF frequencies. The efflux varied as the modulation frequency was shifted.

Later experiments by cell biologist Carl Blackman and his associates at the Health Effects Research Laboratory of the U.S. Environmental Protection Agency in Research Triangle Park, N.C., showed that not only was the efflux affected by frequency, but also that there were only certain field-amplitude "windows" within which the efflux would increase. To further complicate the picture, Dr. Bawin and I found that while ELF-modulated microwaves increase efflux in the tissues at field strengths of 0.1 V/cm, the ELF fields themselves, at much lower field strengths of 10^{-7} V/cm, decrease calcium efflux by similar amounts.

Since the 1970s these calcium efflux experiments have been central to efforts to study the interaction of cells and weak fields.

Highly nonlinear effects must be involved, effects that allow large releases of chemical energy to be triggered or modified by small stimuli. Attempts at models of effects are made more difficult because the cell-membrane structure is itself so complex. The accepted view of the membranes envisions a field of lipid (fat) with rocks of protein that float around in the fat and protrude outward and inward like a field of corn. The protein is heavily electrically charged with terminal amino sugars. In most mechanisms, this field of corn can be made to vibrate or resonate with very weak oscillating fields, transmitting such vibration in some manner through the membrane and into the interior of the cell.

Attempts to explain the mechanisms have increasingly focused on the processes of non-equilibrium thermodynamics, first studied by Belgian chemist and Nobel Laureate Ilya Prigoyine. These are processes in which there are large flows of energy throughout the system, and their study has evolved rapidly over the past decade, shedding light on phenomena ranging from turbulent fluids and plasma to the origin of life. While systems near equilibrium can be characterized by their statistical properties—such as temperature, pressure, and so on—and tend to evolve from more ordered to less ordered conditions, those far from equilibrium exhibit much more complex behavior. Such systems can shift from apparently disordered, chaotic motion to highly ordered patterns when their environment changes in small ways. Non-equilibrium systems also exhibit two of the properties observed in the biological effects of EM fields—very high response to imposed frequencies that resonate with inherent oscillations in the system and windows of response to the amplitude of imposed fluctuations.

For the first time in the history of biological science, the use of EM fields offers a tool that allows a perceptive and precise view of nonlinear processes that are essential aspects in living tissue. Future clinical applications will undoubtedly include both diagnostic methods, such as imaging, as well as therapeutic uses, such as the enhancement of drug efficacy. We are witnessing a biological revolution as fundamental as any since Descartes. Not only are living systems being defined in physical rather than chemical terms, with a far finer resolution of molecular and atomic events than ever possible before, but there is also an awareness that models of living systems based on equilibrium thermodynamics are no longer tenable as necessary and adequate explanations of living matter.

—*W. Ross Adey*
Veterans Administration Hospital
Loma Linda, Calif.

the nuclei of cells are receiving far more absorbed energy per unit mass than is the organism as a whole. For example, an absorption rate of 0.05 mW/g for the organism would yield an absorption rate, at least for some DNA, of 20 mW/g.

Some have questioned how absorption of microwave radiation by DNA could affect its behavior in genes, since the energies involved are small compared with the thermal energy already present in the molecules [see "New findings are puzzling," p. 67]. Dr. Swicord commented on these views following the panel discussion. "You have to realize that in resonant absorption of coherent radiation, energy can be absorbed over time, not just with each photon, just as a bridge can be destroyed by a resonant interaction with soldiers marching in lockstep—each push is small, but the cumulative impact is large," Dr. Swicord told *Spectrum*. "Similarly, a DNA molecule can absorb the energy of not just one but many photons. This energy may still be small

me indicated an all-or-none effect of irradiation. The irradiation treatment apparently served to activate or interact with another factor to produce chromosomal insult. I think that factor was corporal restraint.

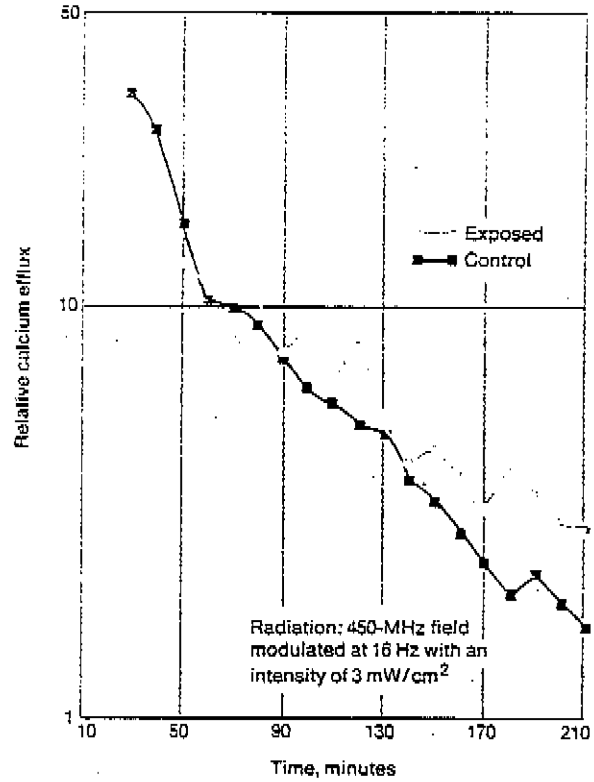
During the early 1970s, rats were subjected in my laboratory to a 4-hour session of intermittent irradiation in a 120-millimeter multipath field; the session-averaged dose rate was 5 mW/g. Twenty-four rats were observed for core temperatures while under corporal restraint. Another 12 rats, not in restraint, also yielded data on the thermal response to radiation. The 24 restrained rats exhibited much higher temperature maxima (40 to 43°C) than did the unrestrained animals (none higher than 39.5°C), and three of the 24 expired before the conclusion of irradiation.

