NTIA REPORT 79-19

Fifth Report on "Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation"

U.S. DEPARTMENT OF COMMERCE
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"Knowledge will forever govern
ignorance, and a people who
mean to be their own governors
must arm themselves with the
power which knowledge gives."

James Madison
Fourth President
of the United States

FOREWORD

This report summarizes activities associated with the Federal Government's program to assess the biological effects of nonionizing electromagnetic radiation being coordinated by the National Telecommunications and Information Administration (NTIA). It covers Calendar Years 1976, 1977 and Fiscal Years 1977 and 1978, the period subsequent to that in OTP's 1976 report*.

This multiagency activity was promulgated and coordinated by the Office of Telecommunications Policy (OTP), Executive Office of the President until March 1978 when it was abolished as a result of Reorganization Plan No. 1 of 1977. Most of OTP's functions, including the coordination, guidance, and overview of this program, are now being carried out by NTIA, established in the Department of Commerce.

The program was recommended in December, 1971 by the Electromagnetic Radiation Management Advisory Council (ERMAC). The Council was established in 1968/69 to advise the Director, Office of Telecommunications Policy, and now the Secretary of Commerce and NTIA, on possible "side effects" and the adequacy of control of electromagnetic radiation associated with the use of the spectrum.

The purpose of this cooperative undertaking is to establish a sound scientific understanding of the interactions of this form of energy with man and his environment as a basis for ensuring safe and appropriate use of the electromagnetic spectrum with the many vital services and societal benefits it provides.

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* o Office of Telecommunications Policy, Fourth Report on "Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation", June, 1976.

o Other reports on the Program were issued in March 1973, May 1974, and April 1975.

Acknowledgement

The efforts, cooperation, and information provided by the Agencies, interagency Side-Effects Working Group, and other individuals is most gratefully acknowledged.

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I. INTRODUCTION

This report summarizes activities pertaining to the Federal Government's cooperative multiagency program to investigate and evaluate biological effects of nonionizing electromagnetic (radio frequency) radiation (0-300 GHz) being coordinated by the National Telecommunications and Information Administration (NTIA). It covers Calendar Years 1976, 1977 and early 1978 and includes information on research in progress during Fiscal Years 1977 and 1978. The report is intended to present an overview of the Program, which is comprised of activities individually funded by the Federal agencies with relevant responsibilities (i.e., health or environment, research, operational and/or regulatory). Aspects of the overall Program are also reported separately by some of the agencies. Additional information, including details of research projects and results of specific experiments, is covered in a variety of technical and conference reports and publications in the general scientific literature. Some of these publications are cited in Appendix B.

This program was recommended by the Electromagnetic Radiation Management Advisory Council (ERMAC) to NTIA's predecessor, the Office of Telecommunications Policy (OTP), Executive Office of the President, in the Council's 1971 report. * It includes guidelines and a framework for a comprehensive Federal program based on an extensive review, with the participation of agency representatives, of scientific knowledge, requirements and related activities within the Federal government. The recommendation outlined the background and need for this Program. It includes objectives, initial priorities, estimated funding levels, and recommended roles for individual agencies and departments consistent with their basic missions and responsibilities. In 1972 the current program was coordinated with the agencies and the Office of Management and Budget, Office of Science and Technology, and Council for Environmental Quality, for implementation in Fiscal Year 1974 or earlier insofar as practicable.

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* Electromagnetic Radiation Management Advisory Council, <u>Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation</u>, Office of Telecommunications Policy, 41 p., December 1971.

As a result of reorganization of the Executive Office of the President, the OTP was abolished in March 1978. Most of its functions are now being carried out by the new National Telecommunications and Information Administration (NTIA), established within the Department of Commerce. This includes coordination and overview of ongoing Federal activities concerned with biological effects of radio frequency (RF) radiation. The ERMAC continues to provide advice and assistance in this area and an interagency working group assists in providing liaison and intra-governmental coordination.

It is known that microwaves (MW) and other radio frequency radiation at sufficiently high power levels can induce heating and associated adverse effects. However, the primary thrust of this Program is to determine whether there are effects of exposures at low power density levels -- particularly over extended periods of time and with reference to environments which might realistically be encountered by general and occupational populations.

The fundamental purpose of the Program is to develop reliable scientific information on effects and interactions of RF energy with living systems and to ensure safe and appropriate use of the RF spectrum. The Program objectives are:

- To determine what effects these radiations have on living organisms under different conditions of exposure -- that is, the effects of various frequencies, waveforms, energy levels, electric (E) and magnetic (H) field components, and exposure durations (in various combinations) -- as well as the possible influence of biological considerations such as age, sex, health, etc.

- To determine the health and ecological significance associated with any observed effects and to assess any potential hazards, with regard to realistic exposure environments.

- To identify and characterize actual RF exposure environments and associated populations.

- To establish a sound scientific basis for the timely development of appropriate guidelines for exposures or use of RF energy, including assessment of their socio-economic and operational impact.

During the period covered by this report, the ERMAC conducted a comprehensive series of overviews of all Agency programs as a basis for developing updated Program fiscal and research guidelines. The Council has been reviewing its 1971 recommendations and initial 5-year fiscal plan in light of research progress and current requirements, and is in the process of preparing recommendations and guidelines for future efforts.

There has been considerable increase in public, Congressional, and media awareness and concern about possible microwave effects. In June 1977, the Senate Committee on Commerce, Science and Transportation conducted oversight hearings on radiation health and safety covering both ionizing and nonionizing radiations. OTP, agencies with research and/or regulatory responsibilities, individual scientists, representatives of various organizations, and other interested parties participated and provided both oral and written information. The associated publication (Appendix B) provides an extensive compilation of information on the subject of RF/MW effects, research, and issues. OTP provided information on agency activities, the status of knowledge, progress, problems, requirements and research needs. OTP's statement is included as Appendix D.

In early 1978, the Office of Science and Technology Policy (OSTP) in the Executive Office of the President formed an ad hoc Working Group to review the state of scientific knowledge and to identify current research requirements. Information and views provided by the participants and material developed by OTP/ERMAC in the course of their comprehensive overviews of Federal agency programs during 1976/77 were made available for this review. The OSTP report (Appendix B) is an excellent source of additional information on the current situation and research results and priorities. Research needs are consistent with those identified by the National Institutes of Health's Second Task Force for Research Planning in Environmental Health Science (Appendix B), the ERMAC and others.

Several Federal, state and local government agencies, other countries, and various national and international bodies are considering, or have proposed, standards during this period as discussed in Section IV.

International exchange and U.S. - U.S.S.R. cooperative research actively continued.

II. THE PROGRAM

Research has continued in the principal program areas discussed in previous OTP reports and shown in Figures 1-7. As can be seen in Section III, more sophisticated techniques and approaches are being used and additional repeatable and complimentary data are being developed, particularly on effects observed in earlier laboratory experiments. This is contributing to and extending our understanding of the results of previous research and provides additional focus and direction for continuing efforts.

There has been greater research emphasis on mechanisms of RFR interaction, effects on the immunological system, blood-brain barrier, and effects and interactions at the membrane, cellular and subcellular levels. Also follow-on studies are being conducted to determine the nature, exposure conditions and causality of previously observed effects. These trends are apparent in the research summarized in Section III and project data contained in Figures 2, 3, and 4 and Appendix A.

With regard to mechanisms of interaction, results of experiments reporting changes in calcium binding in brain tissue have been recently duplicated by other investigators. These changes have been observed with exposure to extremely-low-frequency or modulated VHF/UHF frequencies at low power levels (e.g., < 1 mW/cm^2) and appear to show frequency and amplitude "windows." These experiments imply a possible specific interaction of RF energy at the cell membrane level other than simple thermal deposition. Additional research is needed to understand such phenomena and their implications.

The increasing number of studies concerned with mechanisms of interaction is encouraging. The ERMAC and others have repeatedly underscored the importance and need for more research in this area.

More studies are being conducted to develop a better understanding of effects on lymphocyte transformations and immunologic defense mechanisms. As part of a series of seminars to review the state of knowledge and progress in key research areas, OTP/ERMAC held a seminar on this topic in December 1976. A summary of this session is contained as Appendix C and additional discussion is contained in Section III.

Studies of possible RFR effects on the blood-brain barrier have increased. As noted in OTP's 1976 report, increased permeability to compounds of high molecular weight has been reported in laboratory experiments with small animals exposed to pulsed and CW microwaves at average power densities considerably below 10 mW/cm^2. Additional studies have been performed and a workshop on the subject was sponsored by the Navy in October 1978. Alternative interpretations of results have been put forward and remain a subject of controversy.

Fewer experiments are being conducted on RF/MW effects on the formation of cataracts in laboratory animals. Experiments involving both acute and repeated exposure have shown that lens opacities can be induced at incident power densities on the order of 100 mW/cm^2 or greater. While it is well known that sufficient heating from any source can induce cataracts, in some experiments with apparently comparable heating by microwaves and other means (BRH), cataracts were observed in MW but not conventionally heated lens, raising some question as to whether RF/MW cataracts can be attributable solely to heating. In other experiments (VA), monkeys exposed to short bursts of microwaves at higher power densities (e.g., up to approximately 450 mW/cm^2) during daily test sessions over periods up to several months have not developed cataracts a year or more later.

Experiments at lower power densities (e.g., continuous 10 mW/cm^2 exposure over a 6-month period) have not produced cataracts in animals observed for up to several months following exposure. Additional studies should be conducted to ensure that there are no subtle ocular effects, with long latent periods or accelerated aging of the lens, which might result from acute or chronic repeated exposures. However, based on research to date, it does not appear that RFR at levels typical of environments normally encountered is a significant factor in the formation of cataracts.

Considerable progress has been made in developing more sophisticated techniques and instrumentation for measuring RFR fields and determining absorbed dose. The development of data and techniques for determining specific absorption rates (SAR) for various animal models has facilitated the estimation of whole body absorption for various frequencies, orientations, and RFR conditions and comparison of experiments between animal species. Additional work is still needed to develop and refine techniques for relating incident to internal fields, determining internal fields and energy distribution, and to permit extrapolation of laboratory results from experimental animals to man.

The need for research to determine effects of long-term continuous or repeated exposures (i.e., relevant to environments and conditions actually experienced by various population groups) has been repeatedly emphasized. Experiments are being conducted with more extended exposures -- e.g., several months and more. For example, the Air Force has recently initiated a large study in which animals will be exposed essentially continuously to pulsed microwaves for a major portion of their lifetimes. As part of a US-USSR cooperative research program, experimental animals have been exposed to microwaves at power density levels as low as 500 $\mu W/cm^2$ for periods of several months. In these experiments transient changes have been observed in blood constituents -- i.e., they appear after a period of exposure and subsequentally disappear as the exposure is continued. Such observations suggest a response and subsequent accomodation or adaptation to these exposures. Additional research is required to clarify the observations and to determine their cause and significance to the well-being of the organism.

Measurements and calculations are continuing in efforts to characterize actual RF/MW exposure environments and associated populations. The Environmental Protection Agency and National Institute for Occupational Safety and Health, have been conducting such studies as have the Federal Aviation Administration, National Bureau of Standards, Department of Defense and Federal Communications Commission for special environments (see Section III).

In general, these surveys show that RF/MW levels in most environments encountered by the general public are typically very low (i.e., fractions of a $microwatt/cm^2$ and, in some specific circumstances, in the 50-200 $microwatt/cm^2$ range), particularly with reference to levels reported to produce effects in research to date. However, higher levels have been found to occur in some occupational and other special situations. Additional efforts are in progress to better characterize potential exposure environments and associated population groups.

As related matter, there has been a considerable increase in interest and research in the development of beneficial medical applications of RF/MW energy, e.g., for diagnostic or therapeutic purposes. Recent applications in the treatment of cancer and the development of MW imaging techniques are examples. Better understanding of RF/tissue interactions could facilitate and stimulate the development of such uses.

Research in progress during Fiscal Years 1977 and 1978 is indicated in Figures 3-9 and in Appendix A. In general, efforts continued and concentrated in key Program areas and priorities indicated by previous research. Figures 3 and 4 illustrate the distribution of research effort in FY 1977 and 78 by individual agencies and in the program as a whole. Figure 2, which outlines research during FY 1976, is included for comparison. These activities are described more fully in Section III, and additional information on these projects is contained in Appendix A.

As would be expected, some of the 116 projects indicated in OTP's 1976 report and shown in Figure 2 have been modified, consolidated, expanded or completed. In FY 1977, the program consisted of approximately 105 projects of which 59 were conducted in universities and other non-government institutions and 43 were conducted in government laboratories (3 have both intramural and extramural components). The FY 1978 program was comprised of some 138 projects including 51 extramural, 83 government, and 4 intramural/extramural projects. The majority of these projects represent continuing efforts; some 57 new projects were undertaken (and 62 projects were completed, discontinued or revised). As in the prior years, there are several cooperative efforts supported by more than one agency and interagency agreements.

Figures 5 and 6 illustrate the frequency-spectrum distribution of project efforts in the principal areas of investigation during Fiscal Years 1977 and 1978 and Figure 7 indicates the distribution of projects being conducted in government and non-government laboratories. Note that the attempts to obtain absolute totals from these presentations can be misleading because, due to the nature of research, individual projects frequently deal with related areas and more than one frequency or range of frequencies. Consequently a given project often appears in more than one area.

Figures 8 and 9 show the areas of spectrum in which these studies are being conducted for each agency. Particular frequency regions emphasized in individual agencies programs reflect that agency's responsibilities and/or concern with existing or planned equipment and systems. Here, and in Figures 5 and 6, the concentration of research at microwave frequencies can be seen. Because of the prevalence of use and relative potential for interaction, the microwave portion of the spectrum is considered a priority area for research. However, more research is needed in other frequency regions, particularly at frequencies constituting sources of population exposures such as the Industrial, Medical and Scientific (ISM) bands, broadcast frequencies, and frequencies used for CB and other mobile and hand held communications.

This Program is comprised of efforts independently funded by participating agencies. Major support is concentrated in DOD, HEW, and EPA, which together account for approximately 95% of the total effort as illustrated in Figure 10.

Total funding for Fiscal Years 1977 and 1978 was approximately $7.6 and $10.1 million respectively. (This includes all agencies noted in Figures 3 and 4. It does not include any relevant work by the National Cancer Institute.) For comparison, funding for prior fiscal years, was approximately $6, $7, $7.5, and $9.2 million respectively for FY 1973 - 1976. FY 1979 funding is currently estimated to be on the order of $11.5 million. These funding levels have been considerably below those recommended by the ERMAC in 1971 (i.e., $10-15 M/year in 1971 dollars).

While considerable progress has been made with the available funds, current requirements and the level of public concern clearly warrant a more rapid rate of progress in resolving remaining unknowns and uncertainties. Higher levels of investment (e.g., on the order of 2-3 times present levels) are required both for the acceleration of existing agency activities and the initiation of large-scale research projects, currently beyond the available resources in any single agency for RF/MW research.

III. AGENCY ACTIVITIES AND PROGRAM SUMMARIES

Activities, accomplishments, and principal emphasis and directions of agency programs for 1976, 1977 and early 1978 are illustrated in their summaries as follows. Additional information can be found in Appendix A, which contains information on individual projects in progress during FY 1977 and 78 and in publications associated with these efforts, some of which are cited in Appendix B.

HEW/BUREAU OF RADIOLOGICAL HEALTH (BRH)

The Bureau of Radiological Health, Food and Drug Administration (FDA) operates a radiation control program to protect the public health and safety from unnecessary radiation from electronic products, as established by the Radiation Control for Health and Safety Act of 1968 (P.L. 90-602). The Bureau develops and administers programs to control emission of electronic product radiation and performs research into the effects and control of such emissions. Thus, the Bureau is concerned with testing and surveying radiating devices, their use in practice, associated health surveys, the development of procedures and techniques to minimize exposures, the development of procedures and techniques to minimize exposures, the development of product performance criteria and standards, compliance activities for established standards, and biological research pertaining to radiation exposure.

In relation to radiofrequency and microwave radiation, the Bureau has developed data on emission characteristics of microwave ovens, microwave diathermy, RF sealers, CB radios, and electrosurgical units. Bioeffects research information is available on radiation from ovens and diathermy apparatus. The Bureau has a regulatory standard on ovens, and is developing a standard for diathermy apparatus. In order to determine compliance with the microwave oven performance standard, the capability for calibration of microwave measurement instruments used by laboratory and field personnel became essential. The Bureau now operates a precision microwave power density calibration facility to calibrate instruments at the microwave oven frequencies of 2450 MHz and 915 MHz.

Activities during 1976:

Instrumentation

A part of the technical support required by the microwave oven standard is to evaluate the capabilities of available instruments to perform the requisite leakage measurements. Therefore, a comprehensive testing protocol was developed for such instruments. Laboratory systems were designed and evaluated for the measurement of such parameters as: linearity, frequency response, AM response, polarization elipticity, near field accuracy, pattern isotropicity, radiofrequency interference, etc. Computer programs were written to allow for a statistical evaluation of the calibration data collected from field instruments and to perform a comprehensive calibration analysis.

These systems were used to evaluate five different instruments during the year. The evaluations have revealed numerous unexpected characteristics in these commercial instruments, and have kept several inadequately designed instruments from being marketed as compliance-quality instruments.

Work on developing more precise microwave measurement techniques has a high priority. New approaches to instrumentation and measurement methods are being developed. For example, the Bureau has developed a miniature broad-band isotropic probe which is used to scan emissions from unknown frequency sources and characterize near and complex fields in biological experiments. A small version of the probe (1 x 2 mm tip), single axis dipole/diode device is capable of being implanted in biological specimens to measure field strength. This probe has been used to scan fields in simulated muscle spheres. Data agree well with 2450 MHz and 915 MHz theoretically predicted field maps. Among the unique features of this detector is its optical link to a remote digital readout device. This eliminates perturbation of the electromagnetic fields normally present with wire leads.

Several advanced E and H field probes have been developed by the Bureau in recent years. These devices were designed to overcome problems existing in presently available equipment. All use an optical telemetry system (TM) which was designed to be used with the various probes in a wide variety of applications, allowing much more accurate measurements to be performed than would have been possible with conventional metal-wire signal links. The following are some of the uses of the probes and optical TM.

- UCLA Brain Research Institute, biological effects research. Conventional survey instruments used in the investigator's exposure chamber were not completely satisfactory in providing exposure field information. A site survey was made with a 3D probe and optical telemetry system and a complete evaluation of the fields in the chamber was performed by the Bureau and UCLA. Later a complete probe and TM system was transferred to UCLA. Additional measurements have been made, including field strength measurements in a living cat's brain. The system can provide dosimetric data at a level not achievable with other existing instrumentation.

- Oven compliance program support. Three critical parameters in the evaluation of oven survey instruments are near-field calibration, antenna pattern response, and frequency response. Four manufacturers' probes have been evaluated, using the Bureau's miniature probe with optical telemetry system as a reference standard.

- Dosimetric studies support. A series of microwave oven measurements were performed by the Bureau using the probe/TM system to measure fields within human skulls filled with simulated tissue. For these measurements, the eye socket is placed in close proximity to a leaking microwave oven door crack.

- Microwave diathermy standard development project. A Bureau probe/TM system has been used to map leakage and main-beam fields of various commercially-available and newly-developed applicators. No other instrumentation was available for these high-spatial resolution applications.

- RF product studies. A 3D magnetic field measurement device was produced under contract for the 0.2 -100 MHz frequency range. The unit, when delivered, performed erratically above 25 MHz due to RF pickup from its metallic signal cable. Since this instrument was designed to be compatible with the Bureau's optical telemetry unit it was connected to the TM system and was found to perform properly over a much wider frequency range. This TM interfaced unit has been used successfully in CB radio, RF sealer, and electrosurgical device emission studies.

The Bureau contracted the development of a stable, accurate, and nonperturbing temperature probe for internal dosimetry. A birefringent crystal optical thermometer, using a fiber optics cable and a 1 mm diameter sensing tip, has been developed. Through the use of sophisticated optical and electronic techniques, an absolute accuracy of 0.1 degree C is feasible over a period of many months without recalibration.

A primary objective of the proposed microwave diathermy standard, being developed by the Bureau, is to minimize unprescribed exposure of patient tissue and operator exposure. Leakage and scattered radiation, in the vicinity of spaced applicators used in present clinical practice, easily exceeds 10 mW/cm^2 with 30 mW/cm^2 not uncommon. A study of the technical feasibility of modifying present spaced applicator designs or developing new types of applicators, namely, direct contact applicators, was undertaken. The results of this study show that direct contact applicators are more desirable because they can easily maintain leakage levels below 5 mW/cm^2 in the vicinity of the applicator when loaded with simulated fat-muscle tissue. In addition, these designs can provide for uniform temperature distributions instead of doughnut-shaped heating produced by some spaced applicators presently in clinical use.

Direct contact applicator designs have been developed and tested clinically. One is a teflon slab-loaded rectangular waveguide developed at the Bureau, resulting in a uniform therapeutic field between two dielectric slabs. The other design was developed for HEW under contract. It is a circular aperture horn with circular polarization. Its special design features consist of an output flange-choke to suppress leakage radiation. This design has only 0.2 mW/cm^2 leakage per 25 watts input, when loaded with a planar phantom. (The leakage increases to 1 mW/cm^2 per 25 watts when a 1 cm dielectric shim is placed between the aperture and the phantom.) Its aperture field provides for uniform temperature distribution in simulated muscle tissue. A high efficiency factor in terms of energy deposition to tissue is characteristic of this applicator. Less than 30 watts of net power are required to deposit 2.35 W/kg in the muscle-equivalent tissue of phantom models of the lower back, thigh, and arm.

The calibration and development of suitable field and laboratory instrumentation in the lower frequency portion of the RF spectrum has continued. Instrumentation developed was used to measure emissions of electric and magnetic fields from three electronic products: RF plastic sealers, electro-surgical units, and citizen band radio antennas. The instrumentation used for the field measurements was optically-coupled multi-axis orthogonal electric and magnetic meters developed under contract to Bureau specifications.

The tests revealed that in the case of the RF plastic sealers and the citizen band radio antennas, the ANSI Standard's maximum permissible exposure limits of 200 V/m and 0.5 A/m were exceeded under normal operating conditions. Emissions from electro-surgical units (ESU) also exceeded these levels. There are, however, no standards for the ESU frequency range of operation (0.5 - 2.4 MHz).

The Bureau has established a theoretical basis using finite element techniques for developing and solving the mathematical equations governing the behavior of nonionizing electromagnetic radiation in geometrically irregular, multi-layered biological media. Associated computer programs needed to achieve this capability are partially completed. A program with two dimensional modeling capabilities has been applied to calculating power absorption in a triple-layer, irregular cross-sectional model of the human thigh exposed to microwave radiation. Another application has been to predict field intensities within phantom materials for broadband isotropic field probe development. When fully developed, this capability should provide improvement in the areas of dosimetry, medical devices and therapeutic techniques, microwave field and power density measurements, the design of exposure facilities, and the establishment of realistic national standards and criteria.

Biological Research

Research information developed by the Bureau pertains primarily to the biological effects of 2450 MHz radiation, although some information has also been developed about effects of 383 MHz, 915 MHz, and 10 GHz radiation. Theoretical dosimetric studies include other microwave frequencies. Research completed in 1976 includes the following:

Dosimetry. Concepts and instrumentation have been developed to specify absorption of radiation within biological specimens for biological research. Microwave biological and psychological effects depend not only on external exposure conditions (frequency, field strength, and field distribution), but also upon the distribution of absorbed energy in the specimen. Absorbed energy distribution is affected by the geometry and electrical characteristics of the specimen, the exposure conditions, and the orientation of the specimen with respect to the incident field.

The Bureau has apparatus to irradiate cell samples, hamsters, mice, rats, rabbits, and monkeys and to determine the total and distributed absorbed microwave energy in exposed specimens. Waveguides, cavity and anechoic chambers, and dielectric lenses are adapted to the need of individual experiments and can provide whole- and partial-body exposures of specimens individually or in groups, acutely or chronically. The available frequencies are 383 MHz, 915 MHz, 2450 MHz, and 10 GHz. Instrumentation for dosimetry includes phantom tissue materials, thermographic cameras, calorimeters, implantable temperature and E-field probes, and wideband dielectrometers. In order to establish meaningful dosimetric relationships (quantified in absorbed energy) for man, studies to determine the total and distributed absorbed energy in phantom human bodies for measured exposure fields are needed. Such studies have been initiated.

Because of perturbations of microwave exposure fields by dielectric animal holders, a theoretical study has been performed to determine the resultant changes in the energy absorption of the animals. The study shows that the changes in absorbed energy are small considering some of the large standing wave ratios of the perturbed exposure fields in the holders.

The energy absorption patterns in two sizes of triple-layered phantom tissue circular cylinders have been calculated for plane wave sources of 433, 750, 918 and 2450 MHz. The results indicated that the energy absorption can be highly nonuniform and vary according to the size of the cylinder and the frequency of the source.

A thermographic technique has been used to determine absorbed microwave energy distribution in phantom monkey and human heads irradiated with an aperture source. The phantom heads were a brain equivalent tissue sphere and a bone and brain tissue geometric model of a monkey head. Good agreement was obtained between the experimental results and theoretical calculations. The penetration of microwave energy was less for the phantom human head than for the monkey head. The data indicate that aperture dimensions can affect microwave absorption and indicates a need for further research. They also suggest that various combinations of frequency and aperture dimensions can be used to obtain desired microwave absorption patterns for both biological experiments and therapeutic applications.

Since the size and shape of an animal, as well as its position and orientation in the waveguide, can influence absorbed dose, studies of microwave effects should take these factors into account. The relationship between the total and distributed absorbed energy in rat phantoms and their sizes and orientations in a waveguide exposed to 2450 MHz microwave radiation was studied. Six models of tissue-equivalent materials are used to simulate the sizes and shapes of rats that are 1, 4, 10, 12, 30 and 60 days old. The measurements are made with all models located at the center of the waveguide and oriented tail-on (0°) and head-on (180°) to the direction of the incident wave. For the two smaller models, the orientation is also varied stepwise from 0° to 180°. The patterns of absorbed energy in the cross sections of the phantoms are studied using a thermographic camera. The results indicate that changes in size, shape and orientation of exposed animal models produce only slight changes in total absorbed energy between the 0° and 180° orientation but large differences in the distribution of absorbed energy in the animal phantoms. With the phantom head facing the incident radiation, in most cases the head area, including the brain, absorbs the most microwave. In the opposite orientation, maximum absorption occurs in the tail and abdominal regions. These results further underscore that both the total absorbed energy and the distribution of absorbed energy in animal bodies probably are important in the interpretation of the results of biological experiments.

<u>Animal Physiology</u>. The detection of rise of temperature of unirradiated animals is a continuing problem in microwave research. A reliable method for distinguishing between possible thermal versus so-called "nonthermal" stress of microwave irradiation has not been established. Many investigators utilize rectal temperature as an index of thermal stress in an irradiated animal; however, biological effects are observed at microwave levels and under environmental conditions which may lead either to no detectable rise of rectal temperature, or to an apparent decrease of rectal temperature.

In one investigation, oxygen consumption rate is used as a biological indicator of thermal stress due to microwave radiation. Male CF1 mice are irradiated singly with 2450 MHz CW microwave in a waveguide apparatus with incident power levels of 0 (sham), 0.09, 0.3, 0.6, 1.7 and 3.3 W, resulting in corresponding average absorbed dose rates of 0 (sham), 1.6, 5.5, 10.4, 23.6 and 44.3 mW/g. The environmental conditions are 24°C, 55% relative humidity, and an air flow rate of 78 ml/min. Oxygen consumption of the mouse is determined at 5-minute intervals by means of a paramagnetic oxygen analyzer before, during, and after each irradiation. Each of the stages lasts for 30 minutes. Results of the experiment show reduction of oxygen consumption, by as much as 10% below controls, at average absorbed dose rates of 10.4, 23.6 and 44.3 mW/g. Also, at the two higher average absorbed dose rates, avoidance behavior has been reported in other previous experiments.

Effects of age and sex on acute microwave response were examined in mice exposed to 2450 MHz radiation (7.5 W forward power). Male and female mice at three ages were individually exposed in an environmentally controlled waveguide until they died. Ages at exposure were: 1 month (weanlings), 2 months (sexually mature), and approximately 14 months (retired breeders). A total of 114 mice were used, with a minimum of 14 mice for any single combination of age and sex. Activity of mice in the waveguide was monitored electronically, so that the time of death could be determined by the cessation of movement. Results of the study showed that the mean dose to kill for the forward power used was essentially the same for the ages and weights of animals of either sex. The mean dose to kill for males was higher than for females and increased with increasing age, but neither was statistically significant. For the females, the mean dose to kill tended to decrease with increasing age. The average dose to kill for the most sensitive group (aged females) was 39.3 $\pm$ 5.4 joules/gram and for the least sensitive group (aged males) was 47.8 $\pm$ 9.1 joules/gram.

Cataractogenesis. Research into the effects of microwaves on the eye is continuing. Emphasis has been placed on testing two major assumptions about microwave cataractogenesis. The first is that the cataract is entirely a response to temperature elevation within the eye. This assumption is becoming increasingly questionable on the basis of developing, but incomplete, information from intramural studies. The second assumption, that residual effects from "subthreshold" exposures do not accumulate, remains open. Thorough assessment of these assumptions requires further research. Cataracts of different etiologies are also being compared by histological techniques.

The role of microwave radiation in the induction of lens opacities was investigated by irradiating the eyes of rabbits for 30 minutes at several power levels of either 2.45 or 10 GHz continuous wave radiation. A dielectric lens was employed to focus radiation on the eye region, with distances from the emitting horn to the dielectric lens and from the latter to the eye kept the same in all experiments. Effects were observed by opthalmoscopy and slit-lamp biomicroscopy. Lens opacities were induced at lower power densities at 2.45 GHz than at 10 GHz.

Microwave radiation of sufficient power and duration causes two demonstrable effects in the rabbit eye: (1) a prompt increase in intraocular temperature and (2) after several days, formation of opacities in the posterior subcapsular cortex of the lens. Whether these two occurences have a cause-effect relationship has been neither resolved nor satisfactorily addressed experimentally. Therefore, experiments were undertaken to raise intraocular temperature by the same amount as occurs during a cataractogenic exposure to 2450 MHz microwave radiation and for the same duration, but without employing microwaves. Heat was applied externally to the scleral region overlying the ciliary body, thus heating the blood flowing to it, the iris, and the corneal limbus. The heat source was a thin copper girdle shaped to the contour of this region of the eye. Soldered to its upper surface was a circular brass tube which carried a flow of water from a thermostatically regulated water bath. In an initial series of experiments, water bath temperatures were correlated with temperature measurements made by thermocouple in the vitreous body close behind the lens. This type of heating was found to inflict more severe damage than equivalent microwave heating. Local venous statis, hemorrhage in the ciliary body and iris vessels, corneal neovascularization, and hyphemia were observed. The few opacities which developed were in the anterior lens cortex, thereby differing in location from those induced by microwaves.

In a study of the effects of repeated irradiation at much lower levels, six rabbits were exposed to 2.45 GHz CW radiation in an anechoic chamber to an incident power density of 10 $\pm$ 1 mW/cm2 for 8 hours per day, 5 consecutive days a week for periods ranging from 8 to 17 weeks. Body weight, food and water consumption, and coat condition were monitored daily for possible radiation responses. Weekly counts of total red and white blood cells were made and the lens of the eye was examined by slit lamp for changes. Six litter mates of the above group were sham exposed and similarly treated and observed during identical periods of time. Animals were restrained with foamed polystyrene. A slight lowering of food and water consumption was observed in the irradiated group during the first week of exposure. The lowered consumption was not accompanied by a detectable weight loss. Transient changes observed in white cell counts were suggestive of temporary leukopenia and leukocytosis. No latent eye effects were observed up to two months after irradiation.

Reproduction and Heredity. Bureau research into possible effects of microwaves has emphasized investigations of developmental anomalies in offspring of exposed mammals and chromosomal changes. Ongoing research into mutagenesis is aimed toward detection of molecular changes in DNA, the genetic material. An additional need for mutational studies of misdistribution of DNA in gamete production and early embryogenesis is perceived, but has not been approached in direct experimentation.

Congenital anomalies have been induced in laboratory experiments by exposure to sufficiently high levels of microwave radiation during the period of major organogenesis. Whether acute exposure after major organogenesis can result in neurological deficits is not currently known. During 1976, three studies related to congenital anomalies were completed.