Although the irradiated mice of Dr. Czerski and colleagues did not exhibit symptoms of hyperthermia, they were all subjected to corporal restraint, which has been confirmed repeatedly as a powerful source of physiological and psychological stress. High elevations of circulating steroid, a "stress" hormone, have been known to cause severe ulceration of the stomach, to promote the growth of cancer cells, and even to lead to death. Given the complication of restraint in the mice experiments, one hopes they soon will pursue experimentation in which the factor of restraint is controlled. Also, the temperature difference between sham- and microwave-irradiated mice—the former were hypothermic on release from the waveguide—suggests that a lower ambient temperature should be used to control testicular temperature. The importance of these chromosomal studies, past and contemplated, may lie in confirming the thesis that microwave irradiation interacts with physiogenic or psychogenic stress to produce effects that are not present with irradiation alone.

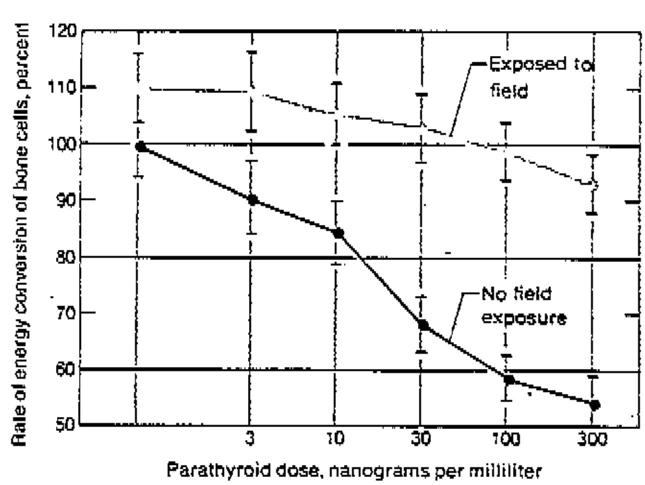
Few, if any, conscious human beings are under involuntary corporal restraint during exposure to radio fields at the levels used in the mice experiments. But there are other sources of stress in the industrial and military environments that could interact with relatively intense fields to produce untoward effects. Not the least of these sources is the chronic anxiety associated with the *supposition* that one is being exposed to harmful radiation.

There are two effective antidotes to such harm: enforced control of fields to limit their intensity in settings where highly powered sources are in use and education of the user to distinguish between probable and improbable outcomes of exposure. Failure to implement the second antidote has exacted heavy economic and moral costs. To paraphrase Shakespeare, "Whether there be harm or no, belief in danger can make it so."

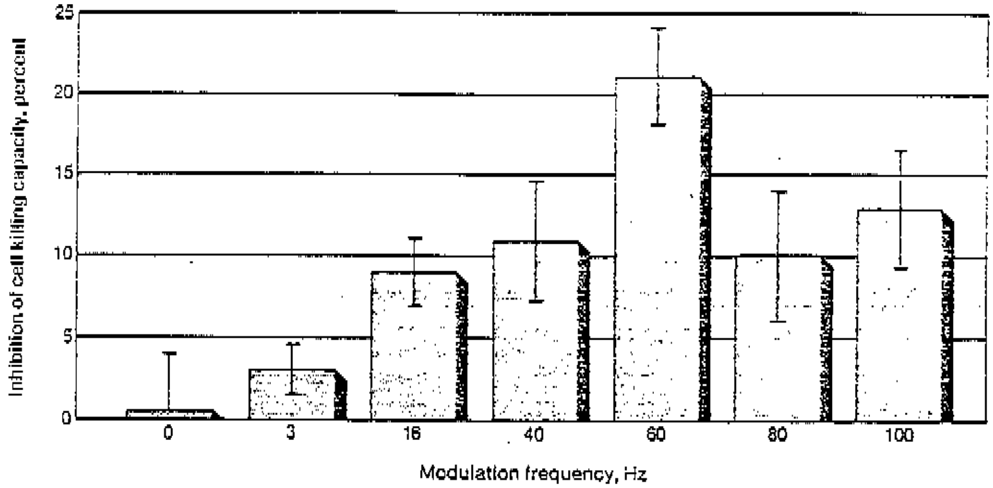
—Don R. Justesen
Veterans Administration Medical Center
Kansas City, Mo.
University of Kansas, School of Medicine
Kansas City, Kan.



[3] Higher levels of efflux of calcium ions from the brain of an intact, living cat is obtained by irradiating the cat's brain with 450-megahertz radiation, modulated at 16 hertz, a frequency near that of the cat's brain waves. The effects are pronounced even though a relatively low power density of 3 milliwatts per square centimeter is employed. Calcium ions are known to play important roles in the transmission of nerve impulses in the brain. The experiments were performed by W. Ross Adey, Suzanne Bawin, and Albert Lawrence at the Veterans Administration Hospital in Loma Linda, Calif.



[4] The hypothesis that extremely low-frequency-modulated fields act mainly on the membranes, or outer surfaces, of cells is supported by experiments on bone-cell cultures performed by Richard Luben of the University of California at Riverside. When the cultures were exposed to fields modulated at 15 and 72 hertz, their reaction to parathyroid hormone—a chemical known to bind to cell membranes and to reduce cell energy-conversion rates—was vastly inhibited. Since parathyroid hormone retards bone growth, these observations may help explain the beneficial effect of pulsed electromagnetic fields to accelerate bone healing.



[5] Lymphocytes—cells that defend against foreign bodies in the bloodstream—act through receptors attached to cell membranes. Thus, fields that disrupt membrane activity can interfere with the lymphocytes' ability to kill invaders. In experiments performed by Daniel Lyle of the University of California at Riverside, the cell's killing power was reduced by over 20 percent following exposure to 450-megahertz fields modulated at 60 hertz, but effects were less at higher and lower modulation frequencies, a typical example of a "windowed" response.

research immunologist at the Loma Linda hospital, studied the effect of ELF-modulated microwaves on mouse T-lymphocytes (cells that kill foreign or cancerous cells in the bloodstream). The lymphocytes kill other cells by bringing receptor molecules, attached to the lymphocyte membrane, in direct contact with the target cell. Anything that disrupts the lymphocyte membranes can therefore be expected to interfere with its capacity to kill harmful cells.

In the experiments, performed in 1981 and 1982, Dr. Lyle tested the lymphocytes for their capacity to kill foreign cells. The killing capacity was reduced by as much as 20 percent when the lymphocytes were exposed to 450-MHz fields with a modulation frequency of 60 Hz, and by lesser amounts at other modulation frequencies [Fig. 5]. Again, Dr. Adey reiterated to the panel, these results both confirm the role of the cell membranes in EM effects and demonstrate that many cell types can be affected.

Other studies by Weldon Jolley, chief of surgical research at the Loma Linda hospital, showed that 4-kHz magnetic fields of 20 to 30 gauss, when modulated at 15 Hz to produce 5-microsecond bursts, could reduce insulin production in pancreas cells by 35 percent. Further, several researchers have demonstrated that adrenal tissue tripled production of corticosterone, a powerful hormone excreted by the adrenal gland, when exposed to 60-Hz fields at a strength of 10 kV/m.

In Dr. Adey's view, these experiments indicate that all cells may respond to weak electrical fields, even those that are continuously generated in the human body. For example, clinical research has indicated that bone growth in normal humans is strongly influenced by weak electrical pulses that are produced when bones are stressed. "Biologists are becoming aware that many tissues have internal communication systems and that it is not something that is limited to the brain," Dr. Adey commented. In effect, he said, the known communication networks of hormones and nerve impulses are supplemented by a "radio network" of weak EM fields.

Health effect is uncertain

While Dr. Adey emphasized the relevance of recent findings to a deeper understanding of how organisms function, the effect of electromagnetic fields on health remains unclear. Do any of the effects cited actually cause harm to intact animals?

Chung-Kwang Chou, associate director of the Bioelectromagnetics Research Laboratory, University of Washington, Seattle, reported to the panel on long-term experiments performed by

him and Arthur Guy, laboratory director, to see if microwaves modulated at ELF frequencies did indeed have health consequences for rats. In these experiments, 100 rats were exposed for 25 months to 0.5 mW/cm^2 of 2.45-GHz pulsed microwave radiation, amplitude modulated at 8 Hz. (The maximum average SAR was 0.4 mW/g and the radiation was at the rate of 800 pulses per second, each 10 microseconds in length.) The vast majority of biological measurements, including behavior metabolism, blood chemistry, and immune response, showed no difference between exposed animals and controls. However, midway through the experiment the exposed animals had increased numbers of B- and T-type lymphocytes, although the increases were not observed at the end of the experiment. Also, at the end of the 25 months, the exposed rats had enlarged adrenal glands.