A total of 145 CF1 white mice with timed pregnancies were used either as unirradiated controls or were exposed individually for 4 minutes to 2450 MHz microwave radiation in an environmentally controlled waveguide (99.12 to 114.6 mW/gr average dose rate and 23.79 to 27.5 Joules/gram average absorbed dose). The environmental temperature was controlled at 25°C and humidity at 50 percent. At least 10 pregnant mice were exposed on each gestation day from 0 through 11 to determine which day(s) were the most sensitive with respect to the production of deaths and anomalies. It was found that day 8 showed a significant increase of resorptions, deaths, and anomalies combined (controls 22.3% and exposed, 68%). The most frequent effects were resorptions and deaths, as observed shortly after irradiation. When only congenital anomalies were counted, days 4 and 8 appeared to show increased anomalies, but they were not statistically significant (controls less than 1%, irradiated 10%). Examinations for anomalies were made at gestation day 18. Results of the experiment suggest that day 8 is the most sensitive day for inducing anomalies in mice.

A total of 118 time-mated CF1 white mice were exposed when their fetuses were 9, 12, or 16 days to 2450 MHz microwave at 7.4 W forward power for 4 minutes, a sub-lethal exposure. This resulted in mean absorptions of energy from 22.4 to 27.2 J/g, the extent of absorption being roughly in an inverse proportion to animal weight and therefore, to gestation age. Irradiated fetal mice were delivered normally. At maturity (2 months of age), they were again exposed to microwave radiation, under the same conditions as previously, until killed. A parallel group of 25 2-month-old control animals were similarly irradiated, and the absorbed dose in J/g and the time in minutes to kill were taken as measures of radiation tolerance or radiosensitivity of the originally irradiated fetuses.

Males initially irradiated as embryos on days 12 and 16 and females irradiated on day 16 showed a slight but stastically significant reduction in the mean time to death. Only the males irradiated as embryos on day 12 showed a significant reduction in the mean absorbed dose at death. None showed mean absorbed doses greater than did the controls, hence there was not evidence of any acquired resistance to radiation effects. Other effects were noted. At 2 months of age, males initially exposed _in utero_ had mean body weight significantly lower than did the control males. At 2 months of age, females initially irradiated _in utero_ on day 16 were statistically lower in mean body weight than any of the other females, irradiated on other days, or controls.

A total of 130 female mice were singly exposed at 8 days gestation to 7.3 watt, 2450 MHz radiation for 4 minutes. Some of the irradiated mice were restrained, but not immobilized or anesthetized. The others were anesthesitized prior to exposure and placed in three orientations with respect to the field (head on, tail on, or sideways). The rectal temperature drop due to anesthetic was roughly equivalent to the microwave induced temperature rise in these acute exposure studies. Among the 1328 offspring examined (1001 irradiated _in utero_ and 327 controls), fetal damage was greater among irradiated unanesthetized dams than those that were anesthetized. Among mice immobilized with anesthesia, fetal injury was least when dams were exposed in the broadside position.

Two chromosomal studies were reported during 1976. One reported chromosomal breaks and increased aneuploidy of cells exposed chronically to microwave radiation. The second reported sequential appearance, after acute high-level microwave exposure, of chromosomal stickiness in mitotic cells and then chromosomal aberrations.

In the first experiment, a 2450 MHz microwave oven was converted into a microwave incubator to maintain cell cultures at 37°C. The energy absorption rate of the culture was calorimetrically measured to be 15.2 mW/g. Rat kangaroo RH-5 and RH-16 cells were grown in 5 ml of medium in plastic T-25 flasks, and were subcultured every 5-7 days. They were incubated with microwave heating continuously for 50 passages (320 days), and then were returned to a conventional incubator and allowed to grow for another 30 passages. Chromosome aberrations were not observed until the cells had been microwave-incubated for 20 passages. After the long-term irradiation (50 passages), RH-5 cells had 0.84 chromosome breaks per cell while RH-16 had 0.10 breaks per cell. After the cultures had been returned to the conventional incubator and maintained for 30 passages, the number of chromosome breaks reduced to 0.18 and 0 breaks per cell for RH-5 and RH-16, respectively. The number of polyploid cells were increased to 35% and 31% during irradiation and reduced to 12% and 11% in the conventional incubator, in RH-5 and RH-16 cells respectively. Many RH5 cells lost one chromosome and became 10 chromosome cells. The number of 10 chromosome cells increased to 44% during irradiation and continued to increase after being returned to the conventional incubator.

In the second study, adult male chinese hamsters (Cricetulus griseus) were injected with 0.1 percent solution of Colcemid (Ciba) either 0.25 hour before or after, or 2 hours after irradiation (2450 MHz at incident power density of 200 mW/cm^2 for 15 min.). Bone marrow cells were removed from femurs and prepared for mitotic and chromosomal evaluations. The mitotic index was depressed in preparations made at 5 hours from animals irradiated after injection, in comparison with either sham irradiated injected animals or animals irradiated prior to injection. The prevalent chromosomal response at 5 hours was chromosomal stickiness. Stickiness phenomena were observed between both chromosomes and sister chromatids. Chromatin bridges were also observed between nuclei, and were interpreted as evidence that cells with chromosomal stickiness escaped the Colcemid block. In one series, such bridges were evident in 10-15 percent of cells completing cytokinesis. One week after irradiation, bone marrow cells from irradiated animals showed a reduction in stickiness phenomena, but chromosome structural aberrations, including breaks and rearrangements, were significantly higher than in controls.

Because of the thermal sensitivity of mammalian germinal tissues, the testes are of special interest in the study of microwave effects. To investigate the possibility that thermal stress by microwave irradiation induces unique biological effects, as opposed to conventional heating, the testes of 100 albino rats of the Sprague-Dawley strain were exposed in vivo to 2.5 GHz continuous wave radiation and histologically compared to the testes of 50 rats heated by immersing the scrotum in warm water. Preliminary experiments indicated that an intra-testicular temperature rise to 40°C by a single microwave irradiation, maintained for periods of 5 to 25 minutes, produced degenerative changes in less than 50 percent of the animals exposed. Temperature rises to 38°C and 42°C were also investigated for single and repetitive exposures. In both microwave and water bath experiments, the intratesticular temperature was continuously monitored and maintained at selected temperatures for chosen periods of time. Similar histological damage was observed after both types of exposure.

Lymphocyte Studies. Blast transformation of lymphocytes in peripheral blood from adult mice was obtained after they were exposed to 2450 MHz microwave irradiation at average absorbed dose rates between 10 and 35 mW/g without any added antigenic stimulus. A 5 minute, 10 mW/g exposure resulted in blast transformation in about 50 percent of animals. After a 20-minute exposure, 100 percent of animals showed the response. At either 20 or 35 mW/g, 100 percent of exposed animals responded after exposures of 5, 10 or 20 minutes. The response was typically observed 68 days after exposure. In some animals, transformed lymphocytes were observed as early as two days after exposure. The appearance of blast forms in the blood persisted for approximately 14 days after exposure in adult mice.

In a separate experiment, mice exposed in utero on the 13th day of gestation to 2450 MHz CW microwaves at 1.5 mW/g for 30 mins. showed mitotic cells in circulating blood at 120 days after exposure.

In experiments conducted collaboratively with the U.S. Navy, data were developed which indicated that the affected lymphocytes were B cells. A single 30-minute exposure of mice to 2450 MHz microwaves at average absorbed does rates to 12 to 15 mW/g in an environmentally-controlled waveguide facility induced a significant increase in the proportion of complement-receptor positive lymphoid cells in the spleen. This effect was further enhanced by repeated (three times) exposures which, in addition, of Ig^+ cells. The proportion of theta-positive cells and the total number of spleen cells remained unchanged.

Behavioral Effects. Previous research has established that microwave radiation is capable of affecting behavioral changes in an organism. A study with the Bureau's waveguide apparatus has shown that the measured percentage of forward power absorbed by a mouse can vary according to the orientation and position of the animal in the waveguide. An experiment was undertaken to quantify the ability of 2450 MHz CW microwave energy to generate avoidance behavior in the male mouse (30-34 g). Subjects were irradiated (30 minutes) in an environmentally controlled waveguide assembly at forward power levels of .84, 1.6, 2.4, 3.2, 4.0 and 4.8 W. At 1.6 W and higher, the absorption rate decreased after the initial 5 minutes and remained lower for the duration of the exposure. Subjects exhibited an average maximum of 57% absorption at .84 W and this decreased with increasing power to an asymptote of approximately 35% at 3.2, 4.0 and 4.6 W. Although no visual observations were possible during irradiation, it is assumed that the subjects actively decrease their potential dose of microwave energy by altering both their orientation and position within the waveguide assembly. The data suggest that the subjects are capable of detecting average dose rates of as little as 28 mW/g. Furthermore, this level of choices; a short tone signalled each correct choice. Errors resulted in a timeout in the dark, thus delaying the onset of the next trial. Baseline rates were obtained for at least 5 days before each exposure. Subthreshold levels of PCPA (p-chlorophenylalanine) or fenfluramine were administered and 10-25 W of microwave energy at 383 MHz was delivered to the head of the monkey. Irradiation of the monkeys combined with fenfluramine administration resulted in a decrease in the response rates greater than that obtained by either microwave or fenfluramine alone. The combination of PCPA and irradiation also decreased response rates more than microwaves or PCPA alone, but less than the combination of microwave and fenfluramine.

Activities during 1977 and 78 include:

Instrumentation Research

Calibration System for Microwave Oven Survey Instruments. - An automated calibration system for microwave oven survey instruments has been completed. It has been used to calibrate hundreds of instruments owned by FDA, and other State, local, and Federal agencies who perform microwave oven leakage surveys. In addition to providing increased speed and improved accuracy of calibration, this computerized system allows immediate access to calibration, location, and repair records for every instrument that has been calibrated with this system. These records have been used to statistically analyze the quantity and accuracy of the calibration factor which is assigned to these instruments by their manufacturers. Since these instruments are used to determine if ovens comply with the Microwave Oven Standard of PL 90-602, the instruments' precision, at the time of manufacture and over their useful lifetime, must be known. The Bureau computer records provide a basis for predicting the quality of calibrations for each model of these instruments. This in turn supports the overall leakage-testing quality-assurance review performed by the Bureau for all oven manufacturers.

Direct Contact Diathermy Applicator. - Microwave diathermy efficacy studies have been performed and results have been published for various applicators developed by the Bureau and its contractors. A direct contact applicator with greatly reduced radiation leakage characteristics and uniform heating capabilities was developed and compared with presently available non-contacting applicators. The feasibility has thus been demonstrated for producing clinically acceptable equipment that meets the safety and efficacy requirements of the proposed Microwave Diathermy Standard. In addition, techniques for characterizing the relative effectiveness of diathermy equipment have been developed. Those techniques can be of value in effectively transferring information from diathermy equipment and researchers and manufacturers to the medical users of this equipment. This cooperation will aid in the overall reduction of unnecessary radiation exposure to patients and equipment operators, and in the improvement of therapeutic procedures.

Precision Thermometry Calibration and Evaluation Facility. - A precision thermometry calibration and evaluation facility has been developed. It is used in conjunction with specialized implantable thermometers which allow thermal dosimetry to be performed in animals and biological phantoms exposed to RF and microwave radiation. Because typical exposures produce only a small temperature rise in biological specimens, precise measurements of this change in temperature must be recorded.

The thermometry facility includes NBS-developed temperature reference standards and specially calibrated reference thermometers. The implantable dosimetric thermometers calibrated and evaluated in this Bureau facility are being used in its various biological effects studies, its dosimetry program, and in other research facilities.

Automated Dielectric Measurement Facility. An automated dielectric measurement facility has been established to allow the microwave characterization of real and simulated biological tissues. This facility will allow Bureau researchers to further define microwave radiation energy deposition as a function of frequency and biological specimen composition. This dosimetric information will also be applied in the microwave diathermy program which requires leakage and effectiveness measurements to be performed in conjunction with accurate phantom models of portions of the human body.

Radiofrequency Interference in Medical Instrumentation. Laboratory tests are being performed on the electromagnetic characteristics of typical medical devices to determine their compatibility with the proposed FDA Electromagnetic Compatibility Standard. To determine its performance characteristics under susceptibility levels set forth by this proposed standard, an ECG unit was investigated during 1978 and other devices will be evaluated.

Microwave Cancer Therapy Product Evaluation. In cooperation with clinical research groups, the Bureau is evaluating microwave cancer therapy products with respect to safety and effectiveness in the laboratory and clinic. Evaluation of new techniques for microwave-induced hyperthermia treatments of a cancer is presently ongoing. A microwave cancer therapy project has been initiated, and a clinical applicator for hyperthermia treatment at 915 MHz has been evaluated.

RF/Microwave Transceiver Product Evaluation. The Bureau is developing techniques which will yield reliable information on the emission intensities from the most popular types of transceiver/antenna systems. Present commercial instrumentation, along with newly developed, specialized instrumentation, are being evaluated for their capability to measure emission levels correctly, at source separation distances commonly used (5 cm for handheld units and up to 1 meter for automobile mounted). Field fall-off for intermediate regions is being measured. Field distribution along the length of the antenna is being mapped.

Automobile mounted 450 MHz antenna systems (monopole and horn) have been measured. Power density levels ranged from 0.1 to 100+ mW/cm^2 inside the unoccupied automobile. Six automobile mounted, and two handheld CB transceiver systems (27 MHz), using legal maximum power of 4 watts to the antennas, were also measured. Measurement distances were 5, 12, and 60 cm. Field strengths exceeded 1000 V/meter and 1.2 A/meter.

Biological Research

Behavioral Studies. - Studies have demonstrated that under certain conditions, exposure to microwave radiation may alter the behavior of laboratory animals. In three separate experiments, Bureau scientists have followed up on their previous reports of microwave effects on behavior, namely; (1) behavioral changes induced by the interaction of microwaves and a neuroactive drug, (2) the stimulus properties of microwaves in producing avoidance behavior, and (3) the possibility of using microwaves as a conditioning agent to produce an acquired taste aversion.

To test the assumption that microwave-induced behavioral changes are a result of neurochemical changes produced by the RF radiation, four monkeys were injected with fenfluramine, an appetite suppressant that acts on the central nervous system--in dosages which, by themselves, did not alter behavior. The animals then were irradiated with 2450 MHz CW microwaves at up to 15 watts total absorption in the head, a dose rate which had been shown to produce no change in their behavior. Although no changes were observed after the administration of fenfluramine or microwaves alone, the combination of the drug plus irradiation produced severe disruptions in the behavior of three of the four monkeys.

In a study to determine whether microwaves can produce avoidance behavior as suggested in the behavioral studies described earlier in this section, investigators exposed CF1 mice to 2450 MHz CW radiation at 2.7 watts. The exposure sessions lasted 30 minutes. The mice could respond by interrupting a beam of light in the waveguide that turned off or delayed the onset of exposure. Over repeated sessions, there was a significant increase in the frequency with which the mice performed the response that allowed them to escape or avoid the radiation.

Since it had been demonstrated that animals could learn to avoid microwaves, another study was undertaken to determine if aversion to the radiation would overcome their known taste for sugar. In this experiment, rats were allowed to drink a sucrose solution and then immediately subjected to a 15-minute waveguide exposure of 915 CW radiation. The average absorbed dose rate was 17 mW/g. When the rats were given access to the sucrose solution 24 hours later, there was no decrease in the amount consumed, indicating they had not learned to associate any aversive properties of the single exposure to radiation with the sweetened taste of the water.

Epidemiology. The Bureau is studying the effects of exposure to radiofrequency radiation, typical for physical therapists. Specifically, the study attempts to determine if the offspring of male physical therapists who use diathermy equipment are at medical risk for birth defects, particularly clubfoot. The study will also assess pregnancy outcome among wives and whether men exposed to radiofrequency energy exhibit a higher incidence of infertility and/or illness and symptoms purportedly related to radiofrequency exposure. Pretest data from 200 men have been collected and are being analyzed in preparation for the full-scale survey. Ambient levels of exposure to radiofrequency energy emanating from microwave and short-wave diathermy has also been determined. Data is being collected, by means of a survey questionnaire, on exposure, health status, and reproductive function of exposed male physical therapists and a group of nonexposed controls.

Symposia and Workshops

The Bureau's current in-house and extramural activities in the area of microwave and other radiofrequency research were reviewed at a Symposium on Biological Effects and Measurement of Microwave and Radio/Frequency Sources. More than 120 persons, including representatives of Federal and State agencies, industry, and the news media, attended the February 1977 meeting in Rockville, Maryland. The meeting brought together Bureau contractors, grantees, and headquarters personnel to exchange information on their research and to review the status of ongoing projects. Among the topics addressed were the biological effects of human and animal exposure to various levels of microwave radiation; microwave/radiofrequency measurement, instrumentation, and techniques; and the health implications of occupational exposures. Proceedings were published as an HEW publication, FDA 77-8026 (see Appendix B).

A Workshop on the Physical Basis of Electromagnetic Interactions with Biological Systems was held at the University of Maryland in June 1977. The workshop was sponsored by the Office of Naval Research, the Naval Medical Research and Development Command and the Bureau of Radiological Health. The purpose of the workshop was to bring together leading investigators in the fields of physics, engineering, biology, and chemistry who are studying electromagnetic interactions with biological systems. Topics included the results of recent research, discussions of the present status of the field and the priority of significant problem areas, and evaluations of conflicting theoretical interpretations and experimental techniques. The proceedings and additional contributed papers were publishied in HEW publication, FDA 78-8055 (Appendix B). Another workshop on this subject is being planned for May 1979.

HEW/NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES (NIEHS)

NIEHS research continues to concentrate on investigating low-level, specific microwave effects on cell systems, developing embryonic systems, and neurological function.

Preliminary studies on the effects of 2450 MHz CW radiation, at 5 mW/cm^2 (0.7 mW/gm absorbed power) power density, on rat lymphocytes showed a depressed simulation when treated with the mitogen phytohemagglutinin (PHA). In these studies no change in stimulation was found on exposure to 20 mW/cm^2 (2.8 mW/gm absorbed power) as noted in OTP's 1976 summary report. During 1976 these studies were repeated several times utilizing very accurate temperature control. The rat lymphocytes were exposed _in vitro_ to continuous wave microwave radiation of 2450 MHz at intensities of 5, 10, and 20 mW/cm^2 (corresponding absorbed power densities were 0.7, 1.4, and 2.8 mW/gm respectively). The lymphocytes were exposed for 4, 24 or 44 hours either with or without the addition of PHA. The transformation of lymphocytes into lymphoblasts was monitored by the addition of tritiated thymidine. In contrast to the preliminary results of 1975, no significant differences (P. = 0.05) were found in the uptake of tritiated thymidine between exposed and control cultures under the conditions tested.

Studies of microwave effects on the embryo are continuing using the Japanese quail as the biological test system. During 1975 developing quail embryo were exposed to 2450 MHz CW radiation at 5 mW/cm^2 (specific absorption rate of 4.03 mW/gm) throughout the first 12 days of embryogensis. The quail were maintained through maturity and mated. A reduction in fertility was observed when the exposed males were mated to either the exposed or control females. Studies to determine the cause of this reduced fertility continued during 1976 and 77. Mating behavior studies have shown no differences in the mating behavior of any of the mated groups. Semen was collected from the males at 23 weeks of age. Spermatozoal numbers and mobility in semen samples was significantly reduced ($\underline{P} < 0.01$). Spermatozal viability and morphology were not different nor were there any differences in testes weights between exposed and control subjects. Histological evaluations of the testes indicate no gross morphological or cellular abnormalities in either control or exposed quail.

Immunological studies are continuing on quail exposed as embryos. At five weeks of age the quail were challenged with sheep red blood cells (SRBC). Four days after antigen challenges it was determined that the levels of the anti-

SRBD antibodies were of the same magnitude for both the exposed and control quail. Preliminary studies in 1975 had found an increase in the size of the bursa in 22 weeks old female quail exposed as embryos but not in males. Since a significant part of humoral immunity in the quail results from the function of the bursa, experiments are being conducted to evaluate the immunological response of the 22 week old quail. Future plans include exposing fertilized quail eggs to microwaves of the same frequency and average power density (i.e. 2450 MHz, 5 mW/cm^2) during the entire developmental period to compare the effects of different modalities.

The measurement of sister chromatid exchange (SCE) constitutes the most sensitive indicator yet developed for detecting cytogenetic effects of mutagens and carcinogens. During 1977 this sensitive assay was used to investigate potential mutagenic effects of microwave (2450 MHz) radiation by comparing the incidence of SCE in bone marrow cells of 12 exposed mice, 12 sham controls, and 12 standard controls following a 28 day treatment period. The entire exposure set-up was placed inside an environmental chamber lined with absorber and maintained at 22° C and 55 percent relative humidity. The daily treatment regime consisted of two 4 hour exposure periods separated by one hour at midday when animals were fed and watered while the horn antenna was turned off. The incident power density inside the styrofoam cages, as measured with an NBS isotropic probe, ranged from 18 to 22 mW/cm^2. At a level of 20 mW/cm^2 the specific absorption rate was determined to be 17.0 mW/gm. Colonic temperature during exposure at 20 mW/cm^2 increased within ten minutes and ranged between 0.8 and 1.1° C above the initial value throughout the four hours of exposure. Measurement of SCE frequency was performed by differential labelling of sister chromatids with the base analog 5-bromodeoxyuridine and subsequent staining of chromosome preparations. Results, after scoring more than 300 cells, show that the incidence of SCE's in the exposed group is not significantly different from the unexposed controls. The value is approximately 3.0 exchanges per cell.

A significant amount of effort has been spent to develop a program to study long-term, relatively low-level microwave exposures. Two contracts were awarded, to the University of Washington and Utah University in July '76 to study the effects of 915 and 2450 MHz CW radiation on the nervous system of rodents. Biochemical analysis of the cholinesterase activity of the blood, the sulfhydryl (SH) groups in the blood, and ketosteroids in the urine are being performed and correlated with EEG and behavioral measurements.

At the University of Washington, exposures are being conducted at an equivalent free field incident power density of 5 mW/cm^2, 8 hours per day, 7 days/week for 4 months with observations made for a two month period after termination of exposure. Additionally, eight pregnant female rats were exposed 20 hours/day during 18 days of gestation to 5 mW/cm2, 918-MHz CW microwave fields without apparent effect upon their health or subsequent deliveries. No discernible physical or physiological deficits characterized the dam's offspring at birth nor throughout development. However, when tested as adults, these offspring demonstrated a significant behavioral deficit during acquisition of a conditioned avoidance response. Evidence suggests that disruption of the normal pituitary-adrenal axis response to stress affected performance in this task. These findings illustrate the value of using adult behavioral protocols as a supplement to more standard morphological measures employed to assess teratogenic effects.

As part of the US/USSR cooperative program in this area being coordinated by NIEHS, eight female rats were exposed to 500 $\mu W/cm^2$ (0.5 mW/cm^2) for 7 hours/day, 6 days a week for 3 months in individual anechoic chambers. All animals were exposed from above in individual chambers with a field closely simulating a plane wave. Monthly assessments of urinary ketosteriods failed to reveal any difference between exposed and sham-exposed control rats. Blood cholinesterase and sulfhydrl (glutathione) activity revealed significant initial decrements in the exposed animals relative to the controls followed, subsequently, by no differences between groups at the end of months 2 and 3. Evaluation of serum electrolytes, CO2 and BUN at the end of the three-month exposure protocol revealed significant differences in Na^+, K^+, CO_2 and ion gap. After a onemonth recovery period, the evaluation of all these parameters was repeated and it was found that the exposed group still differed significantly with respect to Na^+ and ion gap but appeared to be "recovering". Behavioral testing of shock sensitivity monthly, and terminal tests of open field activity and shuttlebox avoidance responding also revealed significant differences between the groups at the end of three month's exposure.

At the University of Utah, the exposure of Long-Evans rats to 918 MHz CW microwave radiation has been completed. The animals were exposed 8 hours/day, 5 days per week for 16 weeks to a power density of 5 mW/cm^2 in a plane wave field. "Innate" locomotor behavior was assessed on a regular schedule during exposure using a running wheel and activity platform. No changes were found in the exposed group when compared with the sham controls. An assessment of rate performance on a multiple fixed ratio-differential reinforcement of low response rates (FD-DRL) reward schedule was also performed. Preliminary analysis of the data indicates a drop in the responses per second on the FR component of the schedule in the exposed animals. Hematological evaluations and serum and urine chemistries have been carried out on the animals. Only one parameter, total free sulfhydryl groups, showed a difference (increase) between the irradiated and sham irradiated groups. This difference was indicated during the first week of irradiation and thereafter returned to baseline levels. This work is continuing and will include 2450 MHz exposures in the future.

HEW/NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

NIOSH is concerned with developing scientific data, information and recommendations in support of occupational protection (standards) activities of the Department of Labor, Occupational Safety and Health Administration (DOL/OSHA).

The OSHA Radio-frequency Microwave Radiation Exposure Standard (29 CFR 1910.97, June 2, 1974) applies to electromagnetic (EM) radiation from 10 MHz to 100 GHz. However, from 10 to 300 MHz this standard is not practically usable because exposure monitoring techniques are not specified and electric and magnetic field monitoring instrumentation has not been commercially available. Additionally, insufficient information is available on biological effects in this frequency range to adequately determine appropriate safety levels. The OSHA standard is based on the American National Standards Institute (ANSI) standard C95.1-1966. Both ANSI and OSHA are aware of these limitations in their standards. ANSI reissued its 1966 standard (C95.1-1974) on December 2, 1974, including equivalent free-space electric (E) and magnetic (H) field strengths of 200 V/m rms and 0.5 A/m rms, respectively.

NIOSH is in the process of reviewing information and developing a criteria document which will contain a recommended RF/microwave occupational health standard. In December 1976 NIOSH solicited relevant information through the Federal Register and in October 1977, announced its intention to develop a recommended standard. Little or no useful information was received and NIOSH undertook a review of world literature which was completed in 1978. The final criteria document with recommendations is expected to be completed in 1979.

A survey project to determine the magnitide of occupational exposures to radio frequency (RF) radiation in industry was formally concluded during 1976, however occasional measurements continue to be made as warranted. The frequency range of interest in the survey was the ISM (Industrial-Scientific-Medical) band frequencies (13, 27, and 40 MHz) which are widely used in industrial processes. Magnetic and electric field strength measurements were performed during surveys in the wood and wood products industry using probes developed by NBS for NIOSH specifically to independently measure the electric and magnetic components of the "near field" in the frequency range of 10-300 MHz. Comparisons with commercially available monitors, using a unique RF exposure synthesizer developed for NIOSH by NBS, showed that only one was usable from 13 to 40 MHz. A total of 88 industrial units were surveyed and 1,359 source measurements were made. Repetitive electric and magnetic-field strength measurements, taken under the same exposure conditions, showed more variation in magnetic-field strength measurements. Differences between field strength readings, taken at seven anatomical positions, indicated the need for multiple readings to describe an individual's exposure. The dependence of field strength readings on the distance from RF power sources revealed the presence of standing waves. At least 76% of the sources emitted electric and magnetic-field strengths that exceeded the ANSI guidelines of 200 V/m and 0.5 A/m; at least 55% exceeded 400 V/m.

Studies of total power absorbed and its distribution in man, utilizing human phantoms, were also concluded during 1976. These studies were conducted at frequency and field strength conditions utilized in experiments on the influence of RFR lymphocyte division response in monkeys. This resulted in final rectal temperatures of as much as 43° C (43.5° C produced lethality.) As reported previously, these experiments demonstrated that at 26 MHz the response has an incident field strength threshold between approximately 2,000 and 3,400 V/m.

The human phantom modeling studies show that a small amount of absorbed power is distributed in some of the long bones and neck, with some general surface heating. This pattern of specific absorbed radiation (SAR) is expected to be constant below (whole body) resonant frequencies, differing only in intensity. When the field impedance drops below 300 ohms, the distribution is expected to more closely resemble that of magnetic coupling, with torroidal eddy current patterns. The SAR is expected to be greatest in the groin and lower thorax under these circumstances. Introduction of a ground plane completely alters the resonant frequency, the distribution of SAR, and the absolute magnitude of the SAR. These effects might be caused by the increased current density in conductive pathways adjacent to the ground plane, or they could also be caused by inclusion of the man as a conductive element in a radiating antenna, since the radiation resistance might be quite low under these circumstances. The presence of ground return paths is being considered at both the University of Utah and the University of Washington, while the radiation resistance has been considered very little. Both of the latter considerations have a very important place in modeling theory as it applies to industrial occupational RF radiation exposures. A report (DHEW/NIOSH No. 77-183) describing the results of the phantom modeling research was published in September, 1977 (Appendix B).

NIOSH has initiated research to investigate the incidence of teratogenic effects in rats exposed to 27.12 MHz--the frequency most commonly used in industry as documented in NIOSH surveys. Experimental protocol has been designed to also determine the maximum tolerance RF exposure conditions for rats. Based on these studies, exposure conditions just short of lethal levels were chosen for the initial teratology studies. Pregnant rats were irradiated in an RF Near-Field Synthesizer operating in the dominant magnetic field mode at 27.12 MHz at a magnetic field strength of approximately 50 A/m. This resulted in final rectal temperatures of as much as 43° C (43.5° C produced lethality). Experimental animals were irradiated without anesthesia for 20 to 30 minutes on gestation days 9, 11, or 13. Control animals were housed and mated under identical conditions but not irradiated. All animals were sacrificed on gestation day 20 (21 day gestation period) and their fetuses examined by standard teratology procedures. The irradiated animals had a specific absorption rate (SAR) of 17 to 35 mW/gm, depending upon total irradiation time. Fetuses of the 21 females initially irradiated had a high incidence of gross external (55.6%) and visceral (33.3% to 50% depending on gestation day) malformations. Malformations were most prevalent in rats irradiated for 30 minutes on gestation day 9 and in rats irradiated for 25 and 30 minutes on gestation day 13. The primary defects noted were exencephaly, meingoencephaloceole, severe facial aplasia, micrognathia, agnathia, microphthalmia, anophthalmia, and various heart, kidney, and liver anomalies.

The RF exposures appear to interfere with fetal growth as evidenced by a decrease in average body length and weight observed in treated animals. In some litters, growth was severely retarded while in others no effect on growth was evident.

The effects seen in these initial experiments appear to be thermally induced. Teratogenic effects have been induced by heat alone. There appears to be a definite correspondence between fetal malformations and final rectal temperature of the pregnant animals (final rectal temperature on order of 43°C). This is in agreement with the published findings of Rugh and others in microwave-irradiated mice. The developing embryo is known to be highly susceptible to teratogenic insult during the period of organogenesis covered here. A sudden, though temporary, increase in embryonic temperature due to the RF in these experiments during this critical period could disrupt normal morphogenetic processes and cause death or permanent malformations. The initial results of this study indicate this may be occurring and additional research is being carried out to determine dose/response curves, thresholds, and to elucidate these effects, particularly as regards their significance with respect to man.

NIOSH is also attempting to establish an epidemiological study of people exposed in their occupations to RF/microwave energy. It is planned to include a retrospective study of mortality, chronic diseases, and to study reproductive health. Various candidate populations are being surveyed to identify appropriate exposed and control groups for such a study.

THE ENVIRONMENTAL PROTECTION AGENCY (EPA)

The Environmental Protection Agency's nonionizing radiation activities are conducted in the Office of Radiation Programs, a part of the Office of Air, Noise, and Radiation, and in the Health Effects Research Laboratory, Research Triangle Park, N.C., a part of the Office of Research and Development.

The Office of Radiation Programs' activities include measurement of environmental levels of microwave (MW) and other radiofrequency (RF) radiation, and analysis and evaluation of the radiation environment and the RF/microwave sources that contribute to this environment. Other activities involve estimating the population exposed to environmental nonionizing radiation levels, evaluating the results of biological effects research, and development of criteria, guidelines, or standards to protect individuals from exposure to excessive levels of environmental RF/MW radiation.

The Health Effects Reserach Laboratory's program activities are directed toward providing biological effects information useful in the development of exposure criteria, guidelines, or standards. These activities include research involving a wide range of biological effects experimentation and the development and use of the necessary exposure facilities and dosimetric instrumentation systems.

Environmental Radiofrequency Radiation Measurements Program

The principal activity of the Office of Radiation Programs during 1976-78 involved continuing and extending measurements of the general ambient-RF/MW radiation environment in several large urban areas in the United States and estimating the population exposed to the existing levels. This activity which began at the end of 1975 with measurements in Boston and Atlanta, continued with measurements in nine additional cities -- i.e., Miami, Philadelphia, New York, Chicago, Washington, DC, Las Vegas, San Diego, Portland, and Houston -- in 1976 and'77, and Los Angeles in early '78. It involves the use of a mobile computer controlled instrumentation system specifically designed to make these measurements. Additions to the computer system and development of specialized computer software have improved the system reliability and permit data to be collected and reduced at a much faster rate than was previously possible, allowing measurements to be made at over forty different locations in Chicago during a ten-day measurement period in October 1976 as compared to nine locations in Boston at the end of 1975 during the same measurement interval.

Another activity is the measurement of RF/MW radiation levels at specific locations in selected tall buildings in Miami, New York, Chicago, San Diego, and Houston. The criteria used in selecting these buildings were either that the upper floors were close to the centers of radiation of radio or television transmitting antennas located on nearby buildings, that radio or television transmitters were located on or near the roofs of these buildings, or a combination of both.

Specific source studies, involving analysis and measurements, were performed to describe the environment near an apartment complex containing 385 microwave ovens, to characterize the RF exposure environments produced by common traffic radar systems used by police for traffic control, and to evaluate possible RF exposures close to certain FM broadcast antennas. Several other source studies, involving analysis only, were performed upon request to evaluate the potential environmental impact of various transmitting stations at specific locations. Source types included microwave relay communications systems such as those used in television and telephone communication, air traffic control radars used by the FAA, and surveillance and tracking radars such as the Defense Department's long range missile detection and tracking radars, PAVE PAWS, at Beale AFB, California and Otis AFB, Massachusetts.

In addition, an analytical study was performed to determine the distribution of sources of RF/MW radiation in the U.S. relative to the environmental radiation levels these sources are potentially capable of producing at various distances from source antennas.

In November 1976, the urban area measurement activity was moved from the Washington, D.C. area to the Office of Radiation Programs' facility in Las Vegas, Nevada. The new field measurement facility became operational in early 1977. This relocation was required for efficient operation in measuring general ambient environmental levels in selected urban areas in the western United States.

Urban Area Ambient Environmental Measurements. As part of efforts to determine the need for standards to control environmental nonionizing radiation exposure, radiofrequency and microwave radiation levels are being measured in urban areas of the United States. Commencing in 1975 with Boston and Atlanta, this activity continued in 1976 with the completion of measurements in Miami, Philadelphia, New York, Chicago, and Washington, D.C. After relocation of the measurement facility to Las Vegas, measurements characterizing the radiofrequency environment were made in Las Vagas, San Diego, Portland, and Houston during 1977; and in Los Angeles in early 1978.

Measurements are made in the frequency bands which had earlier been determined to contribute the most to urban area environmental levels, i.e., broadcast radiation frequency bands. An instrumentation system installed in a van equipped with electrical power generators is used. The measurement system consists of three basic components: (1) various sets of antennas designed to detect RF and microwave radiation in the frequency bands of interest; (2) a scanning spectrum analyzer used to quantitatively analyze the detected signal; and (3) a minicomputer system which controls the operation of the antennas and spectrum analyzer, processes the collected data, and stores and displays the results for future evaluation. Frequency bands measured and antenna types used are as follows:

FREQUENCY (MHz)	USE	ANTENNA
0-2	VLF Communications and AM Standard Broadcast	Active Vertical Monopole
54-88	Low VHF Television Broadcast	Two Horizontal Orthogonal Dipoles
88-108	FM Broadcast	Three Orthogonal Dipoles
150-162	VHF Land Mobile	Vertical Coaxial Dipole
174-216	High VHF Television Broadcast	Two Horizontal Orthogonal Dipoles
450-470	UHF Land Mobile	Vertical Coaxial Dipole
470-806	UHF Television Broadcast	Horizontal Polarized Directional Log Periodic

Cumulative results of the power density measurements are available for 12 cities. They include measurements at a total of 373 sites in these cities in the frequency range from 54 to 900 MHz.

These measurements indicate that the FM band contributes the most to ambient radiofrequency exposure levels between 54 and 900 MHz. Within this range of frequencies each of the three TV bands contributes about equally. The land mobile bands make an almost negligible contribution to the total ambient power density and less active bands would make even smaller contributions. The maximum value measured to date at any of the 373 sites is approximately 150 $\mu W/cm^2$.

Population Exposure Estimates. A method of estimating population exposure must combine information on the distribution of radio frequency levels with the distribution of population to provide numbers of people exposed at various levels. The population data base used consists of the population count for each of 250,000 census enumeration districts (CEDs) in the U.S. along with the geographic coordinates of the approximate population centroid for the CED. The population of an area is considered to be concentrated at a set of discrete points. The total power density from all sources at each of these discrete points is determined and the population exposed at the various levels is summed.

The fraction of the population in the 12 metropolitan areas (total population greater than 38 million, about 17 percent of the total U.S. population) exposed to various levels of power density has been estimated. The estimated median power density -- i.e., that level at and above which 50 percent of the population in these 12 cities is exposed -- is 0.005 $\mu W/cm^2$. Less than one percent of the population is exposed to environmental radiofrequency radiation levels of 1 $\mu W/cm^2$ or more. A summary of estimated fractions of the population exposed to less than a specific level is summarized as follows:

Cumulative Population Exposures

Power Density ($\mu W/cm^2$)	Cumulative Percent* of Population
0.002	17.0
0.005	49.0
0.01	69.0
0.02	83.0
0.05	92.0
0.1	95.0
0.2	97.5
0.5	99.0
1.0	99.5

* For example, 17% are exposed to levels less than 0.002 $\mu W/cm^2$, 69% are exposed to levels less than 0.01 $\mu W/cm^2$, 95% are exposed to levels less than 0.1 μW/cm2, etc.

These estimates do not take into account exposure due to AM broadcast sources, daily movements of the population within an area, exposures at heights other than 6 meters above ground (height of the van's measurement antennas), attenuation effects of buildings, or times when sources are not transmitting.

Measurements of Levels in Buildings. RF radiation levels were measured on the upper floors of several buildings near broadcast antennas. Certain tall buildings in Miami, New York, Chicago, San Diego and Houston were selected because they are located close to FM radio and TV transmitters and, in most cases, the height of the buildings was as great or greater than the height of the nearby transmitting antennas. These measurements were made in order to study RFR environments at locations much closer to the main radiation beam of broadcast antennas than would be possible using the instrument van, in order to supplement the data collected near ground level. The measurements in the upper floor areas of tall buildings show that power density levels can be higher than those commonly found at near-ground levels, at least on the side of the building facing the source. The maximum total power densities (combined over FM and TV frequencies) measured on the upper floors of selected buildings in New York, Miami, and Chicago were 32 $\mu W/cm^2$, 97 $\mu W/cm^2$, and 66 $\mu W/cm^2$ respectively, and consisted primarily of radiation from FM radio and UHF-TV transmitters. The results of all building measurements performed are as follows:

Results of Measurements in Tall Buildings Which Are Located Close to FM And TV Antennas (1976-77)

Location	Power Density ($\mu W/cm^2$)		
	FM	TV	TOTAL
EMPIRE STATE BUILDING - New York			
86th Floor Observatory	15.2		
102nd Floor Observatory			
Near Window	30.7	1.79	32.5
Near Elevator	1.35		
WORLD TRADE CENTER - New York			
107th Floor Observatory	0.10	1.10	1.20
Roof Observatory	0.15	7.18	7.33

(CONT.)

(Building Measurements - Cont.)

Location	Power Density ($\mu W/cm^2$) FM	TV	TOTAL
PAN AM BUILDING - New York			
54th Floor	3.76	6.52	10.3
ONE BISCAYNE TOWER - Miami			
26th Floor	7		
30th Floor	5		
34th Floor	62		
38th Floor	97		
Roof (shielded location)	134		
Roof	148		
SEARS BUILDING - Chicago			
50th Floor	32	34	66
Roof	201	29	230
FEDERAL BUILDING - Chicago			
39th Floor	5.7	.73	6.5
HOME TOWER - San Diego			
10th Floor	18		
17th Floor	0.2		
Roof	119		
Roof	180		
MILAM BUILDING - Houston			
47th Floor	35.8	31.6	67

Specific Source Studies. In February 1976, in conjunction with the ambient environmental measurements in Miami, measurements were made of electric field intensities associated with microwave oven operation at a location outside a large condominium complex in Ft. Lauderdale, Florida. Microwave ovens are installed in the kitchens of all of the condominium apartments. These ovens were manufactured to operate at a nominal frequency of 915 MHz. All of the measurements were made at a location approximately 500 ft. from the two building apartment complex, and at a height of about 20 feet above ground level using the same instrumentation system used for urban area environmental measurements. Polarization components in both the horizontal and vertical planes were measured.

Monitoring was performed on three successive evenings during the time period 5:00 p.m. to 7:00 p.m. EST. The highest field intensity measured was 8.9 mV/m (2.1×10^{-5} $\mu W/cm^2$) centered at 920 MHz. During the measurements, it was never possible to observe that more than three ovens were operating simultaneously, although it might be expected that more ovens could be operating simultaneously. Frequency shifts, superimposing parts of the characteristic spectra of simultaneously operating ovens, could obscure the identification of other ovens operating at the same time.

In March 1976, a study was completed of typical portable traffic radar systems, used by police to determine the speed of vehicles relative to that of police vehicles. The study was initiated by a request for information by the Amalgamated Transit Union, Portland, Oregon, because of their concern over microwave exposure from traffic radars. An analysis was performed to determine radiation characteristics of four different commercially available traffic radar systems, and to predict on and off-axis power densities at various distances from the radiation sources, conical horn antennas. These systems transmit at 10.525 GHz and use the Doppler shift in frequency, related to the relative velocity of source and target, to determine the speed of the target vehicle. Measurements were performed on one system, which was provided by the Montgomery County (Maryland) Police for this study.

For one of the systems analyzed the maximum near-field power density possible was calculated to be 3.6 mW/cm^2. At a distance of only 1 meter from the source, this value was reduced to 0.09 mW/cm^2. The agreement between calculated and measured on-axis power densities at a specified distance from the source became better as the distance from the source increased. For example, for one system the near field on-axis power density was calculated to be 1.25 mW/cm^2. At distances of 1.2, 2.7, and 28.3 m the calculated power densities were 0.10 mW/cm^2, 0.025 mW/cm^2, and 0.00022 mW/cm^2 respectively. The measured power densities were 0.069 mW/cm^2, 0.035 mW/cm^2, and 0.00028 mW/cm^2 at the same distances. It appears that use of traffic radars cannot result in significant exposures to persons in vehicles being tracked by police radar.

Two different specific-source measurements involved specifying the near-ground level exposures possible for FM station employees working at locations close to antenna support towers with FM antennas mounted relatively low to the ground. In one of these situations, whole body exposures as great as 3 mW/cm^2 (equivalent far field power density) were measured while, in another case, partial body exposures (to the hands) of as much as 60 mW/cm^2 were found near the transmission lines.

Environmental impact analyses were performed for situations involving the proposed operations of two identical phased array radars, i.e., the U.S. Air Force's PAVE PAWS radar at Otis Air Force Base, Massachusetts and at Beale Air Force Base, California. The conclusions of the analyses were that there is no knowledge of adverse health effects that could result from exposure to the time-averaged power densities calculated to be produced at selected locations outside the boundaries of the bases.

<u>RF Source Distribution Analysis</u>. An analytical study was performed to obtain source distribution statistics, to evaluate their utility in determining the impact of Federal guidance or standards, and to evaluate the applicability of existing RF source data bases to this type of analysis. It is desirable to identify and specify the number of RF/microwave sources that have the potential to produce environmental levels which may equal or exceed a selected arbitrary threshold at various distances from a source antenna.

The study was performed by EPA with the assistance of the Electromagnetic Compatibility Analysis Center (ECAC), Annapolis, Md. The ECAC data base is a computerized file that contains the frequency assignments and related pertinent characteristics for U.S. sources of RF and microwave radiation except for equipment operating in the amateur bands, citizen bands, land mobile bands, and aircraft and commercial maritime bands. ECAC provided the data base, computer software, data processing and sorting, and graphic results. EPA defined the task, source selection criteria, calculational models, format for presentation of results, and is evaluating the results of the study and recommending corrective procedures where necessary.

The source categories included in the study are satellite communications earth terminals (SATCOMS), radars, and all CW communications systems (including SATCOMS) with the exclusion of broadcast transmitters, which are included in a separate study. Both classified and unclassified systems are included. The frequency assignments selected for anlaysis satisfy the following criteria: all SATCOMS that can be identified; all CW systems which operate at frequencies equal to or greater than 100 MHz with antenna gains equal to or greater than 20 dB_i, and transmitter power of at least 1 kW; all pulsed systems (radars) which operate at frequencies of at least 100 MHz with antenna gain equal to or greater than 20 dB_i and transmitter peak power of at least 100 kW.

On-axis time average power densities were calculated at a number of specific distances using analytical models provided by EPA. The models apply to paraboloidal antennas, but for this study did not compensate for reduction in time average power density of radar systems due to antenna rotation. The results are organized for each system category, i.e., SATCOMS, CW sources, radars, and composite for all system categories.

This initial study requires corrections in the frequency distributions obtained. A follow-up study, to identify and eliminate errors in the data base generated for the study and to modify and expand on the procedure used, is planned but has not yet been performed.

Biological Effects Research

The biological effects research program within EPA concentrated a large amount of resources in 1976 and 1977 on two long-term exposure studies that were similar in nature. These studies were intended to provide a chronic exposure to the animals and to investigate several different biological endpoints on the same set of animals. In one experiment, the exposures were carried out in an environmentally controlled (temperature and humidity) far field exposure facility at 2450 MHz, continuous wave. Exposure was at a nominal 5 mW/cm^2 for four hours per day. The second experiment was conducted using a Crawford cell transmission line at 425 MHz, continuous wave. Incident power to the cell was 20 watts giving a nominal 10 mW/cm^2 at the center line in the unloaded condition; exposures were also for four hours per day.

In the 2450 MHz experiment, exposure of 12 pregnant female rats began on the seventh day of pregnancy and continued until parturition (21 days). Irradiation of dams was discontinued at this point and pups were then irradiated on the same schedule until 90 days of age. An equal number of control rats were sham irradiated.

During the first 20 days, the neonatal animals were tested for reflex development, startle response and righting reflex, and for age at eye opening. At 20 days, half the pups were sacrificed for examination of hematological and immunological parameters. The former included red and white cell counts, hemoglobin, hematocrit and differential measurements. Immunological studies included assessments of the proliferative capacity of blood and lymph node T-lymphocytes using phytohemogglutinin (PHA) stimulation, and evaluation of the circulating antibody titer. At 40 days of age, three quarters of the remaining pups were sacrificed and most of the immunological and hematological tests repeated.

Irradiation of the remaining 12 male rats (plus controls) was terminated at 90 days and mutagenic effects were studied using the dominant-lethal reproductive assay. At 120 days of age (30 days post irradiation) locomotor activity of these animals was measured in a residential maze. Neurological deficits were examined by measurement of the EEG and the visual evoked response using a photostimulus. At 240 days of age, the locomotor activity measurements were repeated.

The experiment at 425 MHz followed the same protocol with a few differences. Space in the exposure facility limited the number of animals to half those in the 2450 MHz experiment and consequently the 20 day measurements were eliminated. Also, because of the small number of animals, the circulating antibody response measurements were not performed at 40 days.

Significant effects were found only in the immunological measurements. Preliminary results were presented at the ERMAC workshop on immunological effects held December 15, 1976 (Appendix C).

Measurements were made to determine the specific absorption rates (SAR) for the animals in these experiments. For the 2450 MHz study, a rat carcass was substituted at various positions in the exposure array and the energy absorbed subsequently analyzed by twin well calorimetry. These measurements showed that the SAR was 5.7 W/kg for 40-60 gram rats and 0.4 W/kg for 300 gram rats. In the 425 MHz study, the energy absorption was determined from measurements of forward, reflected and transmitted power in the Crawford cell exposure chamber. On certain days, these measurements were made throughout the 4 hour irradiation and the data stored by computer. The average SARs were approximately 3.5 W/kg for a 40 gram rat (pup), 4 W/kg for 100 gram rats, and 5 W/kg for 350 gram rats (pregnant dams).

Follow up experiments were conducted for certain aspects of these during 1977. The immunology portion of the long term exposure at 425 MHz was repeated for a total of four experiments. In two of the experiments an absolute neutropenia and relative lymphocytosis was observed in 40 day old rats; however, no such change was observed in the other two experiments. In addition, in a different pair of the four experiments, the repsonse of lymph node (but not circulating blood) lymphocytes stimulated by mitogens was increased after the irradiation regimen. A single additional experiment, where pups were irradiated _in utero_ only, indicates that exposure during gestation may be essential to the development of these changes.

The immunology portion of the 2450 MHz study was also repeated. In each case a significant increase was noted in the response of mitogen stimulated lymphocytes from 40 day old rats. However, no changes in peripheral blood counts were noted.

Results from the other assays conducted on the animals from the 425 MHz and 2450 MHz long term exposure studies all proved negative. These include the dominant-lethal reproductive assay, the test of locomotor activity of rats in a residential maze and the test for neurological deficits from measures of EEG and visual evoked response.

Other long-term exposure studies will be conducted including a similar study initiated in 1978 using a 100 MHz Crawford cell exposure facility and an experiment in which several animals will be exposed individually to 915 MHz continuously for several weeks in circularly polarized cylindrical waveguide systems similar to those designed by Dr. A.W. Guy at the University of Washington. Construction of a set of circularly polarized waveguides for use at 915 MHz was undertaken in 1978 and is expected to be completed in 1979.

Changes in immunological parameters were also found after short-term exposures of animals during 1976. In one study, mice immunized to *S. pneumonia* before exposure to 9 GHz pulsed radiation at 10 mW/cm^2, 2 hours a day for 5 days, showed a significantly higher antibody titer than controls. In another study, blood lymphocytes from Chinese hamsters irradiated for 15 minutes on 5 consecutive days at intensities up to 30 mW/cm^2 (2450 MHz) showed a dose related increase in blastic transformation in unstimulated lymphocytes but a decrease in cell division if stimulated with PHA. In an effort to follow up on this study, lymphocytes from mice exposed daily for 30 minutes to 2450 MHz at 5 and 15 mW/cm^2 for 2 to 17 days were assayed for their response to T and B cell mitogens (e.g., PHA, con A, LPS). Results showed differences in responses between irradiated and control animals that were marginally significant at the $p = 0.05$ level for rats exposed for 2, 5 and 9 days. In a later study, using similar exposure conditions no significant differences were found in these parameters.

In other studies, a large number of mouse litters were examined for teratological changes after daily irradiation *in utero* at 2450 MHz for 100 min/day starting on the 6th day *following* conception. Three exposure levels (3.5, 14 and 28 mW/cm^2) were used and a total of seven encephaloceles were found in approximately 300 litters (3000 animals), while no such anomalies were found in a similar number of controls. The normal incidence of this anomaly is 3 in 10,000. The significance of these results is being evaluated and additional research is being conducted.

The first phase of a study to investigate the microwave hearing effect using post stimulus time histograms for the auditory nerve was completed. Evidence was obtained which shows that transduction of the pulsed microwaves can be mechanical, through stimulation of hair cells, or through direct stimulation of the auditory nerve. An extension of this work is planned.

An epidemiological study of congenital anomalies in children born at Ft. Rucker, Alabama, was completed and the final report has been issued (Burdeshaw et al, Appendix B). The investigators concluded that the available evidence did not support a significant difference in the incidence of anomalies in the study population. However, they also concluded that the measuring device, i.e., examination of birth records, was so insensitive that a very high anomaly rate would be necessary for a significant difference to be detected.

Several behavioral studies are being conducted with both acute and chronic exposures of rats or squirrel monkeys. End-points being investigated include changes in social behavior, in stress-related biochemical substances, EEG prameters, and performance after operant conditioning. In one such study, rats irradiated at 15 and 20 mW/cm^2, 2450 MHz, for 15 hours were found to display at least a 40% decrease in task performance whereas no decrease was found with one hour exposures. Lower powers did not produce statistically significant decreases in behavior after 15 hours of exposure, but a trend towards lowered performance was seen at power densitites as low as 5 mW/cm^2.

Two behavioral experiments were conducted which follow up on these observations. Both used 2450 MHz, 15 hour exposures. In one experiment, rats were exposed at 5 and 10 mW/cm^2 at environmental temperatures of 22, 25, 28 and 31°C.

In general, effects were noted at the 2 highest temperatures at 10 mW/cm^2 exposure but no effects were found at 22°C. Using a different behavioral task, a seocnd experiment was conducted where rats were exposed at 5, 10 and 15 mW/cm^2 and 22°C. Only the highest exposure modified the animals' behavior. These experiments show the strong interaction of microwaves with environmental temperature at moderately thermal levels of radiation.

Another behavioral experiment examined the ability of rats to detect and minimize moderately thermal levels of exposure to 2450 MHz. Rats were placed in the exposure chamber for two hours and their positions inside their holders were noted every 30 seconds using a TV camera and videotape. The rats were exposed to 15 mW/cm^2 during the second hour only. No preferred orientation of the animals was noted during irradiation. This result contrasts with some results and indications found in other laboratories.

A chronic exposure study conducted at Stanford Research Institute has been completed. In this study unrestrained pregnant squirrel monkeys were exposed individually in specially designed multimode cavity chambers throughout gestation to 2450 MHz pulse modulated radiation, three hours per day, five days per week. Half of the infants from each exposure group were exposed on the same schedule to 12 months after birth; their mothers were exposed for 6 months. The calculated exposure levels were approximately 0.1, 1.0, and 10 mW/cm^2, equivalent plane wave average power densities. In addition to behavioral and EEG responses, biochemical and immunological parameters were investigated. No changes were found in behavioral, EEG, immunological or biochemical endpoints, but an unexpected, apparent high incidence of infant mortality, during the first year, occurred among exposed groups, primarily in the highest dose continuing exposure group. However, the numbers of animals per group was small (i.e., 4-6). Gross necroposies were performed on approximately half of the monkeys that died. In one animal the cause of death was diagnosed as mild interstitial pneumonia and for the remaining animals cause of death could not be determined. A paper on this study was presented at the URSI meeting in Helsinki, Finland, in August 1978 and a final report is in preparation.

<u>In vitro</u> work is concentrating on the study of amplitude modulated microwave radiation on the normal processes of enzyme systems, bacterial and mammalian cells, and brain tissue. During 1976 technical difficulties were encountered in the development of a dual line microwave spectrometer capable of identifying wavelengths of energy absorption for <u>in vitro</u> systems. The dual line instrument has been found to be technically unfeasible and effort was redirected to develop a single line instrument with data storage capability.

<u>In vitro</u> exposure of chick brain to 147 MHz radiation amplitude modulated (AM) at frequencies near 16 Hz confirmed the calcium efflux effect first described by Bawin and Adey. The

peak effect was confirmed to be at 16 Hz AM with the effect decreasing to zero as AM frequency is raised or lowered. In addition the effect is found to be power dependent, with a maximum effect at an exposure of about 0.75 mW/cm^2 and again decreasing to zero as the power is raised or lowered from this level. Because this effect is hypothesized to be membrane related an attempt was made to determine if the effect could be reflected as a change in the function of a membrane bound enzyme system. Red cell membranes and mitochondrial inner membranes were exposed *in vitro* to 2450 MHz radiation, amplitude modulated at several frequencies including 16 Hz. The activity of ATPase from the red cell membrane and cytochrome oxidase from the mitochondrial membrane was measured during irradiation. However, no changes in enzyme activity were detected.

Dosimetry work during this period has included: (a) construction of two pairs of twin well calorimeters which allow measurements of whole body absorption in small animals up to the size of adult rats; (b) application of heating and cooling curves to determine SAR for *in vitro* samples; and (c) development of a method for measuring whole body absorption for small laboratory animals using common laboratory equipment. This work, plus the capability for measuring power absorption electrically in the transmission lines (Crawford cell), provides this laboratory with the capability for measuring average SAR for all available exposure systems.

Dosimetry is now being performed for all whole animal experiments which allow an average whole body SAR to be calculated. Both twin well calorimetry and electrical measurements which allow calculation of energy absorption are being utilized. Work on an infrared thermographic camera is continuing so that dose distribution data will be available in the future.

Additionally, a study to calculate characteristics of prolate spheroid models in the resonant region has been completed. This extends earlier work using spherical models. Results confirm similar work by Gandhi at the University of Utah.

DEPARTMENT OF DEFENSE (DOD)

The nonionizing (RF/MW) radiation research activities of the military services are coordinated in a Tri-Service Program developed for the Office of the Director of Defense Research and Engineering (ODDR&E), and are an integral part of the overall Federal Government program.

New applications and the rapid proliferation of electromagnetic radiating sources in the military environment, will continue to produce occupational exposures and can incidentally expose other people. The feasibility of operating existing or newly developed RF/MW generating equipment (e.g., fire control, range finding, missle tracking, navigational, and mobile radars) is affected by safety and operational considerations including the costs of technical control measures and of providing controlled access and exclusion areas around such sources where necessary. It is therefore of considerable importance to develop a sound understanding of biological effects and/or hazards, particularly at low levels, for a wide range of frequencies and various waveforms.

DOD/U. S. ARMY

The Army's intramural and contract research program is designed to develop information on biological effects of electromagnetic radiation (EMR) over a wide range of frequencies (from less than 100 kHz to 100 GHz), primarily centered in the 10 MHz to 10 GHz range. Army systems make extensive use of EMR energy within this range. Such radiation can penetrate biological tissues, is potentially hazardous and, correlatively, also is of potential use in biomedical applications. Accordingly, the research program is designed to develop fundamental scientific information on EMR-biological interactions as well as to research potentially adverse, specific effects.

The research problems addressed have included (a) energy absorption and distribution, (b) fundamental biophysical and physiological effects at the molecular, cellular and tissue levels of organization, (c) effects on nervous and sensory systems and (d) effects on behavior and performance. Notable achievements were made in the 1976-early 78 period in the measurement of absorption of microwave energy, in the formulation and testing of models of energy absorption needed for making extrapolations from experimental animals to man, in the measurement of dielectric properties of biological materials, and in the development of techniques for making an electromagnetic analysis of physiological and pathophysiological states of cells in suspension.

Further improvements have been made in development of RF-transparent, implantable electrodes. The most nearly developed electrode is designed for making temperature measurements locally in tissues of interest during exposure of the experimental animal to microwaves. Such measurements are required frequently to make interpretable the results obtained in biological effects experiments. Improvements in the electrode include: use of the four-terminal method for measuring resistance in the active element (chip thermister) at the tip end of the sapphire needle; glass encapsulation of the transducer to improve long-term stability and physiological inertness; selection of materials and structural design to enhance the electrode's electro-thermal matching with tissue; and development of fabrication methods more suitable for standard production. Use of a hyperthin-film transmission line also has been incorporated to improve RF decoupling, to the extent that the electrode now can be operated in a much higher energy density field (i.e., 250 mW/cm^2, 2.45 GHz CW) than formerly (50 mW/cm^2) without exhibiting microwave heating. The electronics package for temperature encoding has been designed and tested, and the assemblage, including the electrode, has been successfully tested both for long-term stability in a highly controlled temperature bath and for hysteresis. The stability error, attributable solely to the encoding package, was about 0.005° C per degree C, and no detectable hysteresis was found.

Investigations were undertaken to determine the potential use of microwaves to interrogate complex dielectric targets, such as would be represented by biological tissues and organs, to extract information on the physical shape, structure, and RF electrical characteristics of the targets. The first investigations were designed to demonstrate the feasibility of obtaining three-dimensional plots of dielectrically heterogeneous objects by such non-invasive interrogation. Mechanical scanning methods were used to investigate spatial resolutions that might be obtained for dielectric objects immersed in deionized water. In one approach, scattering parameter measurements were employed using amplitude and phase information of S_{11} and S_{21} for a phase-locked 3243 MHz source and dielectrically loaded, matched antennas interfaced to an automatic network analyzer. Complex functions of space obtained in this manner were processed further to create an intensity representation of space. Detection of single and multiple dielectric discontinuities of dimensions much less than one wavelength were obtained. In a second approach, using the same scanning system, the velocity of propagation was used to determine time delays in transmission through dielectric targets for mapping their inhomogeneities. The interrogation signal was a linearly-swept-frequency pulse (2-4 GHz, 16 msec) propagated through a fixed-delay path. In this system, instantaneous frequency differences in the comparator output represent time delays due to changes in propagation velocity and path length effects due to diffraction. Path lengths equivalent to 40 picoseconds of propagation time were resolved, making it possible to detect target dimensions of less than one wavelength.

A new scanning system and new antennas were developed for subsequent investigations of scattering parameters and time-delay spectroscopy. The computer controlled scanner, using optical bench components, has improved the mechanical accuracy of the test system and water-loaded, open-ended waveguide antennas (perhaps the first developed for use under water) have reduced the effective aperture area and multipath interference without sacrificing bandwidth or signal strength. More complex targets have been tested with the improved system. On the basis of results of scattering parameter analysis, it shoud be possible to reach the Rayleigh criterion for resolution of about 5 mm and, for time delay spectroscopy, to detect discontinuities with similar accuracy.

The physical modelling of EMR energy absorption for man, based on use of isotropic, size-scaled models of man, has provided a means for testing general concepts that relate absorption to frequency and field geometry and to the size of man and his location and orientation in the field. These concepts, when verified, can serve to determine maximally hazardous exposure conditions suitable for regulating occupancy. This same information can also be used to establish reliable exposure parameters for animal experiments to investigate biological effects. The most useful theory to date has been the "dipole" absorption theory developed by Prof. Om Gandhi of the University of Utah. With this theory he has demonstrated "resonant" frequency effects, based on model length relative to the incident wavelength, and dependence of absorption on orientation of body long-axis relative to the E-field polarization plane. During this period he has tested the dipole theory further, conducting studies of absorption with models of man with far-field, plane-wave exposures with reflectors located immediately behind the model. In this arrangement, the model replaces the dipole element of a receiving antenna and, when located at an appropriate distance from the reflector, absorption by the model is enhanced by a factor corresponding to the gain of the antenna. With a 90^{o} corner reflector, a "resonant" length model located 1.5 wavelengths from the corner exhibited an enhancement of absorption nearly 27 times greater than that obtained without the reflector. The latency to thermal convulsion by rats of appropriate "resonant" size relative to the incident wavelengths was used to biologically test the antenna effect. With a 100-gm rat located 1.5 wavelengths from the reflector corner, exposure at the "resonant" frequency of 985 MHz with an incident field density of 4.5 mW/cm^2 produced convulsions within 500 seconds. This is an enhancement in energy absorption over exposure without the reflector that is comparable to that found with the size-scaled models of man.

In subsequent work, Prof. Gandhi employed exposure of the isotropic, size-scaled models of man to detect "resonant" absorption of body parts, such as the head portion, arm, torso and neck. These occur at higher frequencies, consistent with the antenna theory relating resonant length of these portions of the body to the wavelength of the incident radiation. In other work during this period, Gandhi and Hagmann have developed an improved method of numerical analysis to mathematically model energy absorption and its distribution in man conceptualized as composed of 180 cubical cells of various size. The results of this modeling are consistent with the experimental measurements made using phantom models. The mathematical model was also used to develop other implications of the "antenna" theory of absorption in man. For example, a 1.75 m tall man, electrically grounded, when exposed to a 10 MHz plane-wave field with the E field parallel to the man's principal body axis, would absorb energy, whole-body, at the rate of 0.016 W/kg per mW/cm^2, or about seven times the amount he would absorb exposed in free space. Furthermore, the rate of absorption near the grounding plane (e.g., the heel) would be enhanced by more than one order of magnitude.

A sample holder, previously designed, was fabricated and tested for use in measuring the complex permittivity of biological materials. The approach employs an automatic network analyzer to determine the complex propagation constant of the transmission line, of which the holder is a part, from reflection and transmission measurements. The system is calibrated using a compound whose complex permittivity is known. A computer program was developed which accepts as inputs the reflection coefficients of the empty sample holder, the holder filled with the unknown, and the holder filled with the calibrating material (e.g., water, carbon tetrachloride). The outputs, given as a function of frequency, are the real and imaginary parts of the complex permittivity, conductivity, and the loss tangent. The system does not require solution of transcendental equations, operates over a broad bandwidth (1 - 500MHz), does not require disassembly for calibration and is simple to use. The system was tested with various substances (e.g., ethanol, methanol, benzene, ethylene glycol) and the values of permittivity that were obtained were within 10% of those in the published literature.