Could these results indicate that the rats had experienced changes in their immune and endocrine systems similar to the changes Dr. Adey pointed to in the cell-level experiments? Dr. Chou believes it is too early to tell. He told the panel that he and his colleagues are now repeating the one-year experiment with more animals. If the effect is confirmed, further studies will be done to find out if the increase in lymphocytes could affect the rats' ability to combat viruses and tumors. "We are still just looking at the pieces," he commented.

revised in 1982, is based on just such a notion of a constant absorbed energy level per unit mass, Michael Shandala, director of the Kiev Institute of General and Communal Hygiene, told *Spectrum* at the conference. For frequencies that couple most strongly with humans, around 100 MHz, this standard allows, in effect, about 0.3 J/g of absorbed radiation.

Matters are further complicated because many effects do not increase steadily with increasing field amplitude, but instead have "windows of effectiveness," Dr. Wachtel noted.

Finally, Dr. Shandala emphasized that Soviet studies had shown that an organism can compensate for many effects of EM fields, but the same organism becomes ill if stressed subsequently. In other words, the fields are an added burden that, if imposed on an already weakened animal, can cause breakdowns.

In one experiment reported at the Bioelectromagnetics Society, Betty Sisken and her colleagues at the University of Kentucky in Lexington showed that pulsed EM fields fail to affect the development of chick embryos under normal conditions—an incubation temperature of 37°C—but the fields significantly increased abnormalities when the chicks were stressed by a higher incubation temperature of 39°C, even though the increased temperature alone produced no effect.

Further research critically needed

Where do we go from here? Progress has been made in the study of electromagnetic-field effects in the past few years, but

New findings are puzzling

Long-standing difficulties in interpreting studies involving the biological effects of low-level electromagnetic (EM) fields raise consequent problems in setting public policy. Claims of subtle responses to weak fields have been debated for much of this century.

The real problem facing scientists and standards-setting bodies is not whether athermal, or weak, field effects exist. Electric shock satisfies the definition of athermal and, while a serious hazard, is sufficiently well understood that effective standards can be established. Many other athermal effects that are well known are not hazards. The more serious problem is what to make of the many reports of poorly understood effects of EM fields.

The literature on biological effects and medical applications of EM radiation is vast, with 4500 papers appearing from 1978 to 1984 alone. In the single-frequency range near 50 to 60 hertz, over 100 effects have been reported for electric fields at strengths as would be measured in the air surrounding the exposed individual, from 1 volt per meter to above 100 kilovolts per meter. Field strengths in the tissue would be far smaller. To date, roughly one quarter of these claimed effects have been independently confirmed, one third apparently negated, and the rest still await attempts at replication.

Two examples illustrate some of the difficulty in establishing and interpreting the significance of biological effects of low level EM fields.

The first example is a study reported in 1978 by Robert D. Tucker and Otto H. Schmitt (the inventor of the Schmitt trigger), both then doing research in Saint Paul at the University of Minnesota's Electrical Engineering Department on the possibility of human perception of 60-Hz magnetic fields of 7.5 or 15 gauss. At a conference five years earlier, these investigators had reported that some individuals appeared able to respond to such fields. But they also noted their suspicion that these "perceptive" subjects might have been cued by other stimuli. They proceeded to increase systematically the isolation of the subjects. Finally, not one of the 200 individuals tested could reliably perceive the field in a series of 30 000 trials.

These investigators were exceptionally persistent and self-critical, but they saw the problem through to a definite conclusion. But many biological experiments are too expensive or time-consuming to allow such an extensive follow-up, no matter how excellent the investigators. Moreover, in exploratory research that is looking for small effects in complex systems, it is difficult to identify all possible artifacts—hence, much of the confusion in the literature.

The second example involves a microwave auditory effect, in which "clicks" are perceived when the head is exposed to pulsed microwave energy of high peak power, but at an average power level that might be far below the current American National Standards Institute guidelines. Researchers have occasionally suggested that the effect represents a direct stimulation of the brain by EM fields—an alarming possibility. I first proposed in 1974 that the clicks might arise from mechanical vibrations generated by abrupt, but very small, temperature rises in the tissue. Shortly thereafter, experimental and theoretical studies were begun by investigators at several institutions, and they confirmed and extended my original hypothesis. The phenomenon is not now considered a hazard. But until a compelling explanation was provided, no one could tell for sure.

Spectrum's panelists raised many vexing scientific questions that must be dealt with separately and at length. Among them were the observations of Mays Swicord, of the National Center for Devices and Radiological Health in Rockville, Md., on the absorption of microwave energy by DNA solutions. He reported high absorption coefficients, and the reader is likely to conclude that this represents a possible mechanism for producing biological effects from weak EM fields. Moreover, calculations by a different group on the vibrational properties of polymers modeling DNA suggest that resonances might be found even in an aqueous solution, although the damping is very strong. Dr. Swicord's observations, if they do arise from resonant absorption by DNA, would also suggest low Q values.