Electromagnetic properties of biological molecules and cells were investigated starting with determination of membrane and cell structure of erythrocytes in isotonic saline suspensions. Experiments were conducted in the HF frequency band using automatic network analyzer measurements based on the system developed for measuring complex permittivity. An HF band relaxation frequency of the suspension was found that could be related to the cell membrane, since it disappeared in sonicated samples. Blockade of membrane transport by treatment with oubain was reflected in a decrease in intracellular dielectric conductivity which probably was due to cell swelling or increased intracellular water concentration. A similar effect, but of smaller magnitude and a different time course than with oubain, was obtained by producing minor osmotic shifts in the suspension by pretreating the blood sample with water. Shifts in dielectric conductivity were also produced by altering the pH state of the suspension. Lower frequency values demonstrated progressively lower conductivities with increasing alkalinity of the suspension. This effect very likely reflects alterations in cell surface charge due to pH-dependent changes in membrane proteins. Treatment of the suspension with cardiac glycoside and ionophoretic agents to alter anionic transmembrane transport produced a reduction in the dispersion of the dielectric conductivity when tested by dosing the suspension with 3 M KCl. It is evident from the results of these investigations that electromagnetic analysis of cells and cellular constitutents would be useful for characterizing normal and pathophysiological conditions.

Major improvements in research equipment and facilities were initiated during this period. A high-power transmitter suitable for use with particular output tubes covering a wide range (1-10 GHz) has been acquired. This will be used to provide accurately controlled CW and pulsed radiation for parametric investigations of biological effects at power levels sufficient for use with the anechoic chambers at Walter Reed Army Institute for Research (WRAIR). With additional modifications this unit can be used to provide very high peak power pulses that can be used for simulating some military sources at average power levels sufficient to produce body heat loading of experimental animals.

A major reconstruction project to modernize the research facility at the Forest Glen Annex of WRAIR was designed and started during this period. This involves (1) installation of independent environmental control systems (heating/cooling, relative humidity control, ventilation) for each of 3 anechoic chambers and of a new chamber for housing a high-gain elliptical antenna radiator; (2) installation of modern animal maintenance rooms, each with independent environmental controls; and (3) improvement of heating and air conditioning of the building's laboratories and offices. During this construction, which is scheduled to require more than one year, research that could temporarily be relocated to other quarters is being continued. Unfortunately, it has been necessary to suspend research projects, including those of other agencies and investigators, that require use of the facilities under reconstruction and some personnel time also is diverted to provide oversight and guidance to the reconstruction work.

DOD/ U. S. NAVY

The major objective of the Navy's electromagnetic radiation (EMR) biological effects research continues to be the examination of the interaction of EMR with biological organisms with particular emphasis on extrapolation to man. The possible environmental impact of some EMR systems is also being studied in detail. The results of this research will help to establish safe exposure levels and tolerance times for personnel exposed to nonionizing radiation from radar, communication transmitters, and other military electronic equipment.

The Navy's program consists of both intramural and extramural activities. Projects are almost equally divided between contract and in-house efforts. The current research effort can be viewed as consisting of two parts each supporting different Navy programs/systems. In support of the Extremely Low Frequency (ELF) Communication System (formerly SEAFARER) the Navy is investigating and evaluating possible effects of ELF (i.e., 72-80 Hz) on various aspects of the biosphere. The other portion of the program is directed toward evaluating potential biological effects of microwave radiation.

Extremely Low Frequency (ELF)

A significant part of the current program is in support of the Navy's Extremely Low Frequency Communication System. Congressional briefings and committee testimony have been presented, inputs were developed for the Draft Environmental Impact Statement, and material has been presented to State officials, local groups and the press.

Although earlier studies to evaluate the safety of the Extremely Low Frequency Communication System were not conclusive, they did identify areas for further, more intensive investigation. It was determined that this could be best accomplished in an experiment in which primates were continuously exposed to ELF electric and magnetic fields in a chronic experiment. The experiment is in progress at the Naval Aerospace Medical Research Laboratory (NAMRL), Pensacola, Florida.

The fields are equivalent in waveform to those experienced by living organisms, including man, in contact with soil surface directly above the buried ELF antenna. The magnitude of the magnetic field, 0.2 mT (2 gauss), is 10 times greater than the worst-case condition at the ELF antenna. The electric field, 20 V/m, is over 10 times greater that at the soil surface near the ground terminals. The electric field is applied to the animal via stainless steel bars which form the walking surface on the floor of the environmental chamber.

The rhesus monkey (Macaca mulatta) was selected as the experimental animal because it is a highly developed species for which a large amount of physiological data has been accumulated. Adult rhesus were not included because of limited availability and logistical difficulties. Using adolescent animals of mixed sex presents some statistical difficulties but these problems are counter-balanced by gaining important data on growth and development.

In experiments of this type, in which subtle effects and trends within the normal range are vitally important, it is not sufficient for subjects to serve as their own controls by comparing pre-, per-, and post-exposure data. In this project each experimental animal was pair-matched to a control animal by age, sex, weight, and medical history. All data are taken from both members of the pair at the same time and under the same conditions.

The number of animals in each group was set at 30 because a sample of this size usually provides a sound basis for statistical analysis. This arrangement allows for both group-to-group and animal-to-animal statistical calculations. An exposure time of one year was selected to allow time for subtle physiological effects to be detected and to provide a sufficiently large number of data points for each animal.

The animals in this experiment are individually housed in a sealed chamber to allow for measurements of oxygen consumption and carbon dioxide production and to reduce the possibility of spreading a communicable disease among the entire group. Food, water, and excretion products were measured and a metabolic balance determined for each seven-day period. Blood samples were drawn at intervals of seven days for biochemical analysis. A more comprehensive exam including a complete physical was administered every six weeks.

The animals have been exposed for 2 1/2 years and much of the data has been analyzed. The only difference between the experimental and control population is in the size and weight of the male, but not the female, animals. The exposed males are significantly larger and heavier than their unexposed counterparts. This difference occurred during the first year and has been maintained.

In experiments at the Armed Forces Radiobiology Research Institute (AFRRI), Bethesda, Maryland, 384 young male rats have been exposed to 45 Hz vertical electric fields for 30 days. Growth, food and water consumption, selected blood biochemical and hematological constituents, and pathological endpoints were evaluated. Electric field strengths of 20 to 100 V/m were used, and a dose-relationship was sought. No biological effects from exposure to these electric fields were observed on growth; food consumption; water consumption; blood total proteins, globulin, glucose, cholesterol, triglycerides and total lipids; or on the hematological values for red blood cells, white blood cells, segmented neutrophils, lymphocytes, monocytes, eosinophils, hematocrit, or hemoglobin. Histopathological examination of tissues from 15 organ systems was also negative.

In experiments at University of Wisconsin-Parkside, CW and modulated ELF fields in the 1-10 V/m range were found to cause mitotic delays in slime mold <u>Physarum</u> <u>polycephalum</u>.

An evaluation of the effect an ELF field on the response of mice to infectious diseases was completed. No evidence was found that ELF electric field had any effect upon morbidity or mortality.

In ELF studies of primate behavior no effects have been found at the ELF Communication System electric levels (at 76 Hz). Behavioral changes have been noted at higher power levels (56 V/m, peak to peak). The primary change is decreased inter-response time. At 7 Hertz, the threshold for change was approximately 10 V/m peak to peak.

Microwave Radiation

The overall objective of the Navy's EMR Research Program is to ensure the safety of naval personnel who may be exposed to various electromagnetic environments during naval operations. First, this required careful determination of the types of electromagnetic fields capable of producing biological effects. Second, these effects must be evaulated in the context of the Navy work environment in order to determine if they represent a threat to the health of naval personnel. Only then can a rational system be developed to prevent the occurrence of potentially hazardous conditions.

It is not feasible to evaluate the safety of all the Navy RF/MW environments which include a variety of pulse and repetition rates, chirps, the spectrum varying characteristics of secure communications systems, and a variety of multi-frequency environments. Therefore, emphasis in the Navy program is placed on discovering those biological systems which are affected by exposure to microwaves and on obtaining an understanding of the scientific principals governing the interaction of microwaves with these biological systems.

Perhaps the most important problem facing the bioelectromagnetic research community today, is the question of extrapolation. Several experimental systems, some *in vivo* and some *in vitro*, have shown that exposure to microwave radiation at the level of 10 mW/cm^2 incident power density will produce undesirable, sometimes even hazardous, results in an experimental model system. The question which the research community must address is how to translate the experimental animal data into information which has meaning for humans. That is, how do we extrapolate from an exposure of the mouse which produced a particular hazardous effect in the mouse to a comparable exposure which will produce a similarly hazardous effect in man.

The Navy's RF/MW biological effects research has and will continue to be largely centered on the nervous system. Little is understood about the biological effects of microwaves on the central nervous system (CNS) or the interactive mechanisms which underlie these effects. Much of the clinical and experimental data available thus far is from the Russian and East European literature. Much more information is urgently needed in terms of effects of microwaves on humans. But before predictions of hazardous exposure levels can be made, a great deal of scientific information is needed regarding effects of microwaves on the CNS of experimental animals.

Major emphasis is now being placed on determining exactly the precise mechanisms by and through which RFR can cause biological responses in laboratory experiments at relatively low levels of energy absorption. A number of studies seem to indicate that the cell membrane is perhaps the critical point of interaction for the electromagnetic field. Research on mechanisms is, therefore, increasing.

Another area of interest is hematology/immunology where several recent reports have linked effects with modest exposures to microwave fields. Research on ocular effects has been decreasing in recent years and will be decreased even further in FY 1979.

A study is in progress to determine the amount and spatial distribution of microwave energy deposited in the human body exposed to military radar transmitters. A man-size phantom model consisting of simulated muscle and simulated bone tissue has been fabricated. Calorimetric dosimetry data is being obtained from the phantom during exposure by inserting a small non-metallic temperature probe, developed by the Navy, into the phantom at various locations and depths. The analog output of the temperature probe is recorded so that the time course of the temperature rise in the exposed phantom is determined at all of the probe locations. Microwave dose rates (SAR) are then calculated from the known physical characteristics of the phantom material and from the initial, linear portion of the temperature probe output record.

In a second study, a model has been developed for predicting the temperature rise in tissue spheres which are exposed to microwaves. This is one of the first attempts to deal with the heat transport in such a model. Three mechanisms of heat transport are being considered; (a) heat convection in blood; (b) heat conduction by blood; and, (c) radiative loss of heat through the skin. The relative importance of these mechanisms has been investigated for a number of cases of different sphere sizes, blood flow conditions, and frequencies.

In order to reduce the number of possible models which could be used to explain microwave effects, a project was initiated to determine whether the electric field or the magnetic field played the major role in producing the observed effect. The biological indicator in this experiment was teratogenic effects in darkling beetles which had been exposed to microwaves at the pupal stage. This preparation has been used by several investigators to evaluate microwave effects. It was found that similar microwave effects were seen when the insects were exposed to either electric or magnetic fields at the same rate of energy absorption. Furthermore, the energy absorption rate must be sufficient to raise the pupal temperature by more than 10^{o} C before teratogenic effects can be observed. The temperature dependence of this microwave-induced effect appears to take the form of a threshold. This finding argues against reciprocity between exposure duration and intensity -- i.e., increased exposure duration cannot be used to compensate for decreased exposure intensity.

Many of the microwave effects which have been observed at low exposure levels appears to either occur at the membrane or be membrane related. Since a membrane's functions are largely determined by its structure, it seemed appropriate to first investigate the effect of microwaves on membrane structure. This is being done in a project using Raman spectroscopy, which can probe specific structural changes in complex molecules without interference from surrounding structures. Phospholipids, the major constituent of membranes, were chosen as the experimental system. The degree of fluidity, or random orientation of phospholipid side chains, is being measured in lipid bilayers and vesicles as a function of microwave exposure. The apparent temperature of the microwave-exposed lipid, as calculated from the Raman measure of lipid fluidity, is a few degrees higher than the bulk temperature as measured with a thermistor.

The most widely accepted effect of microwave radiation is cataractogenesis. The sequence of histological events initiated by microwave radiation and culminating in the formation of a lens opacity has been studied in the rabbit eye. Thresholds (i.e.,>100 mW/cm2) for the formation of experimentally induced cataracts have been determined for several frequencies. They have been found to be both time and exposure level dependent. The effect of modulation characteristics on these thresholds has also been studied. Histological changes in human lenses removed because of cataracts, allegedly caused by microwave exposure, are also being studied. These changes are being compared with similarly obtained and prepared senile cataracts. Long-term, low-level exposures of rabbits (e.g., 24 hrs/day for 6 months to 2450MHz at 10 mW/cm2) have failed to cause cataracts in observations made for as long as two years following exposure.

Studies are being undertaken to define the RFR conditions and the way in which microwaves induce changes in the lymphoid system and affect the reactivity of the mouse to a variety of immunologic challenges, both specific and nonspecific. These studies are designed to characterize and explain the observation that microwave exposure alters the population density of a subpopulation of B-lymphocytes.

Since biological functions depend upon the integrity of structural components, histological and ultrastructural studies are being conducted to evaluate the effects of microwaves on the CNS. These studies will elucidate the effects of low power microwaves on the structure of neurons, glia, and their processes as well as on the environmental changes of the neuropile as judged by blood-brain barrier and metabolic studies. The experiments are so designed that the thresholds for producing reversible and irreversible effects will be identified. Special neurocytological stains are being used to determine degenerating axons, terminal boutons, dendritic spines, myelin, general cytoplasmic staining and gliosis. In addition, electron microscopic investigations are being made of the subcellular aspects of the neurons and glia and alterations in the blood-brain barrier. Autoradiographic techniques are being employed to follow the transport of labelled amino acids, ions and proteins across the blood-brain barrier.

The effect of microwave exposure on the blood-brain barrier is being evaluated in a rat model. Several biochemical techniques including those developed by Rapoport and by Oldendorf are being used. The effect of chronic exposure will be evaluated to determine if a reciprocal relation exists between exposure intensity and duration. Conditions governing reversibility will be evaluated following the demonstration of an effect.

A systematic study is being conducted to determine if and to what extent neurochemical mechanisms of the mammalian brain are affected by exposure to microwaves. A variety of neurotransmitters and neuroenzymes are being evaluated. Several neuroendocrine parameters are being evaluated in primates exposed to microwaves. The total physiological significance of any neuroendocrine effects observed in response to single exposures will be evaluated under chronic/repeated exposure conditions. The interaction of microwave radiation and several neuroactive drugs are being studied in a rat model. It appears that the action of at least some agents which have their major effects on the CNS can be modified in the presence of a microwave environment.

Rhesus monkeys, squirrel monkeys, and rats, trained on various operant tasks are being exposed to microwaves for repeated periods. Several frequencies are used. Performance is evaluated during exposure. In squirrel monkeys, behavior was not consistently perturbed unless colonic temperature increases exceeded 1^{o} C. Operant conditioning techniques are being used to develop complex timing, counting, and perceptual-motor behaviors in rats. Two different behavioral baselines are being used: a multiple schedule of reinforcement and a counting procedure. Such baselines are then used to assess the effects of microwave exposure. Long term chronic exposures will be conducted to determine if any possible cumulative behavioral changes are produced. Subtle, but significant, changes in performance have been observed at relatively low (e.g., 1-10 mW/cm^2) incident exposure levels. Possible effects of microwave exposure on learning are being evaluated in rhesus monkey and rat models using repeated acquisition tasks.

DOD/U. S. AIR FORCE (USAF)

The U. S. Air Force radiofrequency radiation (RFR) research program is comprised of contractual and in-house efforts in a ratio of about 65% and 35% respectively. It includes studies of:

(1) dosimetry (RFR energy distribution and measurement); (2) effects on the central nervous system (CNS) including blood-brain barrier and behavioral studies; (3) effects on the immune system; (4) cellular level effects; (5) pulse modulated versus continuous wave exposures; and (6) long-term, low-level studies. Research efforts are directed to specific Air Force operational systems (current and future), and data are utilized for RFR safety criteria and occupational safety regulations.

1976 activities:

Dosimetry

As part of the tri-service priority one effort (Energy Distribution and Measurement), the Air Force has undertaken a multi-year program to develop an RFR dosimetry handbook. The first edition of the handbook was prepared under contract by the University of Utah and published as USAF School of Aerospace Medicine Technical Report 76-35 in September 1976 (Appendix B). Initial response concerning the acceptance and use of this handbook has been very favorable with many of the calculated curves empirically validated. Follow-on efforts will seek out suggested improvements in the handbook's content and use. Additional empirical data is being actively solicited for inclusion in the next edition. This effort should provide a necessary link between biological effects observed in irradiated animals and corresponding effects which might occur in man.

The observation that nonionizing radiation induced biological effects are frequency dependent led the Air Force to develop and publish a new regulation in November 1975, viz., AFR 161-42, Radiofrequency Radiation Health Hazards Control. It incorporates a slightly higher frequency-dependent exposure limit (i.e., 50 mW/cm^2) for the 10 KHz to 10 MHz portion of the RF spectrum, where no previous standard existed. It remains consistent with the OSHA regulation (i.e., 10 mW/cm^2) which covers the frequency range 10 MHz to 100 GHz. This new safety regulation which defines a complete nonionizing radiation control program has been accepted throughout the Air Force and has been implemented by all major commands. It provides detailed guidance on the application of PELs (permissible exposure limits) across the frequency range of AF RF emitters.

Research studies in support of 10-30 MHz RFR emitters (principally the OTH-B radar) were essentially completed in 1976. Power absorption studies were completed for the 10-50 MHz frequency band and compared with theoretical calculations. These data have been published on monkeys, prolate spheroid and ellipsoid models. Primate temperature profiles, as a function of incident power densities and time, were completed for three

HF band frequencies (15, 20, 26 MHz). Power densities ranged from 500 to 1500 mW/cm2 and exposure times from 0.5 to 6 hours. The previous studies on the effects of HF band radiation on rodent growth and development by the USAF School of Aerospace Medicine (USAFSAM) and its contractors were re-evaluated and documented in SAM-TR-75-51. Air Force program interests are now directed to phased array radar systems using RFR fields in the frequency range 0.4-10 GHz.

Instrumentation

Air Force contractual efforts in support of the tri-service ocular effects program resulted in the development of a system for noninvasive optical evaluation of RFR induced eye abnormalities. A follow-on contract was awarded to conduct bioeffects studies to evaluate the utility of the completed system. Pending successful validation, this new research tool may be applied to objectively quantitate possible effects of RFR induced eye injury in a series of experiments ranging from acute to long-term exposures. It will also provide a permanent record for comparative purposes.

In order to study mechanisms of RFR-biological interaction, and perhaps reduce the use of animals, a specialized exposure system for exposing cell cultures to broadband RF fields under controlled field and temperature conditions was developed under contract with the University of Washington. The system produces a quite uniform electric field strength up to 10,000 V/m (over a frequency range 0-1000 MHz) for a 5 mm sample of culture medium. Preliminary experimental results have been reported. Additional research is in progress.

A six-port vector voltmeter developed by the National Bureau of Standards under tri-service precision electromagnetic and Air Force funding and sponsorship has been completed and is in operation at the School of Aerospace Medicine. This instrument is capable of measuring voltage ratio and phase angle between any two given signals in the 500 MHz to 12 GHz frequency range. Applications of the system include mesurement of coupling ratio for high power couplers, measurement of antenna transmittance and reflectance, and measurement of RF field changes induced by insertion of biological systems into an RF field. The system is controlled by an Hewlitt Packard model 9830A and has unique calibration capability.

Central Nervous System

Microwave inactivation techniques sponsored/developed by the Air Force were used in studies of RF radiation induced CNS effects. Mice were exposed to 19 MHz using a "nearfield" radiation simulator to determine if HF band radiation alters the whole brain level of: (1) serotonin or metabolite 5- hydroxyindole acetic acid; and/or (2) norepinephrine. Other studies were completed for rats exposed to 1600 MHz fields. Additionally, metal ion concentrations in specific areas of the rat brain were evaluated after 1600 MHz exposures.

Blood-Brain Barrier

Recent reports in the literature have indicated changes in the permeability of the blood-brain barrier after exposure to microwaves. References to these effects, as biological hazards, have appeared in both the lay press and in scientific reviews. The mammaliam blood-brain barrier acts as an impediment to the passage of certain solutes from the blood into brain tissue. In a teleologic sense, the blood-brain barrier system probably operates to optimize the fluid environment of the neurons. Changes in barrier permeability thus could alter neuronal function with some effect on "behavior." Though generalized alteration of permeability could produce brain edema and lead to gross disruption, it is not at all clear what the consequences of small, more selective changes may be.

In one reported study, exposure to 1200 MHz radiation pulsed at a low peak power density (2 mW/cm^2) was alleged to increase the permeability of the blood-brain barrier to sodium fluorescein. In the USAFSAM replication, fluorescence due to sodium fluorescein in the brain substance of irradiated rats was observed at the peak power reported in the original investigation. The study was extended to include chemical assay of sodium fluorescein in various areas of the brain. At a peak power of 2 mW/cm^2 no increase in the brain concentration of sodium fluorescein was noted. However, at a peak of 75 mW/cm^2 (37.5 mW/cm^2 average), the fluorescein content was significantly increased as compared to controls. At this higher peak power level, brain temperature was increased about 4^oC. Further research is being carried out to establish a threshold for the increased fluorescein content. Additional studies were initiated using radiolabeled compounds that do not normally cross the blood-brain barrier.

Immune System

The immune system is an important area of investigation for possible RFR effects since host surveillance and defense against pathologic inducers and promoters is a pre-eminent responsibility of lymphocyte cell types and their elaborated mediators. A series of experiments was conducted to investigate the effects of RFR heating on cell-mediated immune defense mechanisms. RFR heating effects, as determined by inflammation and/or the number of peripheral blood and spleen lymphocytes, were followed in rodents exposed to 26 MHz radiation (3° C increase in core temperature), 5 MHz (no measurable increase), and warm air treatment (3° C increase). RFR heating (26 MHz) decreased SRBC (sheep red blood cell)- induced inflammatory footpad swelling by 45% over that observed in warm air or sham control animals. The suppression of inflammatory response was accompanied by a well defined, transient fourfold lymphopenia and neutrophilia which were maximal at 3 hours post-exposure. Normal blood lymphocyte and neutrophil levels were reestablished by 92 hours post-exposure. Triple exposure to 26 MHz radiation at 3-hour intervals resulted in a marked but transient lymphopenia and neutrophilia sustained over a 12-hour period; all animals reverted to normal levels by 92 hours after the final exposure. The time course of this lymphocyte response closely follows gluco-corticoid-induced lymphopenia and suggests that RFR heating is perceived as a simple stress phenomena accompanied by steroid release. In addition, the percentage of T-lymphocytes in the spleens of RFR heated mice (26 MHz) was twofold greater than that observed in 5 MHz, warm air, or sham treated animals. That RFR heating induced an arrest in T-cell splenic traffic resulting in apparent pooling of T-lymphocytes in the spleen, in addition to suppression of inflammatory response and lymphopenia, suggests that cell-mediated immunocompetence may be altered in these animals.

Cardiac Pacemaker Interference

Cardiac pacemaker interference studies were completed for radiofrequencies of 450, 1600, 3200 MHz. A series of new generation cardiac pacemakers was also evaluated under both free-field and simulated implant conditions for 250, 350, and 450 MHz. Potential susceptibility levels were established.

Activities in 1977/78 include:

Blood Brain Barrier

Reported radiofrequency radiation-induced alterations in the permeability of the blood-brain barrier continue to be the subject of studies at the USAFSAM. Recent research has attempted to replicate findings indicating an RFR-induced alteration of the blood-brain barrier at low incident power densities. Fluorescein, serotonin, Evan's blue, and C^{14}-labeled mannitol have been used as test substances. As yet, no apparent RFR-induced alteration of barrier permeability has been observed unless the power density is of sufficient magnitude to raise brain tissue temperature. Contract efforts in this area have likewise yielded negative results. In one investigation (SRI International), very high peak pulse incident power densities were used. No statistically significant RFR-induced changes in the blood-brain barrier system were discerned. In another study (University of Washington), both fluorescein and nonphysiologic amino acids were used as test substances in mice. Incident power densities up to 132 mW/cm^2, producing gross heating of the animals, had no significant effect on permeability of the blood-brain barrier to the test substances. The Air Force and its contractors are contributing new data at a blood-brain barrier workshop in October 1978 which will bring together a number of recognized experts in the field and will document the state of technology concerning this reported biological effect of RFR.

Immune System

Effects of RFR on cell-mediated immunocompetence in allograft rejection, *in vivo* lymphocyte homing, delayed hypersensitivity, the inflammatory process, peripheral blood lymphopenia/neutrophilia, elaboration of migration inhibition factor, lymphocyte mediated cytotoxicity, and antibody production have all been investigated. As a result of AF studies, a mechanism of RFR interaction with the immune system has been postulated and experimentally verified. Briefly, alterations observed in the immune system appear to depend on hormonal response to heat stress resulting from RFR exposure.

Alterations in immune function observed in animals exposed to thermalizing RFR are produced as the result of steroid action on the animal's immune system. Release of steroids into the circulation is triggered by the hypophyseal-hypothalamic-adrenal axis when the thermoregulatory process is activated during thermogenic RFR exposure. Thus, altered immune function may be thought of as an indirect, secondary, compensatory biologic consequence of steroid release due to thermogenic RFR exposure.

Experimental animals exposed to thermalizing RFR released steroids into their circulatory system and manifested effects indicative of steroid induced immunosuppression -- i.e., decreased circulating lymphocytes, reduced thymic mass, loss of delayed hypersensitivity, enrichment of splenic T- and B-lymphocytes, depressed inflammatory responses, migration of circulating lymphocytes into bone marrow, increased mitotic index and lectin-induced blast transformation, decreased antibody production, and suppression of allograft rejection. All of these effects are transient and disappeared when the RFR exposure was discontinued. It should be emphasized that RFR heating is a nonspecific stimulus for steroid release; other stimuli, like noxious noise, also lead to steroid release and immune alterations.

None of the immune effects mentioned above as thermally-mediated would be expected to occur as the result of non-thermogenic RFR exposure. Current, well executed, reproducible investigations show that acute, "low-level" RFR does not lead to measurable effects on the immune system. Further studies will be conducted to investigate the effects of chronic "low-level" RFR.

Pulsed versus Continuous Wave

There is conflicting data and considerable speculation concerning the relative abilities of pulsed and continuous wave (CW) radiofrequency radiation of the same average incident power density to produce different biological effects. So far, the only well established result of pulsed irradiation not produced by CW irradiation is the so-called "microwave hearing" effect. The Air Force has undertaken in-house and contractual investigations which will provide additional data. These efforts are designed to cover a variety of biologic endpoints and use a number of different frequency and pulse modulation parameters. Contract research at the University of Washington has been comparing biological effects of pulsed and CW RFR, i.e.:

- o effects of acute RFR on the blood-brain barrier, immune competence, and heart rate;
- o peak power effects;
- o learning and memory consolidation processes as influenced by exposure to RFR;
- o effects of chronic RFR on rabbits;
- o effects of chronic RFR on the immune competence of mice, and;
- o effects of RFR on cell membrane permeability.

Rabbits were exposed to ventral and dorsal 2450 MHz radiation in both CW and pulsed (1μs, 700 pps) mode. Average incident power density was 5 mW/cm^2. In addition, some exposures were synchronized to the heart rate with 0, 100, and 200 ms delay times with respect to the R-wave of the ECG complex. No significant difference in heart rate between periods of irradiation and nonirradiation was noted. There was no significant change in heart rate when the pulsed radiation was synchronized to the heart beat at different delay times. These results are at variance with those of Presman and Levitina, who reported tachycardia and bradycardia for pulsed and CW, respectively.

Rabbits were exposed for three months to pulsed and CW 2450 MHz radiation at an average incident power density of 1.5 mW/cm^2, EEGs were obtained via implanted carbon electrodes, and integrations of the spectra were calculated for all animals. There were no statistical differences among the pulsed, CW, or sham irradiated groups. A number of biochemical and hematologic parameters were observed including serum electrolytes, total protein, NPN, glucose, T3 and T4, and complete blood count and blood indices. No significant differences were noted when either exposed group was compared with controls. These data were presented at the 19th General Assembly of URSI Open Symposium on Electromagnetic Waves at Helsinki, Finland in August 1978.

Another study to compare effects of pulsed and CW RFR is being conducted under a contract at the Georgia Institute of Technology; i.e., RFR-induced effects on the granulopoietic stem cell. Mice have been exposed at 2 mW/cm^2 at 450 and 2450 MHz. Exposure periods were two hours daily for 30 days or 12 hours daily for five days. After exposure, biologic assays were conducted up to 21 days post-exposure. The biologic assessments consist of a quantitative, liquid assay of granulopoietic stem cells which is an extremely sensitive biological test. The number of granulopoietic precursor cells, the kinetics of stem cell injury and recovery, the growth fraction of granulopoietic colonies, the cell cycle time and the rate of granulopoietic differentiations are evaluated. Exposure regimens have been completed on the 2450 MHz radiations. No consistent or statistically significant effect on the granulopoietic system of mice has been observed in either the pulsed or CW groups.

Research has recently been initiated at the School of Aerospace Medicine to investigate the kinetics of calcium movement in the mammalian brain as influenced by RFR. The study employs 1 GHz radiation and an *in vitro* brain tissue preparation.

Fractionated RFR

Experiments were conducted to compare the effects of RFR given as a single exposure or, using an equal or greater total SAR, as a series of exposures extending over hours, days, or weeks. The biological assay system utilized the ability of splenic B-lymphocytes of mice to form antibody as measured by plaques (PFC) formed in sheep red cell films. (This system is perturbed in known ways by exposure to ionizing radiation.) When RFR was administered no changes were seen unless sufficient energy was deposited to cause an early rapid rise in core temperature. Increased ambient temperature sufficient to hinder the dissipation of RFR generated heat in mice, results in an increase in PFC which can be simulated by the administration of hydrocortisone. This result was interpreted as an expression of an adrenal mediated response to thermal stress which produced a transient shift in relative lymphocyte numbers in the spleen. Corollary studies of the nature of RFR heating in the rat showed a heating curve which had an early spike followed by a thermo-regulated, more gradual rise. Exposure of rats to a humid warm air environment resulted in curves whose slope approximated the RFR curve except for the early temperature spike. Conditions of warm air at 90% humidity gave the nearest approximation to RFR heating. A model to describe RFR heating using conventional thermodynamic equations was developed. Corrective factors to determine equivalent exposure times, when warm air is used as a thermal control environment in RFR experiments, were also specified.

RFR Interaction with Biological Tissues

Investigations in the U. S. and in other countries have suggested possible effects of RF radiation occurring at the membrane or molecular levels. Among these are direct action of a "rectified" modulated RF carrier upon the nervous system. Also suggested are indirect effects due to RF influences on ions or molecules involved in neural or other membrane-mediated events. Studies have been initiated at USAFSAM to assess the possible effects of pulsed and continuous wave RF fields at 1 GHz on a sensitive preparation of gastrointestinal smooth muscle along with its intrinsic nerve plexuses. These studies are intended to elicit the presence of any membrane-level effects. At the same time, pilot experiments are proceeding to study neuroendocrine responses in RF irradiated rodents. A summer Research Fellow has been involved in these studies and will continue them upon returning to his home laboratory. The thrust of the study is to delineate the major steps in an entire neuroendocrine pathway and the effects of 1 GHz RFR upon those steps. Additionally, studies of possible RFR effects upon macromolecules have been initiated using techniques of spectroscopy to evaluate effects on the molecules. Related work involves evaluation of theoretical biophysical mechanisms. Mathematicians and biophysicists are attempting to assess the implications of new or old models of the interaction of RFR with biological substances. The objective of this work is to define mechanisms and predict effects, which may then be tested by laboratory experiment.

Dosimetry

Studies continued under contract at the University of Utah to determine specific absorption rates (SAR) for ellipsoid and prolate spheroid models of man and animals exposed to RFR plane waves from 10 kHz to resonance. These data are the basis for the techniques which have been developed to extrapolate RF exposure of laboratory animals to that of man and were published in the first edition of the RFR Dosimetry Handbook. Six hundred copies of the first edition of the RFR Dosimetry Handbook (SAM-TR-76-35) were distributed to researchers in the United States and Europe, and 300 copies of the second edition, published in May 1978 as SAM-TR-78-22, have been distributed to date (see Appendix B). The second edition extends the frequency coverage from 10 MHz to 100 GHz and covers the entire range of interest in present RFR biological research. Scatter data are included, as are empirical data which show the prolate spherioid model to be quite good for prediction of SAR in rats and mice. Calorimetric techniques were developed at the USAFSAM to determine the SAR for whole body rat and mouse exposures. The results of these experiments compared favorably with the theoretical SAR data published in the second edition of the Handbook. A follow-on activity will investigate near-field SAR both theoretically and empirically. The effects of "hot spots" and tissue inhomogeneity will be investigated, and a more detailed analysis of thermal response will be completed. This information will be incorporated into a third edition of the Handbook.