Simple calculations show that the amount of energy that can be added to a DNA molecule by microwave fields of reasonable intensity would be far smaller than the random thermal energy that is already present. A question arises: How can weak fields produce an effect on the molecule that is not overwhelmed by random agitation?

This same paradox occurs when one examines other possible mechanisms by which weak fields could influence biological systems. Certainly animals exist that are unusually sensitive to weak electric or magnetic fields—electric fish or magnetic bacteria, for example—but they possess specialized receptors that trade high sensitivity for response to only slowly varying fields in a manner that would be understood by any electrical engineer.

Interactions between EM fields and biological systems have been intensively studied for over a century, and a quantitative understanding of many interaction mechanisms exists. Effects can arise from nerve excitation, electronically induced forces, the dielectric breakdown of cell membranes, and other processes that directly involve electric fields. Or they can arise from secondary phenomena, such as temperature changes or in the case of the auditory effect, thermally induced expansion. A common error is to confuse correlation—a change observed subsequent to exposure to EM fields—with causality, attributing change to the direct action of the EM field.

The effects reported by the panelists have only recently been observed, and their underlying mechanisms have not yet been established. It is not possible to predict the exposure conditions under which they would occur. It is easy to understand the difficulties that these reports would create for a standards-setting body as it attempts to develop general guidelines to protect an individual from unacceptable risk.

—*Kenneth R. Foster*
University of Pennsylvania
Philadelphia, Pa.

that one can hardly make any sense out of it, and our work fits right into that," she commented. Especially at high frequencies, the experimental problems are manifold. As Dr. Barnes, the panel's chairman, commented, "I wouldn't minimize the experimental problems of working in this area, having done it. There is a lot of time and money involved in getting these sources to work and to get sensible answers."

As in many other areas of research, in the long run it may be improved instrumentation—not only for the actual measurement but also for controlling the experimental environment—that finally begins to allow scientists to sort out real answers.

To probe further

The scientific literature on weak-field effects on biological systems is massive. Although no journal is exclusively devoted to these low-level effects, they are extensively reported, along with other interactions of electromagnetic fields with living organisms, in the journal of the Bioelectromagnetics Society, ***Bioelectromagnetics.*** Short summaries of recent research developments are also reported in the "Bioelectromagnetics Newsletter." For more information on the society's activities,

including its next annual conference, which will be held July 15–19, in Atlanta, Ga., write to BEMS, 1 Bank St., Gaithersburg, Md. 20878; or call 301-948-5530. Another periodical presenting research news is *Microwave News*, available from P.O. Box 1799, Grand Central Station, New York, N.Y. 10163.

A particularly useful overview of interactions, again not exclusively focusing on weak-field effects is *Biological Effects of Radio Frequency Radiation*, Daniel F. Cahill and Joe A. Elder, editors, U.S. Environmental Protection Agency, June 1983 (EPA-600/8-83-026A). This is at present available only in the form of a preliminary review draft and may be obtained from the EPA Health Effects Research Laboratory, Research Triangle Park, N.C. 27711.

A number of technical papers provide details on the results discussed at the *Spectrum* panel. *Biological Effects and Dosimetry of Nononizing Radiation*, edited by Martino Grandolfo, Sol M. Michaelson, and Allessandro Rindi (Plenum Publishing Corp., New York, 1983), contains contributions by major researchers in the field, including members of the panel.

Research on chromosomal and genetic effects in mice is detailed in "Spermcount and sperm abnormality in male mice after exposures to 2.45-GHz microwave radiation," by C.I. Kowalczuk *et al.*, *Mutation Research*, 1983, Vol. 122, pp. 155–61; "Dominant lethal studies in male mice after exposures to 2.45-GHz microwave radiation," by R.D. Saunders *et al.*, *Mutation Research*, 1983, Vol. 117, pp. 345–55; "Genetic effect of microwave radiation in mice," by S.M. Goud *et al.*, *Mutation Research*, 1982, Vol. 103, pp. 39–42; and "Sperm morphological changes in mice following microwave exposure," by Chiang Huai *et al.*, *Abstracts of the Bioelectromagnetic Society Meeting*, Colorado, July 1983, p. 43. The first indication of such effects is elaborated in "Evaluation of domanant lethal tests and DNA studies measuring mutagenicity caused by nonionizing radiation" and "Mutagenicity induced by nonionizing radiation in Swiss male mice," both by M.N. Varma and E.A. Traboulay, *Bioeffects of Electromagnetic Waves*, Proceedings of the U.S. URSI Annual Meeting, Boulder, Colo., 1975, HEW-FDA 77-8010, pp. 386–405.