Instrumentation for Measuring RFR Fields

Recent concerns by certain citizen groups and Congressional requests prompted development of a specialized instrumentation system to quantitate low-level RFR fields produced by various radars. The first such system was used to measure the RFR levels at distances out to eight miles from the radars at North Truro AF Station, Massachusetts. The instrumentation system assembled by personnel from the Air Force Communications Service (1839 EIG/EPE), Keesler AFB, Mississippi, was capable of measuring electric field intensities as low as 0.003 V/m, resulting in calculated power densities as low as 2.4 picowatts (10^{-12} watts)/cm^2. The system provides values of the peak E-field, the peak power density, the averaged power density, and the true time-averaged power density of the radars in their normal operational mode while sweeping their respective scan sectors. Results of the North Truro AFS survey were published in an Air Force report on 1 June 1978 (see Appendix B) A similar system has been assembled to measure low-level RFR fields associated with the PAVE PAWS radar.

RFR Exposure Systems

A second 10 x 10 x 20 ft. anechoic chamber, complete with climate control, was recently added to the RFR facility at the School of Aerospace Medicine. Exposures are provided by a Cober transmitter system which operates between 1 and 10 GHz. This transmitter provides 350 watts of continuous wave power and 1200 watts of peak pulse power. This exposure system will be used in a series of acute and chronic RFR bioeffects research studies. A new building should be completed at USAFSAM in early 1979. This building will have 3200 sq. ft. and will house the peak pulse power simulator which is presently being designed and constructed by Cober Electronics. This facility will provide peak fields, in a 10 x 20 x 40 ft. anechoic chamber, up to 200 W/cm^2 with average incident power densities up to 200 mW/cm^2. Four transmitters will be provided with operation at 2, 2.8, 5.6, and 9.6 GHz. The facility is designed to study the relative effects of pulsed versus continuous wave exposures.

Long-Term, Low-Level RFR Bioeffects Study

There is increasing national concern over the lack of adequate scientific information on long-term effects of exposure to low-level radiofrequency radiation. This has been given high priority by the Tri-Service Electromagnetic Radiation Panel, NTIA/ERMAC, the former OTP, EPA, BRH, OSHA and others. The Air Force, recognizing this need for information, has initiated one of the largest ($\sim$2 million dollars) contracts to date in the area of radiofrequency radiation bioeffects. At the University of Washington School of Medicine, with Prof. Arthur W. Guy as principal investigator, rats will be exposed for a major portion of their lifetime to essentially continuous radiation applied in a complex pulsed mode. The exposure systems, to be constructed by the contractor, are a unique circularly polarized waveguide design previously developed by the investigator with some Air Force participation. The rats will be monitored by a comprehensive battery of hematological and biochemical tests to assess the degree of effect, if any, from their exposure. The results of the study, expected in 1983, should provide valuable data for assessing hazards to man from long-term, low-level RFR exposures.

DOC/NATIONAL BUREAU OF STANDARDS (NBS)

The NBS/Boulder program on electromagnetic radiation hazards measurement is conducted in support of the Federal agencies who may regulate radiation emission or exposure, those affected by such regulations, and those conducting research in this area. Much of this work is conducted under contract directly for other agencies. This work is concerned with developing basic EMR measurement techniques, and instrumentation for field measurements, surveys, and in support of biological experimentation. It includes the development of calibration and exposure facilities and theoretical and experimental work on problems in support of absorption and dosimetry research.

Accomplishments during the 1976-77/78 period include:

- Development of a system for measuring complex voltage ratios from 0.5 to 10 GHz. The basis of the instrument operation is a "six-port" microwave vector voltmeter which measures the amplitude and phase of one voltage wave relative to a reference voltage wave. The ratio measurements are under the control of a programmable calculator. Its dynamic range is 50 dB with an accuracy of approximately 0.1 dB/10 dB and .05 for expected reflection coefficients.

- Extended Air Force near field synthesizer frequency range from 10-30 MHz to 10-60 MHz.

- Developed calculations to assist in interpretation of experimental data regarding energy deposited in animal bodies.

- A workshop was organized and conducted in March 1976 to disseminate to industry the present state-of-the-art of energy density probes and evaluation techniques.

- The survey of electromagnetic fields around FAA facilities and the data reduction and documentation were completed. The Final Report was published in December 1977 (see FAA, Appendix B).

- Completed the development and demonstrated the feasibility of a miniature implantable thermistor temperature probe for use in biological effects experiments. The probe uses high resistance leads that are insensitive to RF fields and as a result is transparent to RF exposure. Accuracy is 0.01° C over the 0-100° C range. A prototype of this unit was evaluated by the BRH and USAF-SAM. NBS plans to issue a Technical Note on this probe which will enable others to construct and use like units.

- Completed the development of a monopole probe which was tested on a time domain antenna range to show a risetime in the low tens of nanoseconds where the limitation was with the measurement system. Based on this probe a prototype resistively loaded dipole was fabricated and evaluated to verify its potential as a broadband antenna with linear phase for environmental measurement applications.

- Delivered a prototype set of four remote monitoring probes (3 E-field and 1 H-field) for a combined EMI and radiation hazard warning system to the Army for testing. The E-field probes cover the range from 10 KHz-18 GHz, and the H-field probe covers the range from 10 KHz-100 MHz.

Continuing activities include:

- o Development of a high-resistance peak reading electric field probe. This probe is designed to measure fields in the frequency range from 300 MHz to 8 GHz CW and pulse field with pulse widths down to 0.5 μsec and repetition rates as low as 200 Hz.

- o Evaluation of a high level peak reading electric field meter for the NBS developed electric field probe. Initial analysis with the electic field probe showed that the dynamic range was limited to 20 dB.

- o Construction of two automated high power six-port reflectometers for NIOSH to measure changes in the power and reflection coefficient in the E and H field ports of a synthesizer operating in the 10 to 100 MHz frequency range used to study biological effects of subjects introduced into the synthesizer.

- o Development of an ultra-broad, three-axis response antenna to replace the seven antennas presently used by the EPA measurement van to partially cover the frequency range for 50 to 890 MHz. Also, developing a broadband low frequency (0.5 to 1000 MHz), isotropic, electric field probe, and a digital instrumentation package for processing the data from this probe. This work will extend the capabilities of the NBS probe down to 0.5 MHz.

- o Completing a new anechoic chamber capable of operation from 300 MHz - 18 GHz, to be used for research and development of improved measurement and calibration techniques and instrumentation. An automated instrumentation system is being developed for the anechoic chamber to facilitate its use to 1 GHz.

NATIONAL SCIENCE FOUNDATION (NSF)

NSF's participation consists of research supported by the Automation, Bioengineering and Sensing Systems Program in the general area of the interactions of nonionizing electromagnetic energy with biological organisms.

During 1976 two renewal grants were funded for additional two year periods. One is concerned with attempting to quantify the total absorbed electromagnetic power and power distribution in biological tissue and the associated thermal consequences. Prolate spheroid and block-man inhomogeneous models have been tested at lower frequencies. Progress has been made in determining power absorption by using the extended boundary condition method and a numerical solution of the integral equation formulation. The geometrical approximation inherent in modeling and the numerical limitations of the integral equation formulation dictate the need for improved theoretical approaches that are capable of characterizing power deposition in animals and man. An adaption of the finite element technique for the solution of the electromagnetic problem will be explored by means of prediction and animal irradiation studies.

The other grant continues and extends research involving the investigation of telemetering of physiological information and the characteristics of the implanted antenna when transmitting electromagnetic signals to a distant receiver. Theoretical and experimental investigations of various types of antennas, implanted in biological tissue, will continue to develop properties and improved performance characteristics. The characteristics of these antennas will be ascertained for a wide frequency range and for both steady state and pulsed excitation. Properly designed antennas will be used as probes for measuring electric and magnetic fields, the reflecting and transmitting properties, and the internal effects of radiation in a biological body.

Work is also continuing under two grants funded in prior fiscal years. One is associated with the interaction of pulsed microwave energy with the phenomenon of human hearing ("microwave hearing"). It includes analytical studies of stress and force induced by incident microwave energy on the auditory system. A unique characteristic of the grant is the optical techniques that are used to measure vibration in the exposed models of animal and human heads which are particularly suitable for detecting small changes. This grant was renewed in 1977 for an additional two year period.

The other grant is concerned with determining the internal electromagnetic field induced inside the human body and the external EM wave scattered by the body when illuminated. The theoretical investigation involves the numerical solution of a tensor integral equation for the electric field induced inside various models of the human torso. It is anticipated that after the accuracy of the theoretical method is established, a user-oriented computer program for the field calculations will be developed.

No new grants were funded in 1977 or FY 1978.

FEDERAL COMMUNICATIONS COMMISSION (FCC)

The FCC does not allocate specific resources or conduct a biological effects program. However, The Commission has an active interest in the subject and performs sample electromagnetic measurements and analysis when feasible during and subsequent to routine station inspection trips. The purpose of this in-house effort is to obtain information on maximum levels of electromagnetic radiation around typical FCC-licensed equipment/facilities (e.g., rooftops with antenna installations, buildings near transmitters, transmitter rooms, etc.), particularly in occupied or accessible areas.

Surveys are being made in various cities to provide a sampling of field intensities associated with such sources as broadcast facilities of different frequencies, land mobile equipment, TACAN transmitters at airports, and commercial radars. During 1976 radio frequency field intensity measurements were made at selected broadcasting facilities in New York and Maryland, concentrating particularly on transmitters operating below 10 MHz which is the lower frequency limit of the present U. S. standard. E-field measurements, taken 295 feet from a 1090 KHz, 50 kW transmitter tower, ranged from 32.6 V/m to 40.8 V/m. These values are even below the 1976 Soviet standard established for this frequency range. Technical memoranda have been prepared on these data and on a study of environmental levels of RFR (see Appendix B).

Additionally, a theoretical and experimental analysis of power density in the near field of a small linear antenna, of the type that might be used in a walkie-talkie, was performed.

DOT/FEDERAL AVIATION ADMINISTRATION (FAA)

The FAA has been conducting electromagnetic field intensity measurements in order to survey radio frequency (RF) radiation levels at various FAA air traffic control facilities, airport environments, and inside and around various aircraft.
A measurement survey was performed by the National Bureau of Standards (NBS) under an interagency agreement. This survey was conducted in three phases. Reports on Phase I and II were published in 1975. They cover initial exploratory field intensity measurements of 15 FAA systems considered likely to produce RF fields stronger than 0.1 mW/cm^2. The Phase I report discusses the measurement probes used in the exploratory survey, their limitations and calibration. The Phase II report details the findings of exploratory measurements at Stapleton International Airport, Denver and at the FAA Aeronautical Center

in Oklahoma City. Instrument Landing Systems (ILS), Airport Surveillance Radars (ASR) and Air Route Surveillance Radars (ARSR) were included in these surveys. As a result of the exploratory measurements several serious limitations of NBS developed probes were discovered. Nearly all of these limitations were subsequently removed with further probe development by NBS, and three new field intensity meters incorporating these improvements were constructed for use in the Phase III measurements. These included: an isotropic peak field meter for pulse widths down to 0.5μsec with a frequency response from 0.3 - 10 GHz; a directive probe using a small horn with a power meter whose frequency response is from 12 - 26.5 GHz; and an isotropic probe for slowly modulated fields with a frequency response from 3 - 3000 MHz.

In Phase III extensive measurements were made within and in front of various aircraft, in front of various radars such as ASRs, ARSRs, and Airport Surface Detection Equipment (ASDEs); landing guidance systems such as V-Ring Localizers, traveling-wave localizers, glideslope antennas and Microwave Landing System (MLS) elevation and azimuth antennas; and navigation systems such as VORTACs, VORs, and TACANs (including x-ray measurements near TACAN transmitter rack); VHF/UHF communication antennas, and HF antennas. The survey was completed in 1977 and documented in a Final Report (see Appendix B). Both NBS and commercial probes used for these measurements are described.

In 1978, the FAA performed RF surveys of additional ARSRs. Results are contained in two reports cited in Appendix B.

CENTRAL INTELLIGENCE AGENCY (CIA)

The Central Intelligence Agency's role in the biological effects program draws on its expertise in reviewing and analyzing international scientific publications and associated language and translation capabilities. The Agency identifies, evaluates and translates current foreign literature pertaining to the biological effects of nonionizing radiation in support of the multi-agency research program.

This work is carried out in close liaison with other agencies conducting research in this area and helps to ensure awareness and timely access to pertinent foreign research and published findings within the scientific community. Foreign literature which has been translated and made available as a result of this work during 1976, 1977 and early 1978 is referenced in Appendix B.

VETERANS ADMINISTRATION (VA)

The hospital system of the VA makes use of radio frequency (RF) radiation, both clinically and in its research program. RF diathermy at frequencies in and below the microwave portion of the RF spectrum is being used to treat minor ailments of muscle, tendon and circulation, and on a limited investigative basis, is being used an an adjunct of radio- and chemo-therapy in treatment of advanced cases of cancer. Other medical applications are also being explored. Safe use in the clinic from the standpoint of therapist as well as patient requires careful monitoring for stray radiations and calibration of RF generating equipment. The VA is concerned with the well-being of veterans and responds to inquiries concerning RFR radiation.

VA research in the RF/MW area embraces projects related to the VA mission. Cataracts, which can be induced in animal experiments by intense RF fields, is one area of research interest. VA investigators are continuing to study primates in an effort to learn the threshold intensities, durations of exposure, and latencies from time of exposure involved in production of cataracts by intense microwave fields. The approach used in this research has several advantages over that in other previous studies. First, the monkey is a better model of man than the rabbits used by other investigators. Second, by using a "voluntary" subject -- i.e., the monkey is placed in a conditioning context where it is free to accept or reject irradiation of the eyes as it works for a reward of orange juice -- the anxiety and physiological stress of immobilization are avoided. Finally, by using an awake animal, artifacts of anesthesia such as reduced flow of tears aross the eyes, which act as a coolant, are avoided. After months of testing monkeys for period of 15 min. daily during which they experienced multiple exposures to very high power densities of incident radiation (to 495 mW/cm2, 9.3GHz), careful opthalmological examinations have revealed no signs of ocular insult or reduction in lever pressing activity.

Another group of investigators is researching three areas: teratology (birth defects); Pavlovian conditioning of experimental fevers; and the electrical response of the brain of heated animals -- all with respect to intense microwave irradiation. This research employs 915 and/or 2450 MHz multimode cavity exposures and is co-sponsored by HEW/BRH. The teratological studies have shown that the animal model chosen for study is a critical factor in production of anatomical abnormalities. Some strains of mice are more prone to such anomalies than others while the commonly used albino rat is virtually refractory to all but nearly lethal levels of radiation. The same high dosage of radiation that results in deformed extremities or wholesale abortion or resorption in one strain of mouse is associated with few effects in another strain. In the case of the rat and some hardy strains of mice, it has been found that the dam is much more likely to expire from irradiation than to deliver deformed pups.

Pavlovian conditioning in which the unconditional stimulus is microwave radiation that results in a moderate hyperthermia has been performed on rats and has revealed that initially neutral stimuli in the learning environment eventually gain eliciting powers -- i.e., produce a moderate elevation of body temperature in the absence of microwaves. Even the human being who trains the animals becomes, in effect, a conditional stimulus for the hyperthermia. The "learned" fever is highly resistant to extinction, persisting as it were for hundreds of presentations of the conditional stimulus. The import of this phenomenon is that many current biological studies of microwave radiation involve handling, restraint, and other treatments that can also produce a mild hyperthermia. To the extent that scientific endpoints being studied are influenced by temperature, and to the extent that variation of basal body temperature is not measured and monitored across time because of the assumption that basal levels are invariant, confounding by "learned" temperature elevations will occur.

Studies of evoked electrical responses from the brains of guinea pigs are being pursued to determine whether acute exposure to microwaves that results in intense heating -- that mimics the protocols of clinical application of hyperthermia for, say treatment of sinusitis -- has acute and long-term sequelae of neurological function. These studies, which are exploratory in nature, have revealed, not surprisingly, that multineuronal conduction velocity increases as a function of rectal and brain temperature. What is surprising is that core (rectal) temperature is nearly always about 2o C above that of the brain's cortex. This difference is maintained during RF thermal stress. In primates, including the human being, brain temperatures are normally higher than those of the core. One implication is that data based on highly thermal or lethal doses of RF radiation in lower animals could result in considerably over-estimating comparable levels of radiation for primates. Another implication is that current experimental studies of brain-cancer models, usually rats, may generate trial protocols that depart dramatically from those appropriate for clinical use.

DEPARTMENT OF ENERGY (DOE)/NASA

The DOE conducts research associated with various energy sources, generation and transmission systems including the evaluation of environmental and biological impact. The DOE's involvement in the RF/MW effects area stems primarily from work associated with a proposed solar Satellite Power System (SPS). This system would collect and convert solar energy to electricity in space and beam it via microwaves to large collecting antennas (rectennas) on the ground. The DOE also supports research on biological and environmental effects associated with high voltage power transmission lines (HVTL) and the generation of electrical energy (see Section IV).

Before DOE was established in October 1977, these activities were carried out by its predecessor, the Energy Research and Development Administration (ERDA). SPS activities are carried out in conjunction with the National Aeronautics and Space Administration (NASA). RF/MW health and ecological assessment and associated research are being carried out by DOE. These activities involve the DOE's Argonne National Laboratory which is responsible for the overall SPS environmental assessment and EPA which is serving as program manager for MW health and safety aspects. A committee has been established to assist in research planning, review proposed research and reports, and participate in evaluating impact in this area. Previously, NASA sponsored several small pilot studies and the development of a research plan for studying biological and ecological effects of SPS microwave transmissions (i.e., see Appendix B).

During the present three-year concept development and evaluation phase (July 1977 - August 1980) efforts are being made to determine feasibility and limitations of the SPS concept. As in other areas, MW health and ecological activities are directed toward identifying any possible contraindications which would discourage development of the SPS system, identifying areas where further research is needed, and establishing an information base for environmental impact assessment and comparison with other energy alternatives.

Research in this area is at an early stage. In FY 1978 experiments were initiated to examine effects of 2450 MHz microwaves on honey bees. Another study is attempting to identify possible ecological effects of SPS microwaves at the rectenna site and to define research requirements and protocols. Additionally, the EPA's 2450 MHz exposure facilities are being modified and expanded to accommodate SPS related research.

IV. ASSOCIATED ACTIVITIES

ERMAC

The Electromagnetic Radiation Management Advisory Council (ERMAC) continued to advise OTP and now the Secretary of Commerce and NTIA on possible "side effects" associated with the use of the radio spectrum -- particularly, on the Federal program to assess biological effects and ensure appropriate use of radiofrequency RF energy. It is comprised of individuals with expertise in the various relevant disciplines including the engineering, physical, biological and medical sciences. Meetings are attended by officially designated Agency representatives. Two members were added to the Council in 1976: Dr. Charles Susskind (Univeristy of California, Berkeley) and Mr. George Sacher (Argonne National Laboratory). Dr. Arthur Upton (presently of the National Cancer Institute) was also appointed but resigned after a brief period due to the press of other commitments.

The Council continued its program of seminars to review knowledge, ongoing research and progress, and encourage exchange in specific program areas by conducting a seminar on immunologic system responses to RFR. A summary of this seminar is included as Appendix C. A principal activity during 1976 and 77 was to conduct a comprehensive series of reviews of agency programs, over the past 5 years, throughout the Federal government as a basis for evaluating current requirements and developing updated research and fiscal guidelines for future efforts. These meetings are open to all interested parties and are attended by members of the scientific community, industry and the public.

SIDE EFFECTS WORKING GROUP

The interagency Side Effects Working Group is organized within the structure of the Interdepartment Radio Advisory Committee (IRAC) which assists NTIA in developing policies and criteria for use of the spectrum and NTIA's management and assignment of frequencies for U. S. Government RF emitters. The Working Group's principal function is to assist in intra-governmental coordination of the multiagency program concerned with biological effects and guidelines for exposure or use of RF/MW radiation. This is reflected in its membership which consists of each agency's point-of-contact for their bioeffects activities. It serves as a focal point for treating matters pertaining to research programs and provides a forum for the preparation and exchange of information of common concern and interest in this area. It maintains close liaison with the ERMAC; many members also serve as their agency's representatives to the ERMAC.

Activities during the 1976-78 period included: revising and updating information on individual research projects to reflect FY 1977 and FY 1978 Program activities; served as a focal point for information and participated in the ERMAC reviews of government-wide efforts, and; participated in a review and evaluation of the NTIA/OTP computerized information system on relevant world literature, to identify improvements or alternatives which would make the system more compatible with user requirements and result in cost enefits.

The Working Group also considered or maintained awareness of such matters as: research on fields associated with electric power transmission; standards and regulatory activities; US-USSR cooperative research and activities in other countries, and; situations engendering public concern.

STANDARDS AND LEGISLATION

Government agencies with standards authority include: HEW/BRH--electronic product emission, DOL/OSHA--occupational, EPA-environmental. Additionally, the military and the States can develop standards for their own use. These must at least comply with any OSHA or EPA criteria, but may be more restrictive. In the case of product emission standards promulgated by FDA/BRH under PL 90-602 (i.e., for microwave ovens), they cannot differ. There are also a number of international bodies which develop standards.

Current U.S. Government Standards include:

Ocupational Standard (general) - OSHA Standard (29 CFR 1910.97, 2 June, 1974)* adopted in 1972, applies to employees in the private sector. (Section 19, Executive Order (E.O.) 11612 and E.O. 11807 make OSHA Standards mandatory for federal employees including the military). Maximum permissible exposre limits are 10 mW/cm^2, as averaged over any 6 minute period, over the frequency range 10 MHz-100 GHz.

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* Code of Federal Regulations (CFR) Title 29, Part 1910.97.

Occupational Standard (telecommunications) - OSHA Standard (29 CFR 1910.268), adopted on March 26, 1975, applies to work conditions particular the telecommunications industry. 29 CFR 1910.97 is included as the radiation protective guide.

Product Emission Standard - BRH microwave oven standard. Effective 10/71 and amended 12/71, 8/73, 4/75 and 11/75. Ovens may not emit (leak) more than 1 mW/cm^2 at time of manufacture and 5 mW/cm^2 subsequently, for the life of the product -- measured at a distance of 5 cm and under conditions specified in the standard.

Additionally there are non-government organizations which develop recommended standards and safety criteria, e.g.:

American National Standards Institute (ANSI) - A widely recognized, voluntary body with members from government, industry, various associations and the academic community which develops consensus standards (guides) in various areas. ANSI issued a nonionizing radiation safety standard in 1966 with maximum permissible exposures of 10 mW/cm^2, as averaged over any 6 minute period, for frequencies from 10 MHz to 100 GHz which was essentially adopted by OSHA. This standard was reviewed and reissued with minor modifications in 1975 as "Safety Level of Electromagnetic Radiation with Respect to Personnel" (ANSI C-95.1-1974).

Existing Legislation and Orders with Relevance include:

"Radiation Control for Health and Safety Act of 1968" (PL 90-602), administered by HEW/FDA (BRH). Provides authority for controlling radiation from electronic devices.

"National Environment Protection Act (NEPA) of 1969" (PL 91-190). Requires environmental impact assessments and statements.

"Reorganization Plan No. 3 of 1970" created EPA which has authority to establish environmental standards (including radiation).

"Occupational Safety and Health Act of 1970" (PL 91-596), administered by DOL/OSHA. Provides authority to promulgate occupational safety standards. HEW/NIOSH provides research support and recommendations.

"Department of Energy Reorganization Act of 1977" (PL 95-91) established the Department of Energy (DOE) which, like its predecessor ERDA, conducts energy-related research including research on environmental and biological effects of various energy generation and transmission schemes.

During 1976-78, the following standards/legislative-related activities occurred:

- HEW/FDA(BRH), on 31 March 1976, a revised draft standard for microwave diathermy equipment was presented to the Technical Electronic Products Radiation Standards Committee (TEPRSSC) -- a statutory advisory body, established under PL 90-602, which must be consulted by FDA/BRH prior to promulgating standards under that act. TEPRSSC recommended that BRH meet with researchers and clinical users to explore the clinical implications of the applicator requirements prior to publishing the standard as a proposed rule. That meeting was held on March 24, 1977. At the meeting BRH solicited comment on the clinical implications of the draft performance standard. Attendees indicated general acceptance of the draft, but suggested a change that would restate the requirement pertaining to the heating ability of the applicator. The Bureau is studying ways of incorporating the proposed change into the draft and integrating it with the specific leakage limit. Once the standard has been redrafted, it will be published in the Federal Register as a proposed rule.

- The American National Standards Institute (ANSI) rules require that action be taken to review and withdraw, revise or reissue ANSI standards every five years. Presently Subcommittee 4 of Committee C-95, which deals with hazards to personnel is reevaluating ANSI's nonionizing radiation exposure standard, for action in 1979. ANSI working groups have been reviewing pertinent literature as a basis for this action.

- The National Institute for Occupation Safety and Health (NIOSH), at the request of the Occupational Safety and Health Administration (OSHA) and in response to increasing concern from the Congress and the public, is developing a criteria document with recommended standards for occupational microwave and other RFR exposures. On December 23, 1976 a notice was published in the Federal Register requesting information to aid in developing the criteria document. NIOSH announced its decision to develop a recommended occupational health standard, in the RF/MW and other areas, in the Federal Register on October 28, 1977 and again solicited information. No useful information was received as a result of these notices. A review of relevant world literature was conducted in 1978. The criteria document with recommendations is expected to be completed in 1979.

- U.S. Navy on 28 January 1977 issued BUMED INSTRUCTION 6470.13A, "Microwave and Radiofrequency Health Hazards" which cancels and replaces BUMEDINST 6470.13. The Instruction specifies maximum exposure levels in the 10 MHZ to 100 GHz frequency range, provides guidance for medical surveillance, and specifies requirements for reporting microwave overexposure incidents. It applies to all microwave and other radio frequency generating equipment except microwave ovens. Maximum permissible exposure limits are the same as those of OSHA and the ANSI guideline: ANSI C-95.1-1974.

- Interagency Regulatory Liaison Group (IRLG). The Food and Drug Administration, the Consumer Product Safety Commission, the Environmental Protection Agency, and the Occupational Safety and Health Administration in August 1977 agreed to form an Interagency Regulatory Liaison Group "to improve the public health by sharing information, avoiding duplication of effort and developing consistent regulatory policies" in various areas. One of its 8 Work Groups, the Regulatory Development Work Group, recently completed a plan for coordinated regulatory action in the area of radiation protection.

- "Department of Energy Reorganization Act of 1977," (PL 95-91) - see above.

- The State of Texas on August 29, 1977, passed a regulation for control of radio frequency electromagnetic radiation. The regulation took effect on November 18, 1977 and has been adopted by the Texas Board of Health. Its provisions include:

  - requires registration of 10 MHz-100 GHz sources which produce accessible radiation levels 10 times the 1974 ANSI exposure limit of 10 mW/cm^2

  - regulations do not apply to telecommunications services licensed by the FCC or to installations of the Federal Government, however

- the Texas Dept. of Health is to be notified of all normally accessible installations emitting radio frequency radiation in excess of the ANSI limits.

o <u>NATO</u>. A research study group's recommendation for electric field exposure limits in the 1-30 MHz frequency region is still under consideration. The proposed limits are 1000 V/m (266 mW/cm^2) for 1-10 MHz and 500 V/m (66 mW/cm^2) for 10-30 MHz. If accepted, these limits would be added to the current NATO 10 mW/cm^2 standard for frequencies above 30 MHz. The recommended limits would be more permissive than current ANSI/OSHA standards in the 10-30 MHz band.

Foreign standards activities:

o <u>Sweden</u>. The Swedish National Board for Industrial Safety, on June 22, 1976, promulgated a nonionizing radio frequency standard (Worker Protection Authority Instruction No. 111) effective January 1, 1977. This regulation applies to all work which may involve exposure to radio frequencies betwen 10 MHz and 300 GHz. The instruction specifically excludes applications involving the treatment of patients. Maximum permissible exposures (as averaged over a six minute period) are:

5 mW/cm^2	10 MHz	to	300 MHz
1 mW/cm^2	300 MHz	to	300 GHz

The maximum permissible momentary exposure in the range 10 MHz - 300 GHz is 25 mW/cm^2.

o <u>USSR</u>. The State Committee on Standards of the Council of Ministers of the USSR on January 22, 1976, promulgated "Occupational Safety Standards for Electromagnetic Fields of Radiofrequency (GOST 12.1.006-76)," effective January 1, 1977. It specifies the maximum permissible magnitudes of voltage and current density of an EM field at the work place of personnel servicing equipment radiating EM energy. It does not apply to personnel located in sections and institutes of the Ministry of Defense. The standard includes modifications and replaces the previous occupational standard. Maximum permissible RF fields in the workplace must not, during the course of the workday, exceed;

<table>
<tr><th colspan="2">P (mW/cm^2)</th><th>E (V/m)</th><th>H (A/m)</th><th>Frequency Range</th></tr>
<tr><td rowspan="5">Stationary Source (see Note 1)</td><td rowspan="5">Rotating, scanning</td><td rowspan="2">50</td><td>5</td><td>60 KHz-1.5 MHz</td></tr>
<tr><td></td><td>1.5 MHz-3.0 MHz</td></tr>
<tr><td>20</td><td></td><td>3.0 MHz-30 MHz</td></tr>
<tr><td>10</td><td>0.3</td><td>30 MHz-50 MHz</td></tr>
<tr><td>5</td><td></td><td>50 MHz-300 MHz</td></tr>
<tr><td>.01</td><td colspan="3">0.1 (entire workday)</td><td rowspan="3">300 MHz-300 GHz</td></tr>
<tr><td>0.1</td><td colspan="3">1.0 (2 hr. period during workday)</td></tr>
<tr><td colspan="4">1.0 (20 min. period during workday)</td></tr>
<tr><td colspan="5">Note 1: Also applies in environments with ambient temperatures above 28°C and/or in the presence of x-ray radiation, except, under these conditions, the maximum during a 20 minute period is restricted to 0.1 mW/cm^2.</td></tr>
</table>

- <u>USSR</u>. Information presented at a 1978 conference and subsequent discussions between US and Soviet scientists, indicates that the USSR Ministry of Health has endorsed guidelines for maximum exposure limits for the general poplation. These guidelines are said to be enforceable and currently in use. There is however a one year period while the new standard is "on trial." The standard stipulates the maximum allowable levels of electromagnetic energy in human dwellings or in areas of human dwellings, as follows:

P ($\mu W/cm^2$)	E(V/m)	Frequency Range
	20	30-300 KHz
	10	300 KHz-3.0 MHz
	4	3.0-30 MHz
	2	30-300 MHz
5		300 MHz-300 GHZ

o <u>Poland</u>. The Polish Ministers of Work, Wages and Social Affairs and of Health and Social Welfare on February 19, 1977, promulgated a change to the Polish Standard for maximum permissible levels of occupational exposure. The change extends the frequency range down from 300 to 0.1 MHz, as shown below:

Hazardous Zone II T_P		Hazardous Zone I T_P		Intermediate Zone T_P		Safe Zone T_P	Frequency Range
0	250 A/m 1000 V/m	80/H 560/E	10 A/m 70 V/m	Entire 8 hr Workday	2 A/m 20 V/m	No limit	0.1-10 MHz
	300 V/m	$3200/E^2$	20 V/m		7 V/m		10-300 MHz

T_P = Permissible time of exposure/workday (minutes).
E = Electric field (volts/meter).
H = Magnetic field (amps/meter).

- Canada. The Radiation Protection Bureau of Health and Welfare Canada is considering proposed "Emission and Exposure Standards for Microwave Radiation." The maximum permissible levels (MPL'S), when first proposed in 1976 contained two parts; (a) 1 mW-hr/cm^2 average energy flux for whole body exposure as averaged over an hour with a maximum exposure during any one minute of 25 mW/cm^2 for occupational settings, and (b) one tenth of the occupational MPL's for the general poplation. The MPL's would apply for the frequency range of 10 MHz-300 GHz. No distinction is made between CW and pulsed waveforms. The proposal was subsequently modified to eliminate the tenfold difference for the general population... "since it is felt that present data on biological effects does not justify a lower MPL."

INTERNATIONAL

- US-USSR Cooperative Research. "Study of the biological effects of microwave radiation," Topic 4.1, Environmental Health Agreement, being coordinated by NIEHS, has been active for apprixim ately 4 years. Soviet research has been primarily at 2375 MHz CW with power density levels of 1, 5, 10, 50, and 500 uW/cm^2. Most of the U. S. research is being conducted at 2450 MHz with power density levels in the milliwatt range. One project consists of "duplicate" experiments being conducted in both countries. It involves 3 month exposure periods at power densities of 500 μW/cm^2.

  In October 1977, Topic 4.2, "Study of biological effects of static and low-frequency electromagnetic fields," was added. Presently, this topic is concerned with biological effects of high voltage transmission line fields, 60 Hz in the US and 50 Hz in the USSR.

  A workshop is planned on Problem 4 on June 11-15, 1979 in Seattle, Washington. Approximately eight Soviet scientists and twelve U.S. scientists, directly involved in the cooperative program, are expected to participate. The workshop will devote 1½ days to each topic area, and two days to future cooperative projects and plans. Papers on the current cooperative projects will be exchanged, translated and distributed to participating scientists before the workshop. These papers will be published in Environmental Health Perspectives, a journal of the National Institute of Environmental Health Sciences.

- The International Radiation Protection Association (IRPA) charter was broadened in April 1977, to include nonionizing radiation. IRPA is seeking funds to devote to this topic and plans to join forces with the World Health Organization (WHO) on its criteria document (see below).

- The World Health Organization (WHO), a UN technical agency with headquarters in Geneva, has a program for development of criteria documents, covering a variety of health related topics. These criteria documents are essentially textbook presentations of particular insults. WHO currently plans to develop a criteria document on RF/microwaves, with a final draft scheduled for March 1979.

- The European Regional Office (ERO) of the World Health Organization is presently preparing a manual on health aspects of exposure to nonionizing radiation. The manual lacks the strict protocol of a WHO criteria document. It is intended to provide guidance on nonionizing radiation protection and to summarize international experience in the field. Among the topic areas to be included are ultraviolet, optical, laser and infrared; microwave, RF and ELF fields; ultrasound; licensing, legislation and regulations.

OTHER ACTIVITIES

- HEW/National Cancer Institute (NCI). The National Cancer Institue's involvement with RF/microwaves stems from its interest in their use for the diagnosis and treatment of cancer. NCI is supporting a number of intramural and extramural programs, including clinical evaluations of the efficacy of RF/microwaves in the treatment of certain types of cancer. A substantial proportion of this work is concerned with investigating the applicability of RF/microwave heating in cancer therapy. NCI also has interest in basic mechanisms of tissue interactions with RF at the cellular and molecular level.

  This area has been the subject of increasing interest and activity in the U. S. and other countries and has been covered in a number of recent meetings and conferences.

- The National Council for Radiation Protection and Measurement (NCRP) is a non-profit corporation chartered by the Congress with responsibility to develop, select, analyze and disseminate information about radiation protection and measurement. It is not a government organization and there are no appropriated funds. Founded in 1929, it is primarily oriented toward protection against ionizing radiation as used in medical procedures. Its primary task is the preparation of NCRP reports which make recommendations on radiation protection and measurement.

In the RF/microwave area, NCRP recognizing that problems exist with terminology for physical parameters of RF/microwaves and their interaction with matter turned its attention first to quantities, units, and measurment techniques as used in RF/microwave research. An attempt is being made to develop nomenclature which will differentiate between nonionizing and ionizing radiation. NCRP Scientific Committee 39 on "Microwaves" is currently addressing this topic.

NCRP Scientific Committee 53, was recently formed to deal with biological effects and criteria for radio frequency radiation. The Committee is presently concerned with reviewing health effects and not standards development at this stage.

- Electric and Magnetic Field Effects. The Department of Energy (DOE) is sponsoring research to identify and characterize biological and ecological effects that may be induced by electric and/or magnetic fields produced by high voltage transmission lines (HVTL), both DC and 60 Hz AC. DOE chairs an Interagency Advisory Committee on Electric Field Effects from High Voltage Lines established for the coordination and exchange of information. DOE also supports some research on effects of intense magnetic fields.

  Research on electric field effects includes:

  - Rats and mice are being exposed to 60 Hz fields up to 130 kV/m to determine the effects of long term exposure on growth, development, reproduction, biochemical parameters, behavior, immunology, pathology, etc. - Pacific Northwest Laboratories (PNL)

  - Drosophila (fruit fly) and microorganisms are being exposed to DC and 60 Hz AC to study mutagenic effects.- PNL (jointly with EPA)

- Rats are being studied for perception of and aversion to various intensities of 60 Hz AC; possible somatic effects are also being studied. Tissue cultures exposed *in vitro* are being studied for effects on cell physiology, reproduction, growth, morphology and viability. Predictive biophysical models are being sought. - University of Rochester (UR)

- Mammalian cells *in vitro* are being exposed to 60 Hz AC to evaluate effect on genetic and reproductive parameters. - Sandia, Albuquerque and Los Alamos Scientific Lab (LASL)

- Effects of 60 Hz AC on the CNS and behavior. - University of California (UCLA)

- Analysis of testimony submitted for licensing of a 765 kV HVTL in New York State; health and environmental effects. - SRI International

- Electric and magnetic field measurement instrumentation development and calibration. - National Bureau of Standards (NBS)

- Analysis of responses to EPA Federal Register request (March 18, 1975) for information on health and environmental effects of 345 kV or higher EHV. - Illinois Institute of Technology Research Institute (IITRI) (jointly with EPA)

- Electric and magnetic field measurement instrumentation development and calibration. - National Bureau of Standards (NBS)

- Exposure of non-human primates to 60 Hz AC to verify protocol for a potential long term experiment. - SRI International

- Exposure of mammals to ELF (10-60 Hz); effect on circadian regulatory processes. - Argonne National Laboratory (ANL)

- Feasibility of using an assay developed for evaluation of RF/microwaves on the CNS, to determine effects from low level exposure to 60 Hz AC. - Randomline

- Wide spectrum ecological effects from 1200 kV prototype line near Lyons, Oregon. - Bonneville Power Administration (BPA)

- Ecological effects of ± 400 kV HVDC line a Celilo-Sylmar, Oregon. - BPA

- Bird (raven and raptor) nesting habits on HVTL structures with measurements of E-fields in the nests (40 kV/m or more). - BPA

- Bird flight behavior near HVTL. - BPA

Magnetic field research has been recently initiated and consists of generic studies primarily concerned with relatively high field strengths in general, e.g.:

- Studies to understand phenomena in terms of mechanisms and theory; a small animal exposure chamber is being developed; preliminary data has been gathered on insects and moles exposed to strong (1-4 kilogauss) static magnetic fields. - Lawrence Berkeley Laboratory (LBL)

- Epidemiology of 2000 scientists exposed to 4000 gauss-days/year for 5 years. - LBL

- Effects of magnetic fields on growth, development, behavior and other endpoints in mice and trout. - PNL

- Genetic affects of static magnetic fields in *Drosophila* and *Tradescantia* (a flowering plant). - Brookhaven National Laboratory (BNL)

o The Bioelectromagnetic Society, a new scientific society, was formed in 1978 to promote research on the interaction of nonionizing electromagnetic and acoustic energy. It plans to sponsor meetings, and publish a newsletter and journal.

Industry Activities:

o Motorola. Beginning in 1975 and continuing through 1977/78, the Motorola Corporation has funded research to characterize the electromagnetic fields surrounding portable hand-held transmitters in the frequency bands: 30, 150, 450 and 800-900 MHz, during typical and "worst-case" operation. A portable transceiver was placed in front of a phantom head such that the radio case was 0.2" from its nose to simulate "worst case" use. Temperature rise was measured at several locations inside the head following exposure from 6W units. Incident fields and resultant SAR's which would be necessary to produce the temperature changes found in the head were calculated. Peak SAR's in the phantom head, as calculated from temperature measurements, ranged from immeasureably small at 30 MHz (instrument sensitivity 0.5 mW/g) to 5 mW/g during the 800-900 MHz band exposures. These studies seam to indicate that the average SAR level in the head of a user would be between 0.1 and 0.01 mW/g from a 6W transmitter held at 0.2" from the nose.

- The Electric Power Research Institute (EPRI), was organized in 1973 by public and private utilities to develop and administer a coordinated national electric power research and development program. It provides, through combined funding, a means of financing electric power research that exceeds the individual capability of most utilities. As part of its activity EPRI supports research into the biological/ecological effects of HVTL at universities and other organizations. These activities are interactive with research supported by the DOE and EPA in this area. Additionally EPRI participates in the US-USSR Cooperative Program on Energy (research at power line frequencies).

Meetings. Some meetings, symposia and conferences which treated the subject of biological effects and/or medical applications of nonionizing electromagnetic radiation include the following:

1976

Health Physica Society Occupational Health Physic Symposium, Denver, Colorado, February 9-12, 1976.

National Bureau of Standards Symposium on Measurement for the Safe Use of Radiation, Gaithersburg, Maryland, March 1-4, 1976.

Aerospace Medical Association 47th Annual Scientific Meeting, Bal Harbour, Florida, May 10-13, 1976.

IEEE International Microwave Symposium, Cherry Hill, New Jersey, June 14-16, 1976.

International Microwave Power Institute 11th Annual Microwave Power Symposium, Leuven, Belgium, July 27-30, 1976.

European Microwave Conference, Rome, Italy, September 14-17, 1976.

International IEEE/AP-S Symposium and USNC/URSI Meeting, Amherst, Massachusetts, October 11-15, 1976.

Radiological Society of North America Science Assembly and Annual Meeting, Chicago, Illinois, November 14-19, 1976.

<u>1977</u>

Bureau of Radiological Health Symposium on Biological Effects and Measurements of RF/Microwaves, Rockville, Maryland, February 16-18, 1977.

DOD Electromagnetic Compatibility Analysis Center (ECAC) Conference on Undesirable Electromagnetic Effects, Annapolis, Maryland, April 5-7, 1977.

International Radiation Protection Association IV International Congress, Paris, France, April 24-30, 1977.

American Industrial Hygene Association Conference of Governmental Industrial Hygiene, New Orleans, Louisiana, May 22-27, 1977.

International Microwave Power Institute 12th Annual Microwave Power Symposium, Minneapolis, Minnesota, May 25-28, 1977.

Workshop on Physical Basis of Electromagnetic Interactions with Biological Systems, Univ. of Md., College Park, Maryland, cosponsored by the Bureau of Radiological Health and the U.S. Navy, June 15-17, 1977.

9th Annual National Conference on Radiation Control - Meeting Todays Challenges, sponsored by the Conference of Radiation Control Program Directors, Inc., June 19-23, 1977.

International IEEE/AP-S Symposium and USNC/URSI International Electromagnetic Symposium, Palo Alto, California, June 20-24, 1977.

IEEE (MTT-S) International Microwave Symposium, San Diego, California, June 21-23, 1977.

Second Electromagnetic Compatibility Symposium and Exhibit, Montreaux, Switzerland, June 28-30, 1977.

National Bureau of Standards Electromagnetic Interference (EMI) Workshop, Gaithersburg, Md., July 12, 13, 1977.

IEEE Electromagnetic Compatibility Symposium, Seattle, Washington, July 26-28, 1977.

IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1977.

17th Hanford Biology Symposium on Developmental Toxicology of Energy-Related Pollutants, Richland, Washington, October 17-19, 1977.

USNC/URSI International Symposium on Biological Effects of Electromagnetic Waves, Airlie, Virginia, October 30 - November 4, 1977.

Alliance for Engineering in Medicine and Biology Conference on Engineering in Medicine and Biology, Los Angeles, California, November 5-9, 1977.

1978

17th Annual Meeting of the San Diego Biomedical Symposium, San Diego, California, February 1-3, 1978.

Seminar/Workshop on Cardiac Pacemaker Safety for Power Frequency Fields and Currents, sponsored by the Electric Power Research Institute (EPRI), Chicago, Illinois, February 23-24, 1978.

10th Annual National Conference on Radiation Control, Sponsored by the Bureau of Radiological Health, Commonwealth of Pennsylvania, Harrisburg, Pa., April 30 - May 4, 1978.

International IEEE/AP-S Symposium-USNC/URSI Meeting, University of Md., College Park, Md., May 15-19, 1978.

Symposium on Electromagnetic Fields in Biological Systems, sponsored by the MTT-S/IEEE and IMPI, Ottawa, Canada, June 27-30, 1978.

13th Annual Microwave Power Symposium, sponsored by the International Microwave Power Institute, Ottawa, Canada, June 27-30, 1978.

URSI-19th Assembly - Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, August 1-8, 1978.

8th European Microwave Conference, Paris, France, September 4-8, 1978.

18th Hanford Life Sciences Symposium - Biological Effects of Extremely Low-Frequency Electric Fields, sponsored by Batelle-Northwest Labs., Richland, Washington, October 16-18, 1978.

National Bureau of Standards Workshop on Causes, Effects and Regulation of Electromagnetic Pollution, Gaithersburg, Md., November 2-3, 1978.

<u>1979</u>

Symposium on Health Aspects of Nonionizing (Microwave) Radiation, sponsored by The New York Academy of Medicine, April 9-10, 1979.

IEEE/MTT-S International Microwave Symposium, Orlando, Florida, April 30 - May 2, 1979.

International Symposium on Electromagnetic Compatibility, Rotterdam, The Netherlands, May 1-3, 1979.

Workshop on the Mechanisms of Microwave Biological Effects, sponsored by the Navy and the BRH, University of Maryland, College Park, Md., May 14-16, 1979.

International Conference on Communications, sponsored by IEEE, Boston, Mass., June 10-13, 1979.

XIVth Microwave Power Symposium, sponsored by the International Microwave Power Institute, Monaco, June 11-15, 1979.

Workshop on Problem 4 of the US-USSR Cooperative Research Program, Seattle, Washington, June 11-15, 1979.

Bioelectromagnetics Symposium, sponsored by the Bioelectromagnetic Society and USNC/URSI, Seattle, Washington, June 18-22, 1979.

FIGURES

FIGURE 1.
PROGRAM AREAS: AREAS OF INVESTIGATION

No.

1. Genetic/Hereditary/Developmental

    Chromosomal
    Mitotic
    Reproduction/Fertility
    Embryology
    Pre- and postnatal development,etc.

2. Nervous System

    CNS
    Sensory
    Neurochemical-neuroendocrine
    Single cell - membrane phenomena

3. Behavioral/Psychological

4. Gross Physical Condition/General Health

    (specifics, as appropriate)

5. Epidemiology

    (specifics, as appropriate)
    Pro- and retrospective

6. Clinical Examinations

    (specifics, as appropriate)

7. Mechanisms of EM Interaction (with molecules, tissues, body systems, etc.)

    Micro-
    Macro-

8. Other Areas

    A. Ocular
    B. Cardiovascular
    C. Metabolism/Endocrinology/Biochemical
    D. Thermal/Thermoregulatory/Lethality
    E. Cytological/Histological/Morphological
    F. Other Effects: Blood, GI, Respiratory, Motor, Physical Endurance, Stress, Rhythms/ Biological Clocks, Disease, Immunology, etc...

FIGURE 1 (continued)

9. <u>Instrumentation/ Techniques/ Calibration/ Facilities</u>

   A. Bioresearch: EM measurement, special biomedical instrumentation, exposure and calibration facilities
   B. Field Measurements: Equipment, methodology, etc.

10. <u>Absorption/ Dose</u>

   A. Analytical/ Mathematical/Theoretical
   B. Experimental: Animal, phantom, models

11. <u>Environmental and Safety Studies</u>

   A. Environmental Surveys
   B. Population Studies
   C. Hazard Assessment/ Safety Standards

12. <u>Special Features</u>

   Specifics, such as:

   - Multiple frequencies
   - RF with other stressors and environmental factors (e.g., drugs, ionizing radiation, disease, etc.)
   - RF heating comparisons with other heat sources
   - Chronic/ acute comparison
   - Age, sex, and other biological factor comparisons
   - Literature studies/ data base
   - Medical applications: therapy, diagnosis
   - Waveform comparisons

FIGURE 2

EMR/BIOEFFECTS PROGRAM (Summary Data)- FY 76

			PROGRAM AREAS (See Figure 1)																
AGENCY	#PROJECTS	I=Inhouse O=Out	1 G/H/D	2 NS	3 BEHAV/ PSYCH	4 GROSS COND	5 EPIDEM	6 CLIN EXAM	7 MECH	8A EYE	8B C-V	8C MET/END/ BIOCHEM	8D T/T.REG	8E CYT/HIST /MORPH	8F OTHER	9 INST	10 ABSORP	11 ENVIR/ SAFETY	12 SPECIAL FEATURE
DOD(total)	(67)	(I=31 O=36)	(10-2,8) (1J)	(18-2,16)	(13-5,8)	(5-0,5)	(3-0,3)	(3-0,3)	(12-0,12) (2J)	(8-0,8) (2J)	(4-1,3)	(22-0,22) (3J)	(4-0,4)	(4-0,4)	(14-0,14)	(15-5,10)	(13-5,8) (1J)	(8-0,8)	(13-2,11) (3J)
ARMY	11 1w/BRH,DOD	I=7 O=4		2-0,2	2-1,1				2-0,2			3-0,3	2-0,2		2-0,2	4-1,3	4-2,2		2-1,1 1J
NAVY	43 2w/BRH 1w/BRH,DOD	I=19 O=24	9-2,7	15-2,13	11-4,7	5-0,5	3-0,3	3-0,3	8-0,8 1J	7-0,7 2J	4-1,3	16-0,16 2J	1-0,1	4-0,4	10-0,10	5-1,4	4-1,3	4-0,4	6-1,5 2J
AF	13 2w/NIOSH 1w/BRH,DOD	I=5 O=8	1-0,1 1J	1-0,1					2-0,2 1J	1-0,1 1J		3-0,3	1-0,1		2-0,2 1J	6-3,3	5-2,3 1J	4-0,4	5-0,5 2J
DNA	3T	I=3T	1-0,1 1T	1-0,1 1T		1-0,1 1T				1-0,1 1T		3-0,3 3T			1-0,1 1T				
HEW(total)	(27)	(I=15 O=12)	(11-2,9) (1J)	(8-0,8)	(5-0,5) (1J)	(1-0,1)	(2-0,2)		(7-0,7) (2J)	(2-0,2) (2J)	(1-0,1)	(9-0,9) (4J)	(2-0,2) (1J)	(4-0,4)	(7-0,7) (2J)	(6-0,6)	(8-0,8) (3J)	(6-0,6)	(6-1,5) (4J)
BRH	19 3w/DOD 1w/VA	I=8 O=9 O+I=2	7-2,5 1J	5-0,5	3-0,3 1J	1-0,1	2-0,2		3-0,3 1J	2-0,2 2J	1-0,1	6-0,6 2J	2-0,2 1J	4-0,4	3-0,3 1J	3-0,3	5-0,5 1J	5-0,5	4-1,3 3J
NIEHS	6	I=4 O=2	3-0,3	3-0,3	2-0,2				3-0,3			2-0,2			3-0,3	2-0,2	2-0,2		1-0,1
NIOSH	2 1w/AF	I=1 O=1	1-0,1 1J						1-0,1 1J			1-0,1 1J			1-0,1 1J	1-0,1	1-0,1 1J	1-0,1	1-0,1 1J
EPA	17	I=12 O=3 O+I=2	5-1,4	5-1,4	4-1,3		1-0,1		6-0,6			5-0,5			6-0,6	4-0,4	1-0,1	2-0,2	3-0,3
DOC-NBS	1+6T	I=1+6T														5-5,0 4T	1-1,0 1T	1-1,0 1T	
NSF	5	O=5		2-0,2					2-0,2					1-0,1		1-0,1	4-2,2		
FCC	1	I=1																1-1,0	
FAA	1	O=1																1-1,0	
CIA	1	I=1																	1-1,0
VA	2 1w/BRH	I=2	1-0,1 1J		2-0,2 1J					1-0,1		1-0,1 1J	1-0,1 1J		1-0,1 1J		1-0,1 1J		2-0,2 1J
TOTALS*	116	G=70, N=42 G+N=4	25	33	23	6	6	3	25	9	5	33	6	9	26	27	25	18	19

KEY

Example: DOD has a total of (67) projects: 31 are being conducted within DOD and 36 by outside contracts, grants, or another agency.
In program area No. 1, G/H/D (defined in Fig. 1) there are 10 relevant projects, of which:
- o 2 are concerned only with program area No. 1,
- o 8 are concerned with program area No. 1, and other program areas as well.

J - indicates a project jointly funded with another agency. (1J) or (2J) indicates number of jointly funded projects.
T - indicates a project funded by transfer dollars from another agency. (6T) indicates 6 transfer fund projects.
O+I - indicates extramural/intramural projects.

*Totals are adjusted to account for joint and transfer funding; similarly, G= 70 Government and N=42 Non-government projects.

EMR/BIOEFFECTS PROGRAM (Summary Data) -FY 77

FIGURE 3

AGENCY	#PROJECTS	I=Inhouse 0=Out	PROGRAM AREAS (See Figure 1): 1 G/H/D	2 NS	3 BEHAV/ PSYCH	4 GROSS COND	5 EPIDEM	6 CLIN EXAM	7 MECH	8A EYE	8B C-V	8C MET/END/ BIOCHEM	8D THERMAL T.REG	8E CYT/HIST /MORPH	8F OTHER	9 INST	10 ABSORP	11 ENVIR/ SAFETY	12 SPECIAL FEATURE
DOD(total)	(59)	I=25 0=33 I+0=1	(8-1) 1J	(19-1)	(11-4)	(2-0)			(13-0)	(5-0) 1J	(1-0)	(17-0) 1J	(5-0)	(6-0)	(19-0)	(10-2)	(17-3) 1J	(1-0)	(14-2) 2J
ARMY	12	I=8 0=4		3-1	1-1				2-0			4-0	2-0		2-0	6-1	5-0		2-0
NAVY	37 3w/BRH 3T	I=11 0=25 I+0=1	8-1 1J	14-0	10-3	2-0			11-0	4-0 1J	1-0	11-0 1J		6-0	13-0		7-2 1J		9-2 2J
AF	10	I=6 0=4		2-0					1-0	1-0		2-0	3-0		4-0	4-1	5-1	1-0	3-0
DNA	3T	I=3T	1-0 1T	1-0 1T		1-0 1T				1-0 1T		3-0 3T			1-0 1T				
HEW(total)	(24)	I=11 0=12 I+0=1	(10-1) 2J	(9-0) 1J	(8-0) 1J	(2-0) 1J	(2-0)		(5-0)	(1-0) 1J		(7-0) 2J	(3-0) 1J	(2-0)	(7-0) 1J	(5-0)	(6-0) 2J	(5-0)	(9-1) 3J
BRH	16 3w/Navy 1w/VA	I=8 0=8	6-1 2J	4-0 1J	3-0 1J	2-0 1J	2-0		2-0	1-0 1J		3-0 2J	3-0 1J	2-0	2-0 1J	4-0	6-0 2J	5-0	7-1 3J
NIEHS	7	I=3 0=4	3-0	5-0	5-0				3-0			4-0			5-0				2-0
NIOSH	1	I+0=1	1-0													1-0			
EPA	16	I=12 0=1 I+0=3	5-3	5-0	4-0				4-0			3-0		1-0	6-0	4-0 1T	1-0	1-0	3-0
DOC-NBS	1+3T	I=1+3T														3-3 2T		1-1 1T	
NSF	4	0=4		1-0					1-0					1-0		1-0	4-2		
FCC	1	I=1																1-1	
FAA	1	0=1																1-1	
CIA	1	I=1																	1-1
VA	2 1w/BRH	I=2	1-0 1J	1-0 1J	2-0 1J	1-0 1J				1-0		1-0 1J	1-0 1J		1-0 TJ		1-0 TJ		1-0 TJ
TOTALS*	105	G=59, N=43 G+N=3	22	34	24	4	2	0	24	6	1	26	8	10	32	21	27	9	25

EXPLANATION

I and O indicate intramural or extramural projects for an Agency.
I+O = a project conducted within and outside an Agency.
DOD and HEW totals are shown in ( ).
The number of projects in the various program areas are indicated as follows:

6-2 - the first number, 6, indicates the total number of relevant projects; of which 2 are concerned only with this area; (the other 4 are concerned with other program areas as well).
J - indicates a project jointly funded with another Agency. (e.g., 1J indicates one jointly funded project.)
T - indicates a project funded by transfer dollars from another Agency. (e.g., 6T indicates 6 transfer fund projects.)

*TOTALS - are adjusted to account for joint and transfer funding.
Similarly, G & N are adjusted to indicate projects conducted by government or non-government organizations.

EMR/BIOEFFECTS PROGRAM (Summary Data) -FY 78 FIGURE 4

			PROGRAM AREAS (See Figure 1)																	
AGENCY	#PROJECTS	I=Inhouse 0=Out	1 G/H/D	2 NS	3 BEHAV/PSYCH	4 GROSS COND	5 EPIDEM	6 CLIN EXAM	7 MECH	8A EYE	8B C-V	8C MET/END/BIOCHEM	8D THERMAL T-REG	8E CYT/HIST/MORPH	8F OTHER	9 INST	10 ABSORP	11 ENVIR/SAFETY	12 SPECIAL FEATURE
DOD (total)	(75)	I=37 0=37 I+0=1	(8-2) 1J	(25-1)	(13-3)	(2-0)			(23-2)	(3-D) 1J	(1-0)	(12-0) 1J	(5-0)	(7-0)	(27-0)	(13-4)	(15-4) 1J	(1-0)	(17-1) 1J
ARMY	15	I=11 0=4		3-1	2-1				1-0			2-0	3-D	1-0	1-0	9-2	6-0		2-0
NAVY	44 2w/BRH 2T	I=16 0=27 I+0=1	8-2 1J	17-0	9-2	2-0			18-2	2-0 1J		9-0 1J	1-0	6-0	18-0		6-2 1J		9-1 1J
AF	16	I=8 0=8		5-0	2-0				4-0	1-0	1-0	1-0	1-0		8-0	4-2	3-2	1-0	6-0
DNA	2T	I=2T	1-0 1T	1-0 1T		1-0 1T						2-0 2T			1-0 1T				
HEW(total)	(35)	I=22 0=11 I+0=2	(12-1) 2J	(8-0) 1J	(8-0) 1J	(3-0) 1J	(3-0)		(7-0)	(1-0) 1J		(8-0) 2J	(2-0) 1J	(3-0)	(9-0) 1J	(11-2)	(7-1) 2J	(10-0)	(13-0) 2J
BRH	22† 2w/Navy 1w/VA	I=17† 0=5	6-1 2J	2-0 1J	3-0 1J	2-0 1J	2-0		2-0	1-0 1J		3-0 2J	2-0 1J	2-0	2-0 1J	10-2	7-1 2J	9-0	9-0 2J
NIEHS	10	I=3 0=7	4-0	6-0	5-0				5-0			5-0		1-0	7-0				3-0
NIOSH	3	I=1 I+0=2	2-0			1-0	1-0									1-0		1-0	1-0
EPA	17	I=13 0=1 I+0=3	6-2	5-0	3-0				4-0			3-0	1-0	1-0	8-0	4-0	1-0	1-0	5-0
DOC-NBS	1+3T	I=1+3T														4-4 3T			
NSF	4	0=4		1-0					1-0					1-0		1-0	4-2		
FCC	1	I=1																1-1	
CIA	1	I=1																	1-1
VA	2 1w/BRH	I=2	1-0 1J	1-0 1J	2-0 1J	1-0 1J				1-0		1-0 1J	1-0 1J		1-0 1J		1-0 1J		1-0 1J
DOE	5	I=1 0=4			1-0	1-0										1-1		2-1	2-1
TOTALS*	138†	G=83†, N=51 G+N=4	25	39	26	6	3	0	35	4	1	22	8	12	44	31	26	15	37

EXPLANATION

I and O indicate intramural or extramural projects for an Agency.
I+O = a project conducted within and outside an Agency.
DOD and HEW totals are shown in ( ).
The number of projects in the various program areas are indicated as follows:

6-2 - the first number,6, indicates the total number of relevant projects; of which 2 are concerned only with this area;(the other 4 are concerned with other program areas as well).
J - indicates a project jointly funded with another Agency. (e.g., 1J indicates one jointly funded project.)
T - indicates a project funded by transfer dollars from another Agency. (e.g., 6T indicates 6 transfer fund projects.)

*TOTALS - are adjusted to account for joint and transfer funding.
Similarly, G & N are adjusted to indicate projects conducted by government or non-government organizations.

† Includes eleven projects previously treated as two.