A review of earlier work in genetic effects can be found in "Genetics, Growth and Development Effects of Microwave Radiation," by W.M. Leach, *Bulletin of the New York Academy of Medicine*, 1980, Vol. 56, pp. 240–57.

Observations of DNA absorption are described in "Chain-link dependent microwave absorption of DNA," by Mays Swicord *et al.*, *Biopolymers*, 1983, Vol. 22, pp. 2513–16.

Work cited by W. Ross Adey is detailed in "Effects of Weak Amplitude-Modulated Microwave Fields on Calcium Efflux from Awake Cat Cerebral Cortex," *Bioelectromagnetics*, 1982, Vol. 3, pp. 295–307; "Effects of electromagnetic stimuli on bone and bone cells *in vitro*," *Proceedings of the National Academy of Sciences*, July 1984, Vol. 79, pp. 4180–84; "Tissue Interactions with Nonionizing Electromagnetic Fields," *Physiological Reviews*, April 1981, Vol. 61, pp. 435–514; and "Frequency and Power Windowing in Tissue Interactions with Weak Electromagnetic Fields," *Proceedings of the IEEE*, January 1980, Vol. 68, no. 1, pp. 119–25.

Friedrich Kremer's work on midge chromosomes is further explained in "The Non-Thermal Effect of Millimeter Wave Radiation on the Puffing of Giant Chromosomes," Friedrich Kremer *et al.*, in *Coherent Excitation in Biological Systems*, edited by H. Frohlich and F. Kremer, Springer-Verlag, 1983. The response of yeast to gigahertz radiation is discussed in "Sharp Resonances in Yeast Growth Prove Non-Thermal Sensitivity to Microwaves," Werner Grudler and F. Keilmann, *Physical Review Letters*, Vol. 51, no. 13, pp. 1214–16.

Ideas presented in "New findings are puzzling" [p. 67] are elaborated upon in "RF-Field interactions with Biological Systems: Electrical Properties and Biophysical Mechanisms," by Herman P. Schwan and Kenneth R. Foster, *Proceedings of the IEEE*, 1980, Vol. 68, no. 1, pp. 104–13, and in "Tests for Human Perception of 60 Hz Moderate Strength Magnetic Fields," by Robert D. Tucker and Otto H. Schmitt, *IEEE Transactions on Biomedical Engineering*, 1978, Vol. 25, no. 6, pp. 509–18.

Ideas presented in "Constraints on restraint" [p. 62] are elaborated upon in "A Microwave Oven for Behavioral and Biological Research," *Journal of Microwave Power*, 1971, Vol. 6, pp. 237–258. ◆

The drive to regulate electromagnetic fields

In the United States, states and localities are imposing regulations, and industry is seeking action by the Federal government

SPECIAL REPORT
ELECTROMAGNETICS HAZARDS

A few years ago, the electronics and communications industries were more than content that, in the United States, there were no compulsory regulations limiting human exposure to electromagnetic (EM) fields. In the view of many industry spokesmen, the dangers of such fields were minimal in any case. Today many corporations and trade groups, ranging from broadcasters to radar manufacturers, are urgently demanding that the Environmental Protection Agency (EPA) or some other national agency set up standards.

The reason for this shift is rooted in large part in actions by state and local lawmakers. In the past 18 months, Massachusetts and New Jersey, among other states, and even individual towns, have begun either to consider or actually to impose their own regulations, some as strict as or stricter than the only existing U.S. national standard, the voluntary one set forth by the American National Standards Institute (ANSI). With the number of lawsuits and citizens' battles over EM fields increasing monthly, the electrical and electronics industry may face a morass of 50 or more sets of contradictory state and local regulations. Thus, there is growing demand for national regulation.

There is still an ongoing scientific debate over the real hazards from EM fields and where the standards protecting people from these hazards should be set—although progress toward a consensus has been made and the EM-field standards of most countries seem to be converging slowly toward rough agreement. In 1980, for example, the U.S. ANSI standard allowed an 8-hour exposure to 10 000 microwatts per centimeter squared at 100 MHz, while the Soviet standard allowed only 5 mW/cm^2,* a two-thousandfold gap. Today the new ANSI standard has lowered the allowable power density for such duration and frequency to 1000 mW/cm^2,* while the Soviets have increased their standard to 25 mW/cm^2,* closing the gap to fortyfold [Fig. 1].

While the entire population is exposed to some degree to EM fields produced by the vast array of electrical devices in modern society, at frequencies ranging from dc to 300 gigahertz, the range of exposure is great. The vast majority of the public are rarely exposed to power densities above a few nanowatts per centimeter squared, far below the most stringent standards anywhere in the world. Some occupational groups, such as personnel on naval warships and broadcast-station workers, have exposures falling between the Soviet and ANSI standards and would thus be most affected by where an occupational standard is set. Finally, one occupational group, the workers in the plastics and other industries in the United States who use radio-frequency heat sealers (industrial devices that employ RF radiation for heating), are exposed to radiation not only above the revised ANSI standard, but also in many cases above the old ANSI standard.