FIGURE 5

FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY77

AM | FM | VHF TV | UHF TV | ← MW →

PROGRAM AREAS	NO. OF AGENCIES / RELEVANT PROJECTS*	ELF 0-3 KHz	VLF 3-30 KHz	LF 30-300 KHz	MF 300-3000 KHz	HF 3-30 MHz	VHF 30-300 MHz	UHF 300-3000 MHz	SHF 3-30 GHz	EHF 30-300 GHz	OTHER 300-3000 GHz EMP, vague, etc
1 GENETIC/ HEREDITARY/ DEVELOPMENT	7/22	45(2) 60 76 Hz(3)				27.12	150	425 915(2) 2450(14) 1700	12(2) 12.4 8.5—9.6 3 9		
2 NERVOUS SYSTEM	9/34	10 1—32 7 60(2) 76 Hz					100 147	2000 1600 900 425 450 1550—S 915(5) 918 1700 960 2375 985 2450(16) 1200 2700 1300 2800	12.4 —X— 11 3.7		
3 BEHAVIOR/ PSYCHOLOGY	6/24	1—32 7 60 76 Hz(2)					100	425 1200 450 2375 915(6) 2450(17) 960 2800	6 9.3		
4 GROSS COND	4/4	45 76 Hz(2)						915 2450			Various/ military sys
5 EPIDEMIOL	1/2										Various/ military sys
7 MECHANISMS	7/24	10 1—32 7 60(3) 76 Hz(3)				EMP/23.5	250 147	2000 900 450 1550—S 915 1200 918 1300 960 1700(2) 2000 2450(7)	20 4 —X— 11		
8A OCULAR	5/6							2450(5) 2890	16 9.3 10		

FIGURE 5 (continued)

FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY77

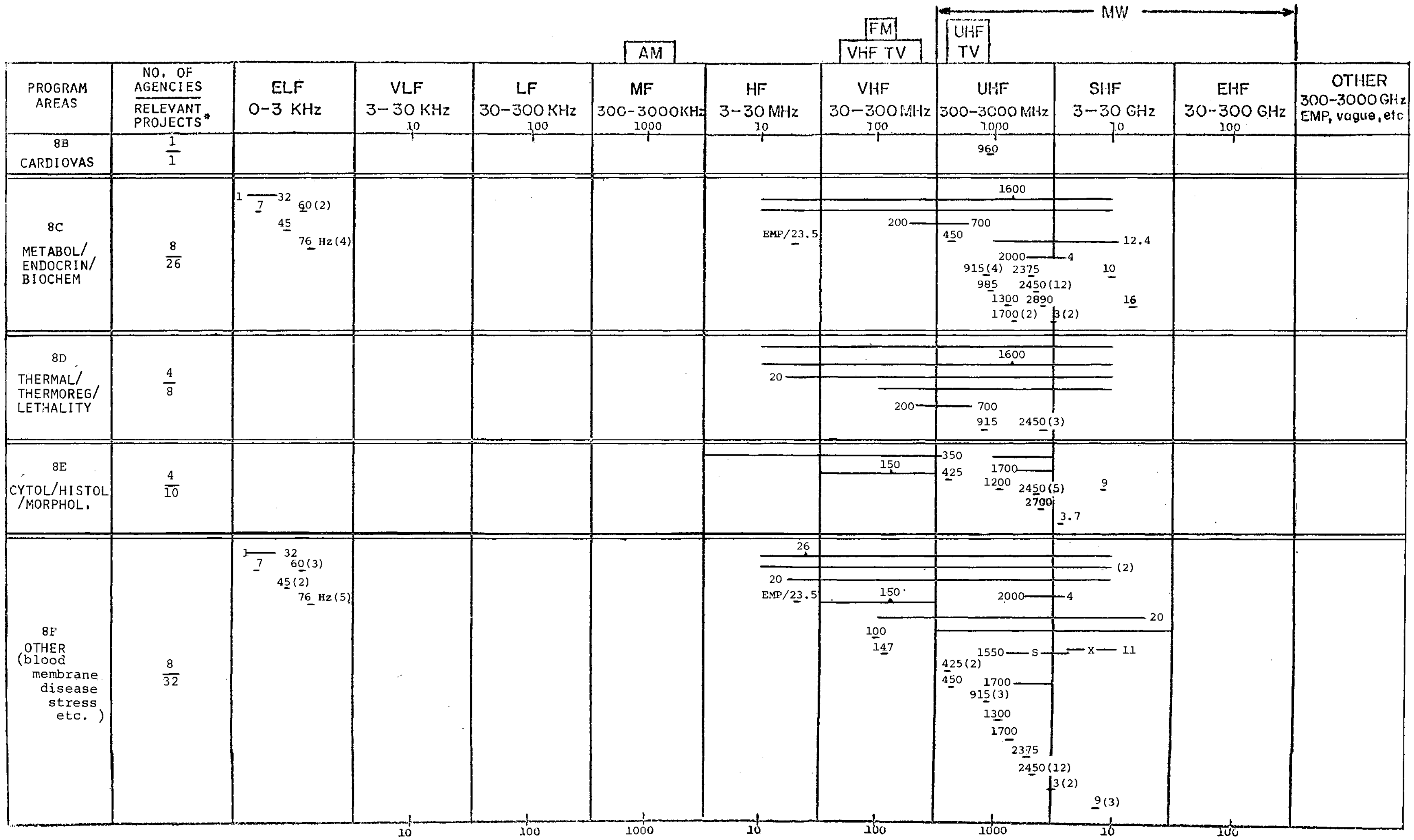
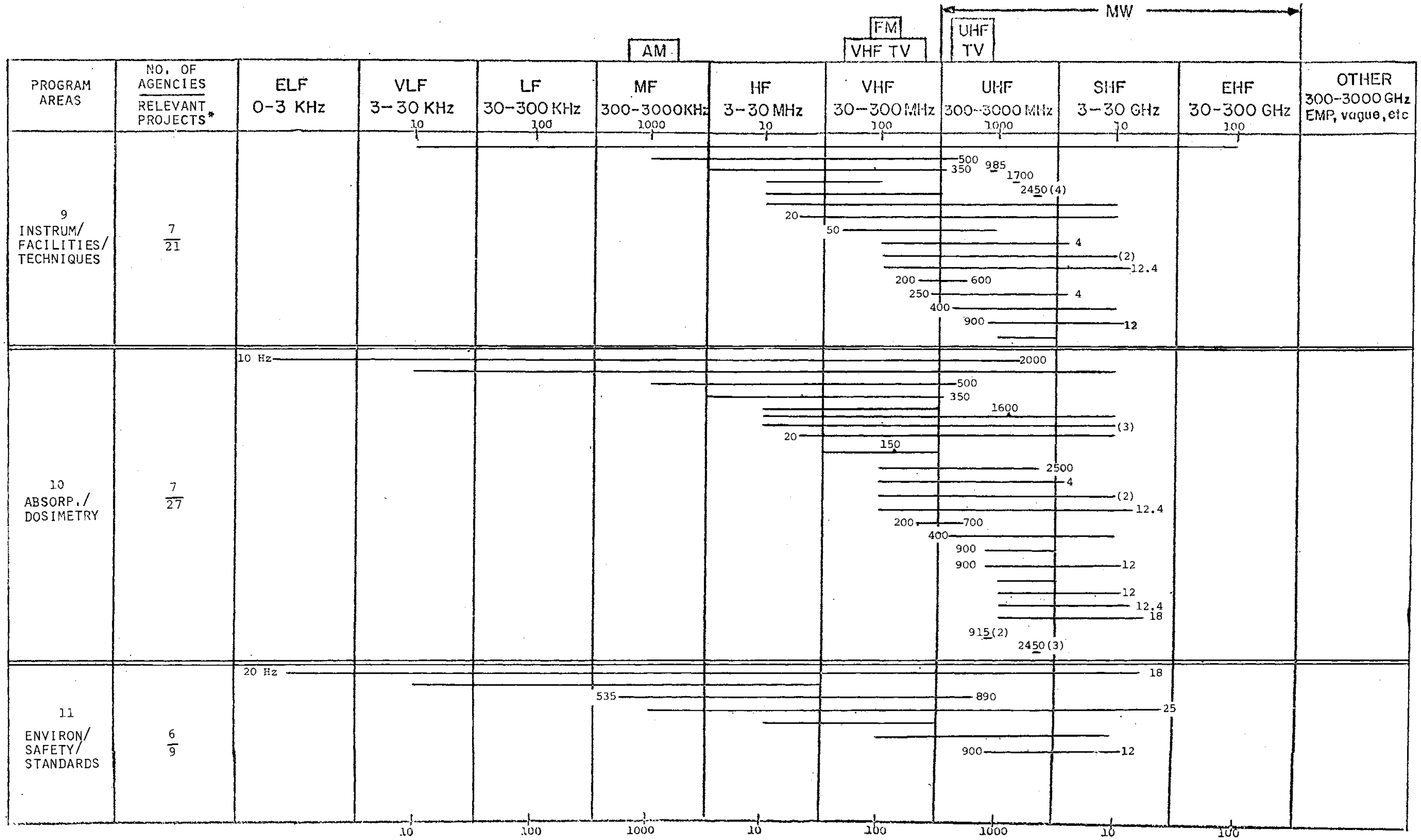


FIGURE 5 (continued)

FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY77



EXPLANATION: A number in ( ) indicates that more than one project applies.
Note, however that a single project may deal with more than one frequency (or range).

* Indicates total relevant projects. Individual projects which deal with more than one area are plotted in each applicable program area.

FIGURE 6

FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY78

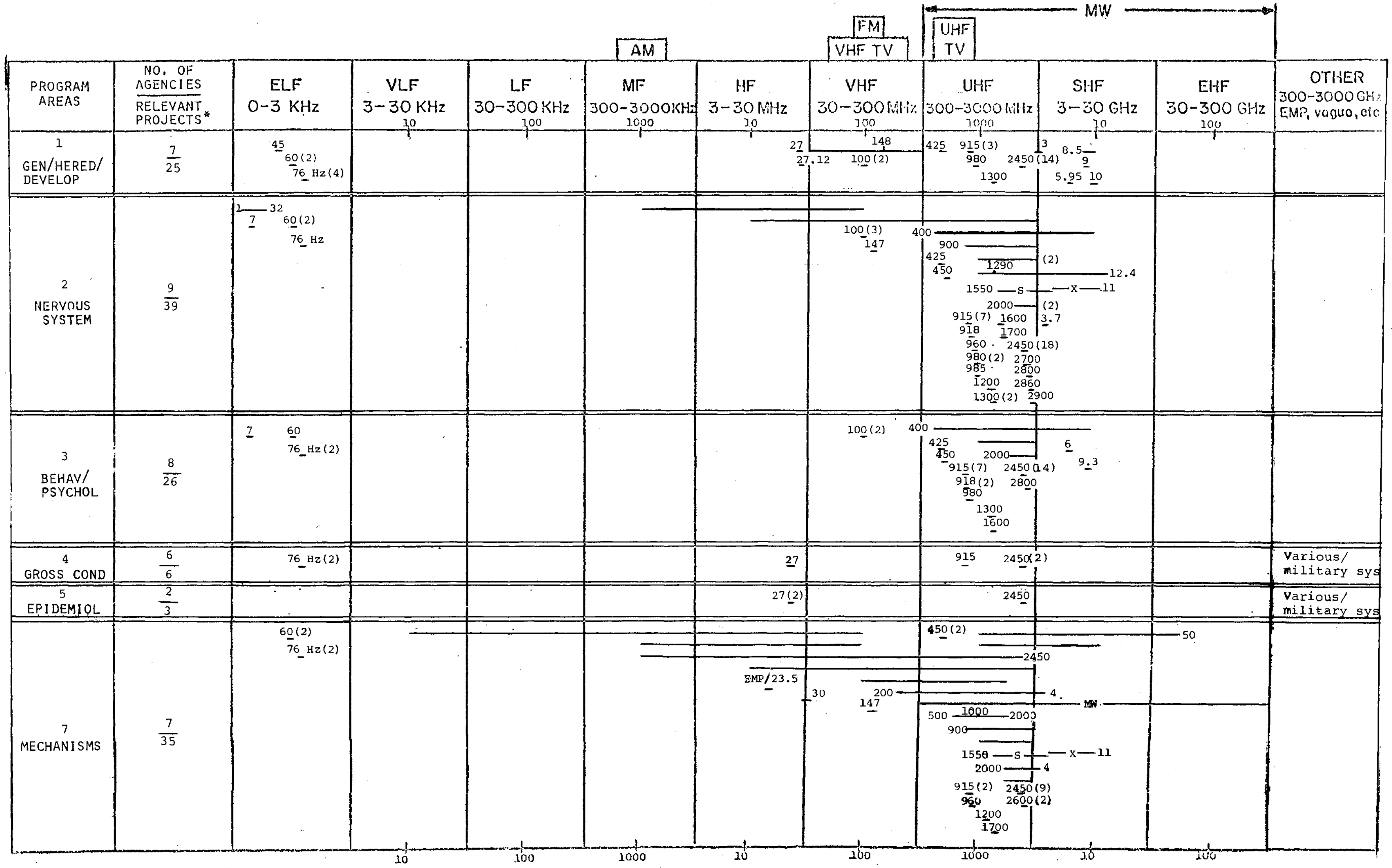
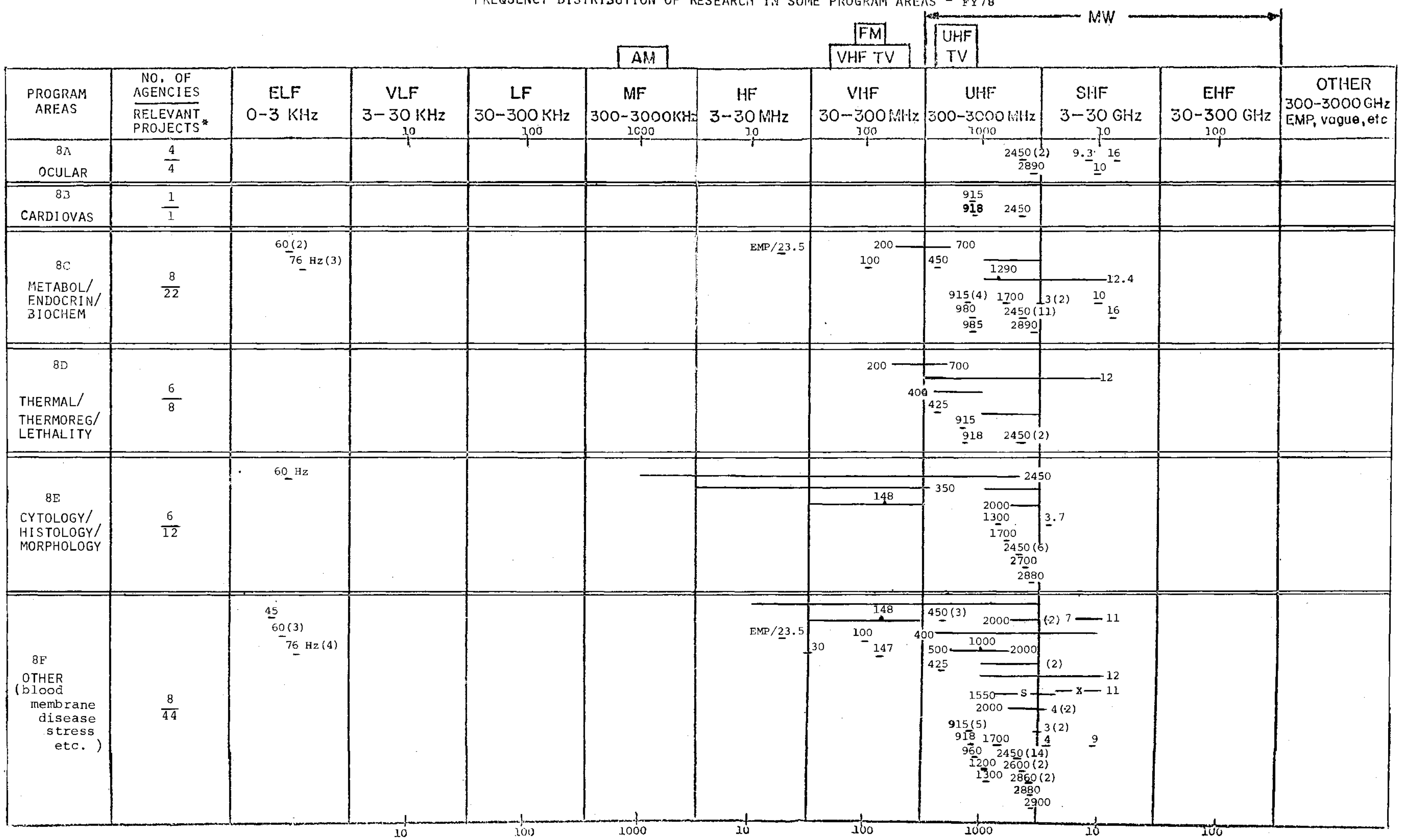


FIGURE 6 (continued)

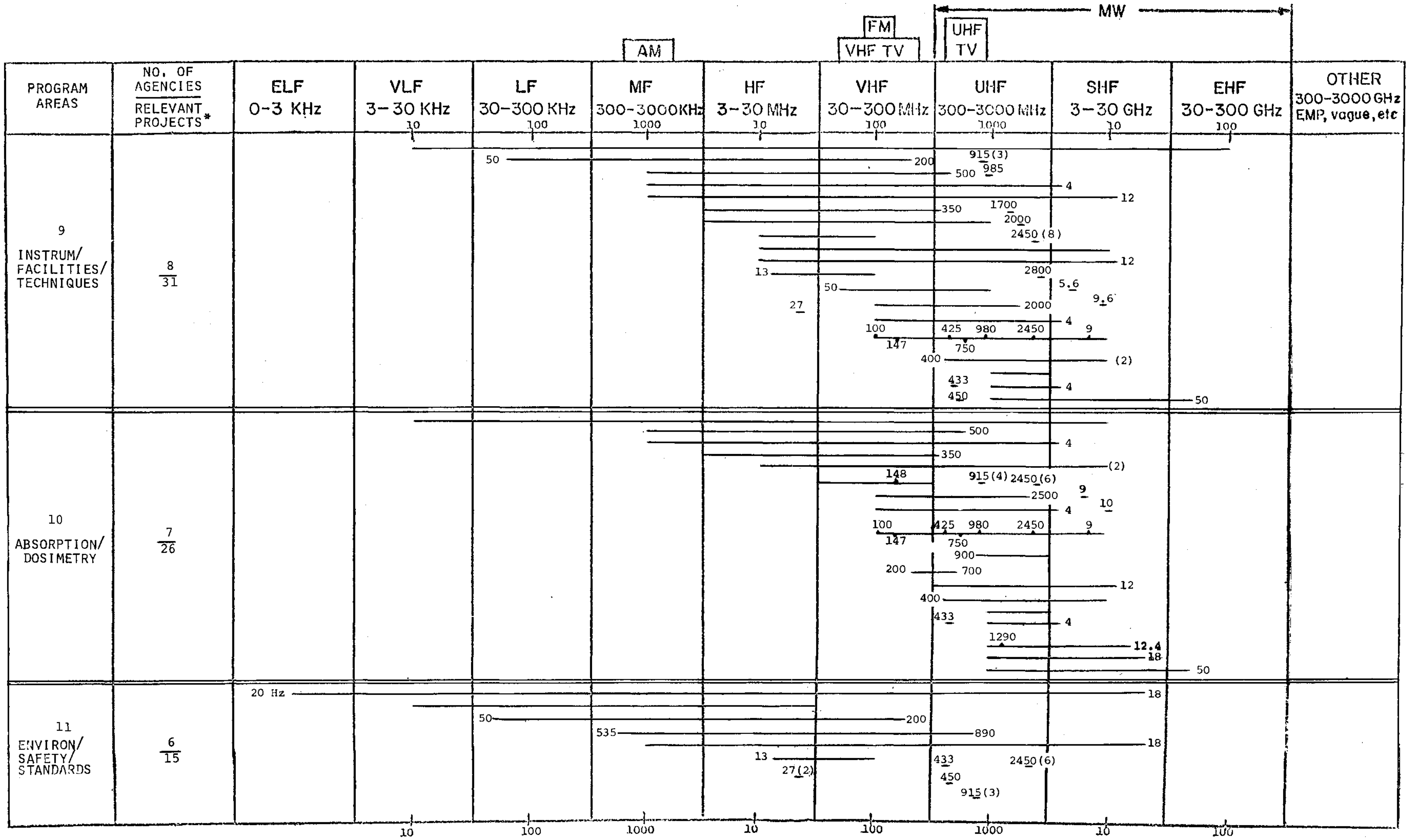
FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY78



110

FIGURE 6 (continued)

FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY78

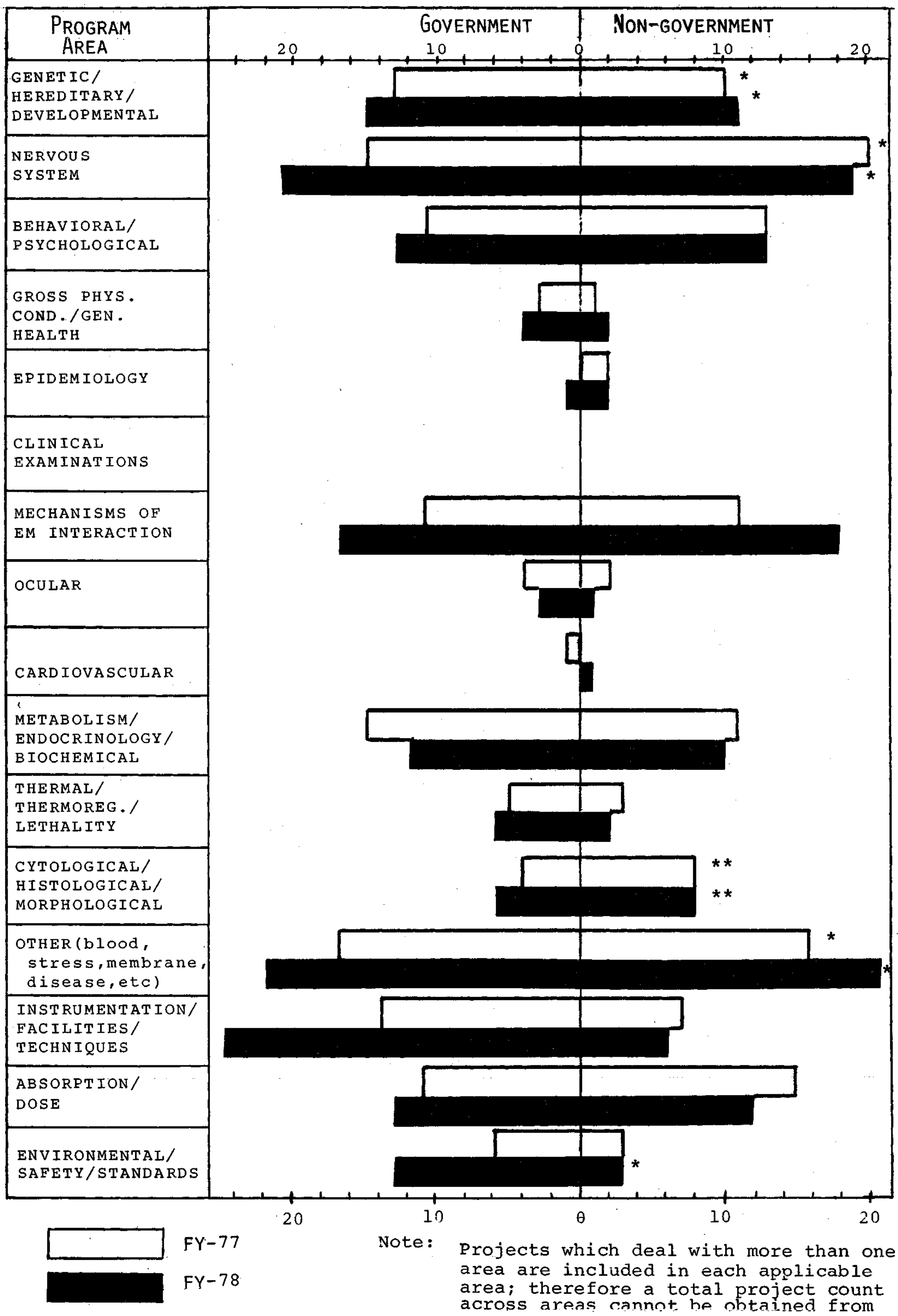


EXPLANATION: A number in ( ) indicates that more than one project applies.
Note, however that a single project may deal with more than one frequency (or range).

* Indicates total relevant projects. Individual projects which deal with more than one area are plotted in each applicable program area.

FIGURE 7

DISTRIBUTION OF GOVERNMENT/NON-GOVERNMENT PROJECTS BY PROGRAM AREA
(FY-77 & 78)



Note: Projects which deal with more than one area are included in each applicable area; therefore a total project count across areas cannot be obtained from this chart.
*Includes one gov-nongov project.
**Includes two gov-nongov projects.

FIGURE 8

FREQUENCY DISTRIBUTION OF RESEARCH BY AGENCY - FY 77

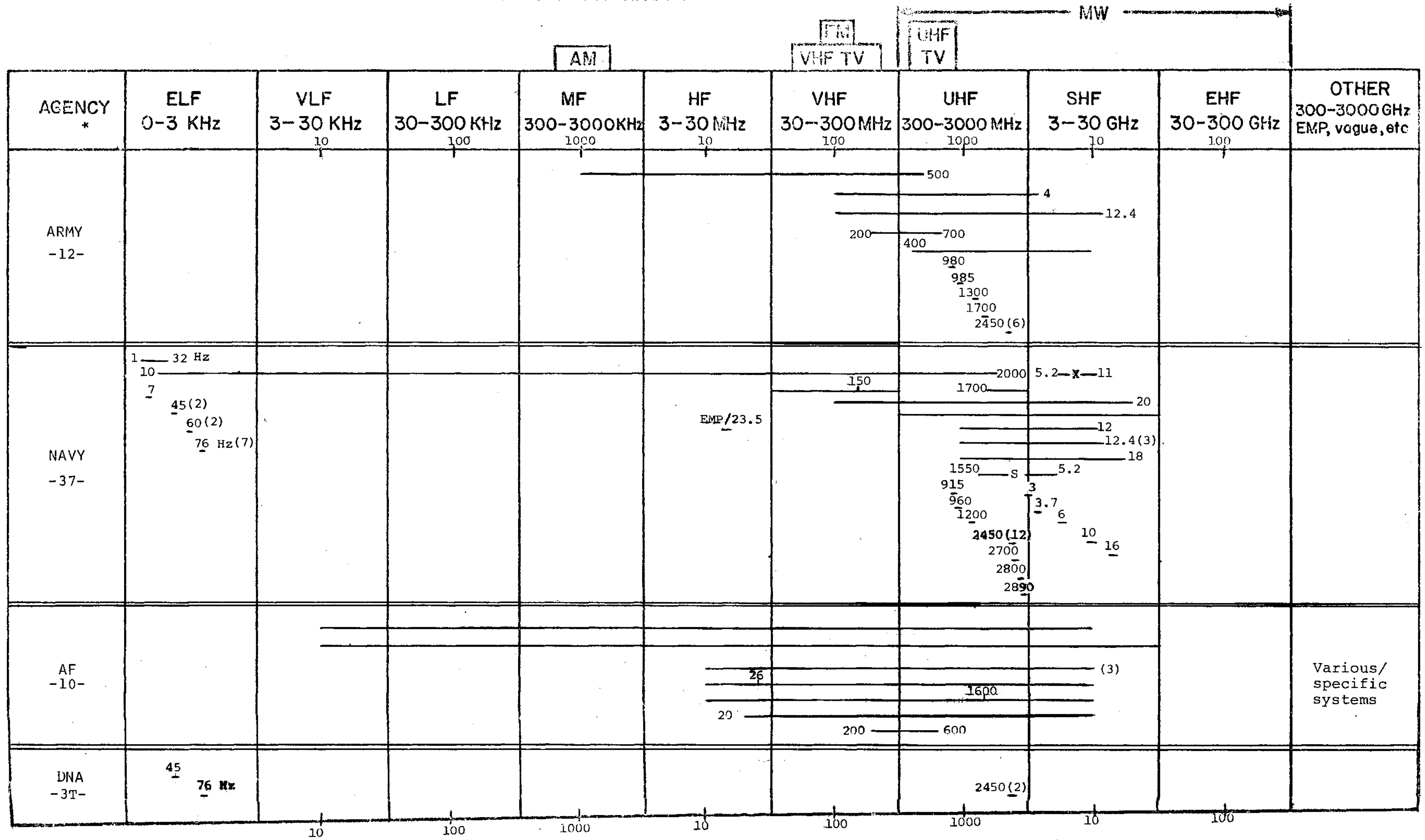
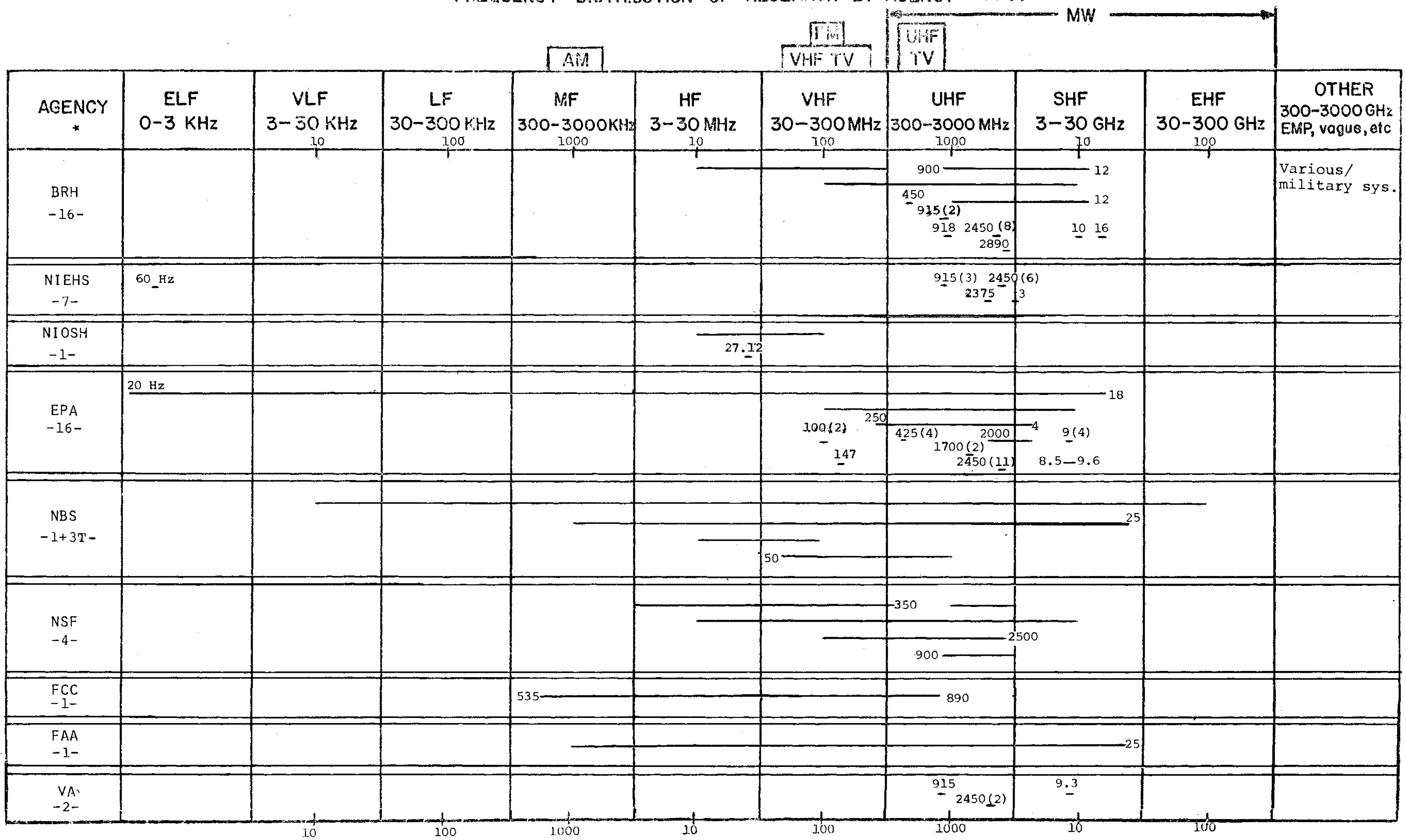


FIGURE 8(continued)

FREQUENCY DISTRIBUTION OF RESEARCH BY AGENCY - FY 77

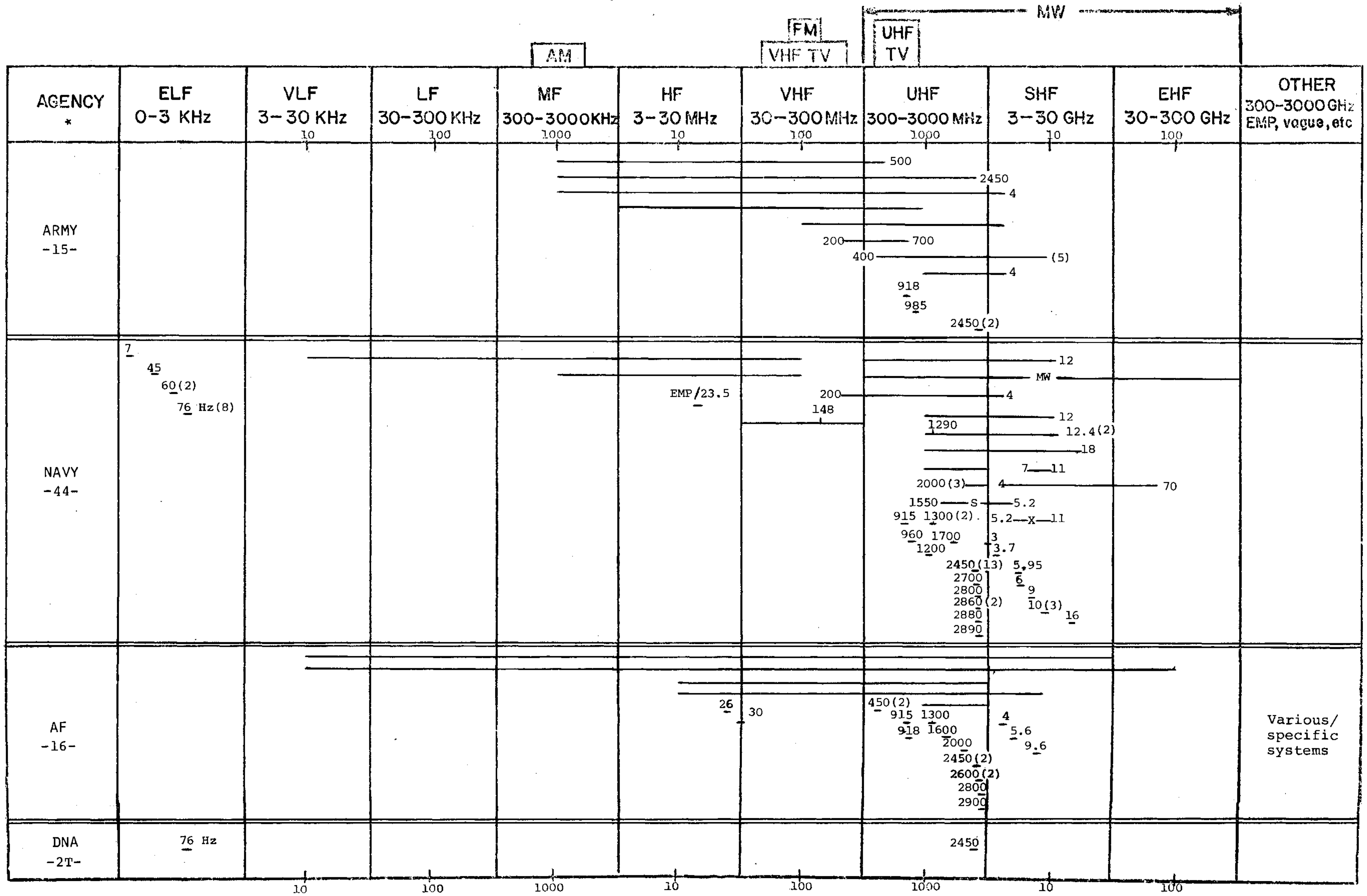


EXPLANATION: A number in ( ) indicates that more than one project applies.
Note, however that a single project may deal with more than one frequency (or range).