Paradoxically, while there is growing support for a standard to protect the public, which is rarely exposed to even moderate levels of EM fields, there is little pressure for a similar compulsory standard to protect employees at their work places, where the highest exposures occur. At present, no such compulsory standard exists in the United States, and the Occupational Safety and Health Administration (OSHA) appears unlikely to promulgate one.

Even the setting of national regulations for the general public will not be simple. The bureaucratic machinery for regulation setting is slow and cumbersome; there are many conflicting economic interests pulling on the regulatory process; the Reagan administration takes a dim view of regulations in general and a number of different agencies are involved [see "EM-field standards and how they are made," p. 70]. In addition, accumulating evidence of the biological effects of electromagnetic fields may be outdating existing standards, such as the present ANSI, which is itself already undergoing a review.

To find out how the efforts to promulgate regulations in this field are progressing, *Spectrum* sponsored a special panel meeting on June 13, 1983, in Boulder, Colo., in conjunction with the annual conference of the Bioelectromagnetics Society, an interdisciplinary organization dealing with the biological effects of electromagnetic fields. The participants [see "List of

List of participants

Chairman:

Henry J.L. Rechen, former deputy director, Division of Electronic Products, National Center for Devices and Radiological Health, Food and Drug Administration, Rockville, Md.

Panelists:

Przemyslaw A. Czerski, M.D., visiting scientist, National Center for Devices and Radiological Health, FDA, Rockville, Md.

David Davidson, senior scientist, GTE Laboratories Inc., Waltham, Mass.

Arthur W. Guy, director, Bioelectromagnetics Research Laboratory, School of Medicine, University of Washington, Seattle.

Elliott Postow, electromagnetic-radiation program manager, Naval Medical R&D command, Naval Medical Center, Bethesda, Md.

Maria A. Stuchly, research scientist, Environmental Health Center, Radiation Protection Bureau, Department of Health and Welfare, Ottawa, Ont., Canada.

Richard A. Tell, chief of nonionizing branch, Office of Radiation Programs, U.S. Environmental Protection Agency, Las Vegas, Nev.

Robert T. Watkins, radiation scientist, Massachusetts Department of Public Health, Boston, Mass.

Max M. Weiss, supervisor, Radiation Protection Group, Bell Telephone Laboratories, Murray Hill, N.J.

Eric J. Lerner Contributing Editor

* Here m = μ = microwatts

light of what's been happening—regulation is the lesser of two evils."

The alternative to uniform regulation was illustrated in ring 1983 when the town of Wayland, Mass., passed a bylaw equiring corporations to obtain the permission of neighboring landowners if the corporate activities would lead to the production of radiation-power densities in excess of 5 $\mu W/cm^2$ over any nearby property. This dosage was 40 times less than the statewide standard. The regulation arose out of concern over the testing of radar at a Raytheon Co. plant in Wayland. Raytheon did not challenge the regulation, nor did it test any radar that would violate it. When the statewide regulation went into effect, it superseded the town regulation.

A similar sequence of events took place in New Jersey following a local dispute. "We needed a standard for the Bureau of Radiation Protection, an agency of the state of New Jersey, to use to answer citizens' concerns," Max M. Weiss, an engineer at Bell Laboratories, told the *Spectrum* panel. Dr. Weiss and others on the New Jersey Radiation Protection Commission are urging the adoption of the revised ANSI standard as a state regulation without any modification of the dosage limit.

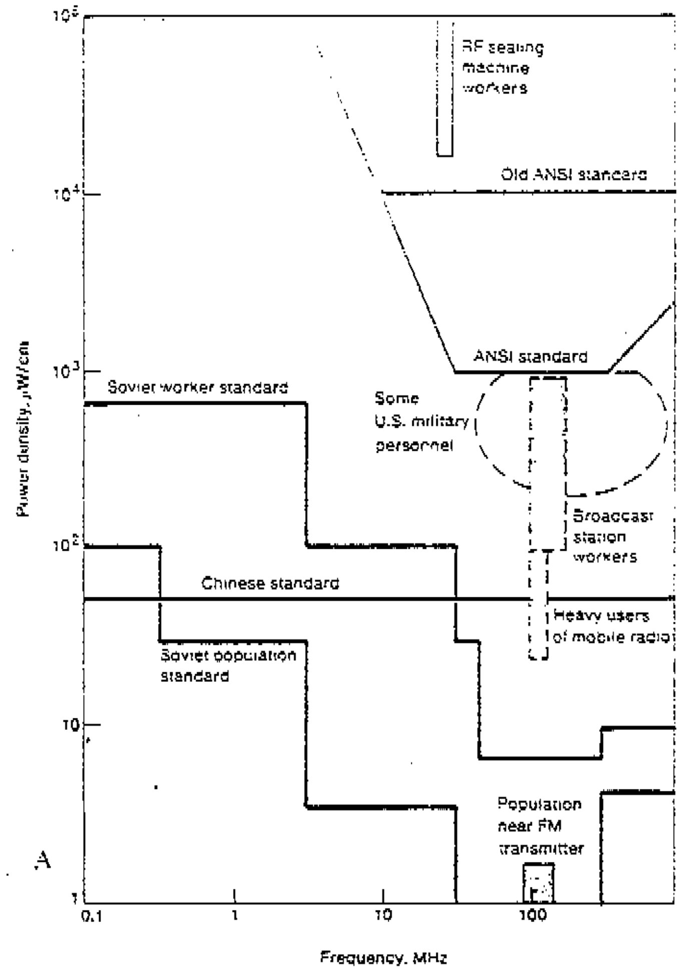
Searching for a site: new problem for industry

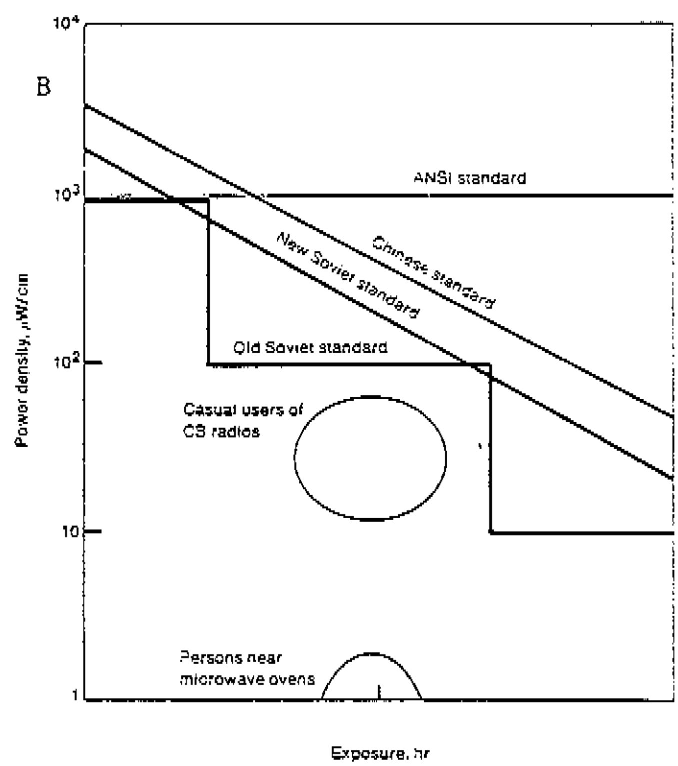
The worries in industry that are spurring such state regulations were graphically illustrated at the *Spectrum* forum by Arthur W. Guy, past chairman of the ANSI C-95.4 subcommittee that set the revised ANSI standard. Dr. Guy, who is director of the Bioelectromagnetics Research Laboratory at the University of Washington School of Medicine in Seattle, presented examples showing that public concern over extremely low levels of radiation had blocked the siting of various facilities.

"Take the infamous case of Bainbridge Island," Dr. Guy recounted. "RCA came in here and wanted to put up an earth atellite communication] station on an island across from Seat-:. The highest exposure level along the property line was projected to be 3 $\mu W/cm^2$. There was concern about these levels, and it was turned down by the county. So RCA moved to a more remote site in Kingston, Wash., and the highest level there would have been 42 nW/cm^2, and again it was turned down."

To David Davidson, an engineer on the senior scientific staff of GTE Laboratories Inc. in Waltham, Mass., the problem is at least partly caused by misinformation. "When people see an earth station, they really don't understand what it is doing," he told the *Spectrum* panel. "It takes a lot of good PR work to educate people to the fact that industry spends a lot of money to reduce the antenna side lobes for reasons that have nothing to do with safety but that do enhance safety in the end."

But the panelists agreed that the lack of uniform regulation was another key factor contributing to public confusion. "The public feels," said Richard A. Tell, chief of the EPA's nonionizing branch, the Office of Radiation Programs, "that where





[1] Standards regulating exposures to electromagnetic fields around the world have both converged and proliferated since 1980. In the United States, Massachusetts, along with individual localities such as Portland, Ore., have proposed standards for the general population that are five times more stringent than the 1982 revised ANSI standard, itself a more strict rule than the previous ANSI regulation. In addition Massachusetts regulations would be compulsory, while the ANSI standards are voluntary. Eastern European and Soviet standards in the meantime are shifting to emphasize energy density rather than power density. he result has been to narrow the gap between Eastern and Wes- ern standards and nearly eliminate the gap for short exposures (those of less than 30 to 60 minutes). RF-sealer workers are exposed to fields deemed hazardous by all the standards. Other groups, such as some in the military and some broadcast-station workers, are subject to exposures lying between the highest and lowest regulations.