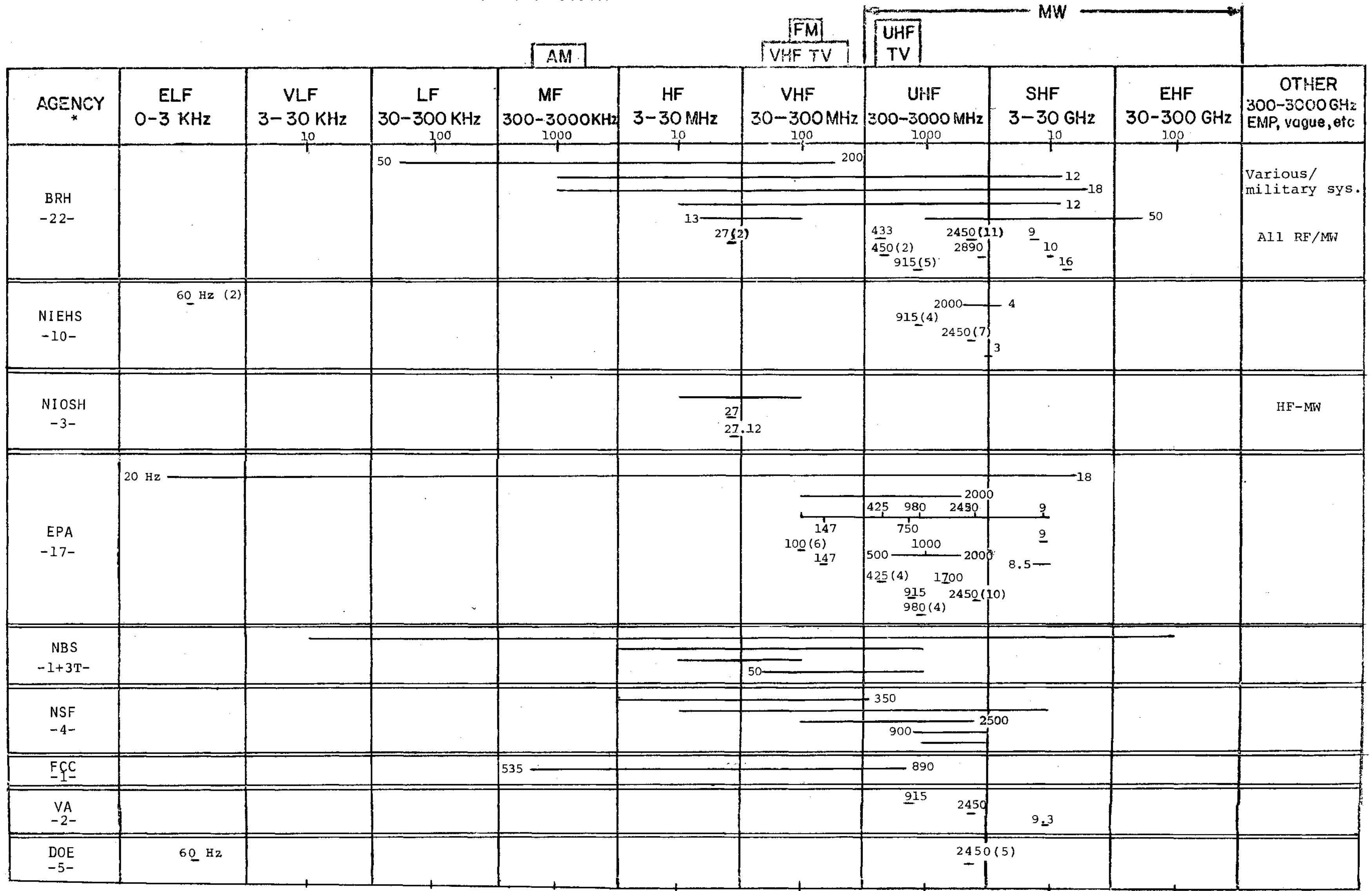
* Number denotes total projects for that Agency.

FIGURE 9

FREQUENCY DISTRIBUTION OF RESEARCH BY AGENCY - FY 78



FREQUENCY DISTRIBUTION OF RESEARCH BY AGENCY - FY 78

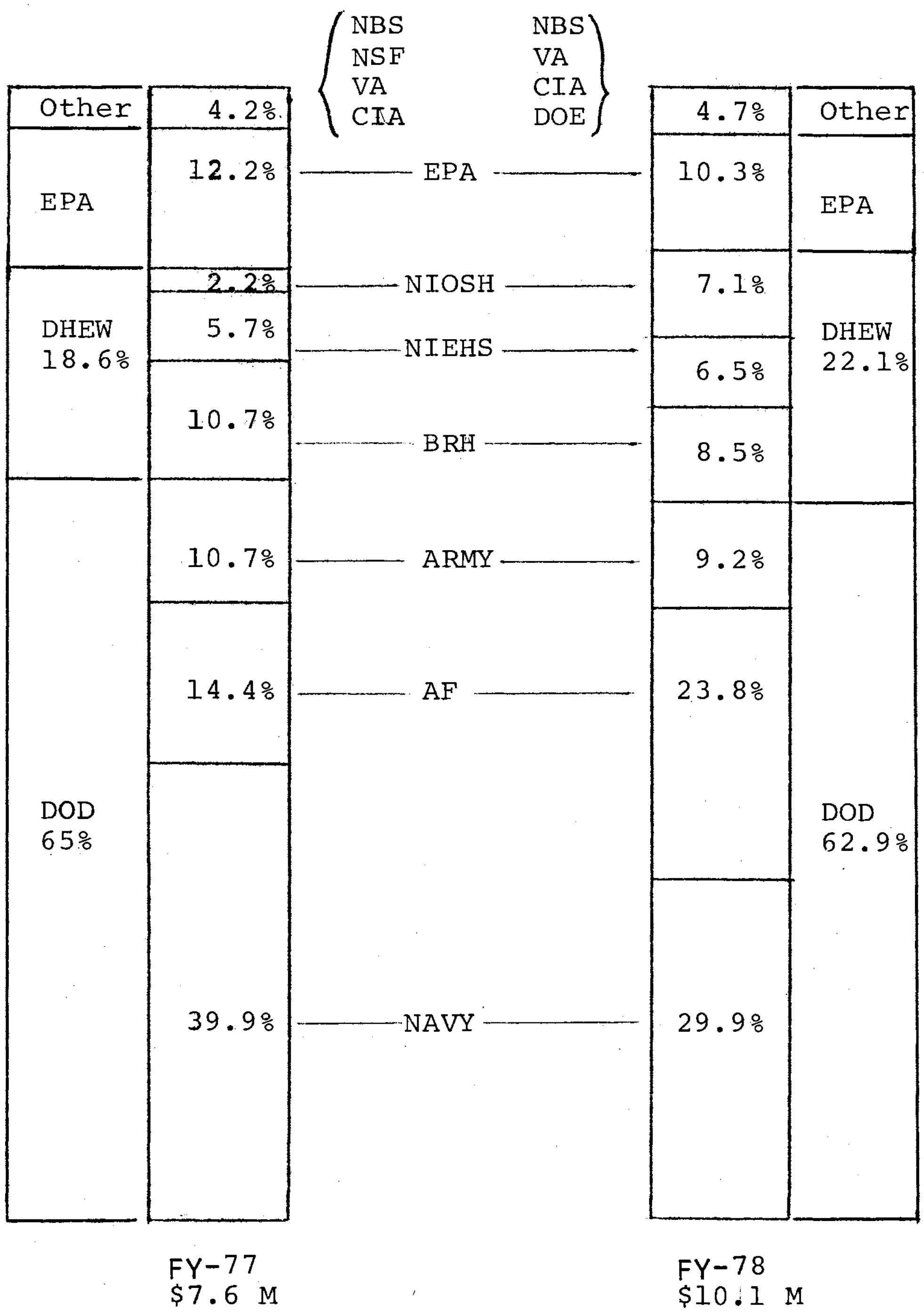


EXPLANATION: A number in ( ) indicates that more than one project applies.
Note, however that a single project may deal with more than one frequency (or range).

* Number denotes total projects for that Agency.

FIGURE 10

PROGRAM FUNDING



APPENDIX A

PROJECTS

Projects for Fiscal Years 1977 and 1978 are as follows. Included are titles, experimental subject, research frequency, applicable program areas (Figure 1) and performing organization for extramural projects. Collaborative efforts between agencies are noted. This information is summarized in Figures 3 through 9 and is presented here to further characterize the Program activities. It should be noted that changes affecting specific projects can occur during the year.

- FY 1977 -

HEW/BUREAU OF RADIOLOGICAL HEALTH

PROJECT	FREQUENCY*	PROGRAM AREAS**
Biophysical Characterization of RF/MW Exposures of Biological Specimens (various-including human phantoms and mice) H. Ho	2450M	8D,9A,10,12
Effects of MW Radiation on Animal Behavior (monkey, rats, mice) J. Monahan	915,2450M	3,12
Mutagenic, Chromosomal & Reproductive Effects of Microwave Radiation:		
-In Cultured Mammalian Cells	2450M	1,8E
-Mutagenesis in Bacterial Cells	2450M	1
-Effects on Reproductive Tissue and Capacity (mice & rats) F. L. Buchta (Task Mgr.)	2450M	1,8E,12
Microwave Cataractogenesis (rabbit, other rodents, eye models) (jointly with Navy) E. Ferri, R. Carpenter	2450,2890M 10,16G	8A,8C,12

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* H, K, M and G designate Hertz (Hz), kilohertz (KHz), megahertz (MHz) and gigahertz (GHz) respectively. While not indicated here, these studies also employ various waveforms.

** See Figure 1.

RF Calibration & Instrumentation Development M. Swicord	10-300M	9,10,11
Microwave Measurement Development & Compliance Technical Support M. Swicord	900M-12G	9,10,11
Quantitative Effects of EM Energy on Human Tissue (phantom models, cat, rodents, bird) A. Guy University of Washington Seattle, Washington	100M-10G	2,8D,9A, 10,11C,12
Biopsychological Studies of MW Irradiation (small mammals, unicellular organisms, birds) (with VA) D. Justesen VA Hospital Labs. of Experimental Neurology Kansas City, Missouri	915,2450M	1,2,3,4,8C, 8D,8F,10,12
Vestibulo-Cochlear Effects of UHF-Microwave Radiation (cat, monkey) R. Lebovitz Univ. of Texas SW Med. School Department of Physiology Dallas, Texas	918,2450M	2,7
Electromagnetic Radiation and Biological Systems (monkey, cat, rat, chick, duck) S. Bawin Brain Research Institute UCLA School of Medicine Los Angeles, California	450M (1-100H mod.)	2,3,7,8C,8F
Microwave Radiation Effects - Occupational Exposure to Radar C. D. Robinette Nat'l. Academy of Sciences/NRC Medical Follow-up Agency Washington, D. C.	Various/ military systems	4,5,11
Effects on Offspring of (Paternal) Microwave Radiation Associated with Military (or other) Occupational Environments C. Arnold American Health Foundation New York, New York	to be determined	1,5,11

Influence of MW Frequency & Power Level on Cumulative Teratogenesis (beetle pupae) (jointly with Navy) F. J. Rosenbaum Washington University St. Louis, Missouri	1-12G	1,10
Workshop on the Physical Basis of MW Interaction with Biological Systems (with Navy) A. Cheung University of Maryland College Park, Maryland	N/A	12

<u>HEW/NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES</u>

Effects of 2.45 GHz MW Radiation on Embryonic Development, Immunological Response, and Fertility (quail) D. McRee	2450M	1,3,8F,12
Effects of 1-10 GHz MW Radiation on Cell Systems (various: DNA, bacteria, -phage, RBC, lymphocytes) P. Hamrick	2450,3000M	1,7,8C,8F, 12
Investigation of Microwave Radiation Effects on Neurological Functioning (isolated nerve & preparations-mollusc to mammalian) D. McRee	2450M	2,7
Pre and Postnatal Effects of MW Irradiation (rat) R. P. Jensh Jefferson Medical College Philadelphia, Pennsylvania	915,2450M	1,2,3
Effects of 60Hz Field on the Mammalian Central Nervous System (rat, cat) W. R. Adey UCLA Brain Rsch. Inst. Los Angeles, California	60H	2,3,7,8C,8F

Effects of Microwave Radiation on the Nervous System (rat) R. Lovely & A. W. Guy Univ. of Washington School of Medicine Seattle, Washington	915,2375, 2450M	2,3,8C,8F
Effects of Microwave Radiation on the Nervous System (rat) O. P. Gandhi Univ. of Utah Salt Lake City, Utah	915,2450M	2,3,8C,8F

HEW/NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

RF/Microwave Teratogenic Effects Studies (rats) D. Conover	27.12M	1,9A
includes:		
Development of HF Absorbed Power Measurement System (six-port circuit) C. Hoer, H. Bussey National Bureau of Standards Boulder, Colorado	10-100M	

ENVIRONMENTAL PROTECTION AGENCY

EM Dosimetry and Exposure Evaluation J. Ali, G. E. Anderson, J. B. Kinn, C. M. Weil	100M-10G	9A,10
Effects of Microwave Radiation Functional Aberrations in Bio-polymers (membrane bound enzymes) J. W. Allis	1700,2450M	7,8C,8F,9A
The Effect of Nonionizing Radiation on the Immune Defense System J. A. Elder, EPA and A. T. Huang, Duke University Medical Center, Durham, N. C.	425,2450M, 9G	8E,8F,12
Neurobiological Effects of Exposure to MWR (rat) L. W. Reiter	100,425, 2450M	2,3

Radiofrequency Microwave Program (environmental measurements and assessment) D. Janes	20H-18G	9B,11 (A,B,C)
Mutagenic Effects of Microwave Radiation (bacteria, cells in culture) S. Dutta, Howard University, Washington, D. C. and C. Blackman, EPA	1700,2450M 8.5-9.6G, 68-74G, 85-94G	1,12
Effects of Microwave Irradiation on Membrane Structure & Function (mitochondria) J. Elder, H. Fisher	2-4G	7,8C,8F
Teratological Effects of Nonionizing EMR (mouse, rat) E. Berman	425,2450M 9G,	1
Effects of MWR on Immune Defense Mechanisms (mouse, rat) R. Smialowicz, C. Liddle	100,425, 2450M,9G	8F,12
Behavioral & Electroencephalographic (EEG) Responses of Squirrel Monkeys Exposed _in utero_ to 2450MHz EMR J. N, Kaplan, P. Polson Stanford Research Institute Menlo Park, California	2450M	1,2,3,8C,8F
Learning & Memory in Rats Exposed to 2450MHz M. Gage	2450M	2,3
Interaction(s) of Amplitude-Modulated (AM) Nonionizing EMR with Biological Systems (brain tissue & bacteria) C. Blackman, J. Elder R. Smialowicz, E. Whitcomb	147M,(3-30 H mod.) 9G	2,7,8C,8F
Define Specific Absorption Frequencies of Nonionizing EM Radiation in Biological Systems (molecules to tissues) J. Allis, C. Blackman, J. Elder, C. Weil	250M-4G	7,9A

Mutagenic Effects of MW Radiation in the Rat E. Berman	2450M	1
Effects of Microwave Radiation on the Gestation Length of Mice E. Berman	2450M	1
Effects of Acute and Chronic Exposure to Microwaves and Pulsed UHF Radiation on Short Term Memory of Squirrel Monkeys M. Gage	2450M	2,3

DOD/U. S. ARMY

Development of RF-decoupled Tissue Electrodes L. Larsen	2450M	9A
Effects of Low Intensity MW Radiation on Mammalian Serum Proteins S. Cleary Va. Commonwealth Univ. Medical College Richmond, Virginia	1700,2450M	7,8C,12
Methodological Improvements for Tissue-Enzyme Inactivation (in small mammal brain) R. Lenox, P. Brown L. Larsen, O. Gandhi	985,2450M	2,8C,9A
Modulated Microwave Bio-Effects: Nervous System (rat) K. Oscar, T. D. Hawkins, E. Hunt	1300M	2,7,8C,8F
Modulated Microwave Bio-Effects: Behavior & Performance (rat) E. L. Hunt, J. F. Schrot	980,2450M	3
Dielectric Properties of Various Tissues J. Jacobi	100M-12.4G	9A,10

Biological Effects of Resonant EM Power Absorption in Rats (phantoms & human figurines) O. Gandhi University of Utah Salt Lake City, Utah	200-700M	8C,8D,10
Microwave Energy Absorption and Distribution (small animals & human models) E. L. Hunt, L. E. Larson, J. H. Jacobi	400M-10G	9A,10B
<u>In vivo</u> Determination of Energy Absorption in Biological Tissue H. A. Ecker Georgia Inst. of Technology Atlanta, Georgia	100M-4G	9A,10
Stress Factors with Microwave Irradiation (e.g., latency to convulsions, adaptation) (rat) E. L. Hunt, J. F. Schrot, T. D. Hawkins	2450M	8D,8F,12
Quantification & Measurement of Internal EM Fields Induced in Finite Biological Bodies by Nonuniform EM Fields K. M. Chen Michigan State University East Lansing, Michigan	1-500M	9A,10A
Microwave Radiation Effects on CNS Excitability (rat) T. D. Hawkins, E. Hunt	2450M	2

<u>DOD/U. S. NAVY</u>

An Evaluation of Possible Effect of 60 Hz & 75 Hz Electric Fields on Neurophysiology & Behavior of Monkeys (also chick brain) R. Gavalas-Medici Brain Research Inst., UCLA Los Angeles, California	7,60,76H 1-32H	2,3,7,8C,8F

A Physiological & Biochemical Study of the Effects of EM Fields Generated by (ELF) Naval Communications System on <u>Physarum polycephalum</u> E. Goodman Univ. of Wisconsin-Parkside Kenosha, Wisconsin	60,76H	1,7,8F
The Effects of Extremely Low Frequency (ELF) Radiation on Primates (monkey) J. D. Grissett	76H	4,8C,8F
Effects of MW Radiation on Physiological & Behavioral Factors in Laboratory Animals (rats, mice) R. D. Phillips Battelle Memorial Inst. Pacific N. W. Labs Richland, Washington	2450,2800M	2,3
Effects of MW Radiation on the Central Nervous System (Chinese hamster) E. N. Albert George Washington University Washington, D. C.	1.7-3G	2,8E,8F
Quanitation of MW Radiation Effects on the Head & Eyes of Rabbits, Primates and Man P. O. Kramar University of Washington Seattle, Washington	2450M	8A,10
Neurophysiological & Behavioral Effects Due to MW Fields (guinea pig, rat, phantoms) R. H. Lovely Univ. of Washington Seattle, Washington	915M	2,3,7,8C,10
Ocular Effects of Microwaves (rabbit, other rodents, eye models) (jointly with BRH) R. C. Carpenter BRH, Northeast Labs Winchester, Mass.	2450,2890M, 10,16G	8A,8C,12

Effects on Biological Systems Due to MW Irradiation (isolated turtle & rat hearts) C. M. Durney University of Utah Salt Lake City	960M	2,7,8B
Determination of EM Parameters that Affect the Brain and Behavior at Low Power Density (mouse, rat, crayfish nerve) A. Frey Randomline, Inc. Huntingdon Valley, Pa.	UHF,SHF, light	2,3,7,8F
Studies of the Effect of ELF Electric Fields on Rodents (mouse) A. Krueger Univ. of California at Berkeley Berkeley, California	45,76H	1,8F,12
X-ray & Microwave Radiation Interaction with Muscle Cells: Application to Protection and Treatment (frog & rat skeletal muscle) A. Portela Consejo Nacional de Investigaciones Cientificas y Tecnicas Inst. de Investicigaciones Biofisicas Buenos Aires, Argentina	S&X Bands	2,7,8F
Investigation of the Biological Effects of Pulsed Electromagnetic Fields Generated by Naval Operations) (rabbit, artificial membranes, RBC's) S. F. Cleary Va. Commonwealth Univ. Medical College Richmond, Virginia	EMP(23.5M), 3G	7,8C,8F,12
Limiting Conditions for Effects of Navy Generated ELF Fields on Free Flying Migrant Birds in No. Wisconsin T. C. Williams Marine Biological Laboratory Woods Hole, Massachusetts	76H	3

Effects of Nonionizing Radiation on Biomembranes & Biological Macro-molecules J. P. Sheridan	100M-20G	7,8F,12
Biological Effects of EM Radiation (BEEMR) Quarterly Digest B. Kleinstein Franklin Institute Philadelphia, Pennsylvania	N/A	12
Alterations in Lenticular Proteins as Potential Biochemical Indicators of MW Induced Cataractogenesis (rabbit) G. Oosta Armed Forces Radiobiology Research Institute Bethesda, Maryland	2450M	8A,8C
Studies of Biological Effects of Extremely Low Frequency (ELF) Electromagnetic Radiation in Rats N. S. Mathewson Armed Forces Radiobiology Research Institute Bethesda, Maryland	45,76H	1,4,8C,8F
Neurochemical Alterations in the CNS of Mammals Exposed to MW Radiation (rat) G. N. Catravas Armed Forces Radiobiology Research Institute Bethesda, Maryland	2450M	2,8C
A Study of Dendritic Spine Morphology in Rat & Rabbit Brain Following Chronic Exposure to Low Intensity Microwave Radiation A. McKee/J. L. Hosszu (Navy) and U.C.L.A. Los Angeles, California	2700,3700M	2,8E
Behavioral Characteristics of Monkeys and Rats Irradiated With Microwaves J. O. deLorge	2450M,6G	3

Biochemical Effects of Microwave Radiation (monkey) W. G. Lotz	1-12.4G	2,8C
Reflection and Diffraction Aspects of Biological Microwave Dosimetry R. G. Olsen	1-12.4G	10B
Biological Effects of Localized E-and H-Fields in the Standing Microwave Field (small organisms e.g., *Tribolium* pupae) R. G. Olsen	1-12.4G	1
Ultrastructural Studies of MW Cataractogenesis (rabbit, monkey) D. R. Simon	2450M	8A,12
Effects of MW Radiation on Behavioral Baselines (rat) J. R. Thomas	2450M	3
Effects of Microwaves on Maturation in the Rat S. Michaelson University of Rochester Dept. of Radiation Biology and Biophysics Rochester, New York	2450M	1,8C,8E
Effect of MW Irradiation *in utero* (as from radar) on Embryonic Brain Tissue (and Postnatal Behavior & Growth Rate) D. M. Rioch Inst. for Behavioral Rsch. Silver Spring, Maryland	2450M	1,2,3,8E,8F
Biomedical Effects of RF Radiation (mouse, human & mouse phantoms) J. C. Lin Wayne State University Dept. of Electrical Engineering Detroit, Michigan	150M (30-300M)	1,8E,8F,10B
Effects of Extremely Low Frequency (ELF) Electric & Electromagnetic Radiation on Tissue Cells (human cells *in vitro*) R. Wistar	76Hz	7,8C

Influence of MW Frequency and Power Level on Cumulative Teratogenesis (Beetle pupae) (jointly with BRH) F. Rosenbaum Washington University St. Louis, Missouri	1-12G	1,10
Behavioral Responses to a Chronic Microwave Environment (rats) R. Lebovitz Univ. of Texas Hlth. Sci. Cntr. Dallas, Texas	1200M	2,3,8E
Effect of Low-Dose Microwaves on the Immune Response of Mice K. Sell	2450M	7,8F,12
Effect of RF and MW Radiation on Nervous Systems (simple systems to mammalian brains) S. Takashimi University of Pennsylvania Philadelphia, Pennsylvania	10H-2G	2,7,10
Experimental Development of Simulated Biotissues A. Cheung Univ. of Maryland College Park, Maryland	1-18G	10
MW Exposure Effects on Behavioral Actions of Pharmacological Agents J. Thomas	2450M	2,3,12
Workshop on the Physical Basis of MW Interaction with Biological Systems (jointly funded with BRH) A. Cheung Univ. of Maryland College Park, Maryland	N/A	12

DOD/U. S. AIR FORCE

Development of Laser (& Holographic) Eye Measurement & Evaluation System (monkey) A. P. Bruckner University of Washington Seattle, Washington	N/A	8A,9A
Radio-Frequency Electromagnetic Environment Simulation and Measurement (phantom models, monkeys) S. J. Allen	10M-10G	9,10,
Biological Effects of Air Force RF Transmitter Fields (rat, monkey) J. W. Frazer	10M-10G	2,7,8C,8D, 8F,10
Radiofrequency Radiation Interference with Medical Prosthetic Devices J. Mitchell	various/ specific systems (10K-30G)	11,12
RF Radiation Effects on Biochemical Systems in the Central Nervous System (rat) J. Merritt	1600 (10M-10G)	2,8C,8D,10
Comparison of Theoretical and Experimental Absorption of RF Power (human and animal models, monkeys) C. C. Johnson & C. H. Durney University of Utah Salt Lake City, Utah	10K-10G	10(A&B)
Measurement of Power Absorption at Resonant & Nonresonant Frequencies (thermographic studies - animals, models & cell culture studies - lymphocytes) A. W. Guy University of Washington Seattle, Washington	selected frequencies 20M-10G	8D,8F,9A,10
Effects of RF Radiation on Immune Systems (Mice) R. Liburdy	26M (10M-10G)	8F,12
Development of Phased Array Radiation Simulator Contract to be determined	200-600M	9A

Effects of Multiple RF Radiation Exposures (Mice) J. H. Krupp	10M-10G	8F,12

DOD/DEFENSE NUCLEAR AGENCY/ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE

Alterations in Lenticular Proteins as Potential Biochemical Indicators of MW Induced Cataractogenesis (rabbit) (AFRRI for Navy) G. Oosta	2450M	8A,8C
Studies of Biological Effects of Extremely Low Frequency (ELF) Electromagnetic Radiation in Rats (for Navy) N. S. Mathewson	45,76H	1,4,8C,8F
Neurochemical Alterations in the CNS of Mammals Exposed to MW Radiation (rat) (for Navy) G. N. Catravas	2450M	2,8C

DOC/NATIONAL BUREAU OF STANDARDS

Probes for EMI/RF Radiation Measurements F. Reis, R. Bowman	10K-100G	9
FAA Field Survey Measurements (NBS for FAA) E. B. Larson, R. Bowman	1M-25G	11A
Broadband Radiation Probe (NBS for EPA) F. Ries, D. Belsher	50-1000M	9B
Development of HF Absorbed Power Measurement System (six-port circuit) (NBS for NIOSH) C. A. Hoer, H. E. Bussey	10-100M	9A

NATIONAL SCIENCE FOUNDATION

Probes & Antennas in Biological Material S. S. Sandler, R. W. King Northeastern University Boston, Massachusetts	3-350M 1-3G	8E,9A, 10(A&B)

Electromagnetic Power Deposition In Man C. Johnson University of Utah Salt Lake City, Utah	10M-10G	10
Interaction of EM Fields with the Human Body K. M. Chen Michigan State University East Lansing, Michigan	100-2500M	10(A&B)
Mechanisms of Pulsed MW Interaction with Human Auditory Systems (human & animal head models & theoretical studies) J. C. Lin, F. T. Yu Wayne State University Detroit, Michigan	900-3000M	2,7,10(A&B)
FEDERAL COMMUNICATIONS COMMISSION		
Electromagnetic Radiation Measurements	535K-890M	11(A&C)
FEDERAL AVIATION ADMINISTRATION		
Electromagnetic Radiation Measurements E. B. Larsen, R. Bowman National Bureau of Standards Boulder, Colorado	1M-25G	11(A&C)
CENTRAL INTELLIGENCE AGENCY		
Review of Published Foreign Scientific Literature on Biological Effects of Nonionizing Radiation D. Meyers	N/A	12
U. S. VETERANS ADMINISTRATION		
Biological Effects of Microwave Irradiation: Cataractogenic and Behavioral Effects of Chronic Irradiation of Monkeys R. MacAfee	2450M,9.3G	3,8A
Biophysical Studies of MW Irradiation (small mammals, unicellular organisms, birds) (with BRH) D. R. Justesen	915,2450M	1,2,3,4,8C,8D,8F,10,12

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HEW/BUREAU OF RADIOLOGICAL HEALTH

PROJECT	FREQUENCY*	PROGRAM AREAS**
Biophysical Characterization of RF/MW Exposures of Biological Specimens (various-including human phantoms and mice) H. Ho	2450M	8D,9A,10,12
Effects of MW Radiation on Animal Behavior (mice/rats) J. Monahan	915,2450M	3,12
Mutagenic, Chromosomal & Reproductive Effects of Microwave Radiation:		
-In Cultured Mammalian Cells	2450M	1,8E
-Mutagenesis in Bacterial Cells	2450M	1
-Effects on Reproductive Tissue and Capacity (mice & rats) F. L. Buchta (Task Mgr.)	2450M	1,8E,12
Microwave Cataractogenesis (rabbit, other rodents, eye models) (jointly with Navy) E. Ferri, R. Carpenter	2450,2890M 10,16G	8A,8C,12
Biopsychological Studies of MW Irradiation (small animals: mice, rats, guinea pigs, birds) (with VA) D. Justesen VA Hospital Labs. of Experimental Neurology Kansas City, Missouri	915,2450M	1,2,3,4,8C 8D,8F,10,12
Electromagnetic Radiation and Biological Systems (monkey, cat, rat, chick, duck) W. R. Adey V. A. Hospital Loma Linda, California	450M (1-100H mod.)	2,3,7,8C,8F

* H, K, M and G designate Hertz (Hz), kilohertz (KHz), megahertz (MHz), and gigahertz (GHz) respectively. While not indicated here, these studies also employ various waveforms.
** See Figure 1.

Microwave Radiation Effects -- Occupational Exposure to Radar C. D. Robinette Nat'l. Academy of Sciences/NRC Washington, D. C.	Various/ military systems	4,5,11
Relationship of (Paternal) RF Exposure and Selected Reproductive and Health Factors (diathermy operators) J. Stellman American Health Foundation New York, New York	27,2450M	1,5,11
Influence of MW Frequency & Power Level on Cumulative Teratogenesis (beetle pupae) (jointly with Navy) F. J. Rosenbaum Washington University St. Louis, Missouri	9G	1,10
Nonperturbing Temperature Probe Using Birefringent Optical Crystal H. Bassen	1M-12G	9A
Miniature E Field Probes for Internal Dosimetry and External Field Mapping H. Bassen	10M-12G	9 (A&B)
Development & Applications of Theoretical Dosimetry S. M. Neuder	all RF/MW	10A
Microwave Absorption Studies (*E. Coli*, DNA & other biosubstances) M. Swicord	1-50G	7,9A,10
MW Product Evaluation/Product Related Projects:		
-RF/Microwave Products Survey (data base development) W. Nesmith	1M-18G	11,12
-Medical RF Product Evaluation P. S. Ruggera	50K-200M	9B,11,12

-Microwave Cancer Therapy Products (in collaboration with National Cancer Institute)	433,915,2450M	9,10,11,12
-Microwave Diathermy Standard Development G. Kantor	915,2450M	9,10,11A&C, 12
-Industrial RF Product Evaluation (in cooperation with NIOSH & DOL/OSHA) P. S. Ruggera	13-100M	9B,11
-RF/Microwave Tranceiver Product Evaluation	27,450M	9B,11
-Microwave Oven Standard Enforcement W. A. Herman	915,2450M	9B,11

HEW/NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES

Effects of 2.45 GHz MW Radiation on Embryonic Development, Immunological Response, and Fertility (quail) D. McRee	2450M	1,3,8F,12
Effects of 2.45&3 GHz MW Radiation on Cell Systems (various: DNA, bacteria, -phage, RBC, lymphocytes, mammalian cells) P. Hamrick	2450,3000M	1,7,8C,8F, 12
Investigation of Microwave Radiation Effects on Neurological Functioning (isolated nerve & preparations-mollusc to mammalian) D. McRee	2450M	2,7
Pre and Postnatal Effects of MW Irradiation (rat) R. P. Jensh Jefferson Medical College Philadelphia, Pennsylvania	915,2450M	1,2,3
Effects of 60Hz Field on the Mammalian Central Nervous System (rat, cat) C. Clemente Experimental Neurobiology UCLA Brain Rsch. Inst. Los Angeles, California	60H	2,3,7,8C,8F

Effects of Microwave Radiation on the Nervous System (rat) R. Lovely & A. W. Guy Univ. of Washington School of Medicine Seattle, Washington	915,2450M	2,3,8C,8F
Effects of Microwave Radiation on the Nervous System (rat) O. P. Gandhi Univ. of Utah Salt Lake City, Utah	915,2450M	2,3,8C,8F
Biological Effects of 60Hz Fields (rats, mice, rabbits) A. Marino SUNY Upstate Med. Center Syracuse, New York	60H	1,8C,8E,8F
Vestibulo-Cochlear Effects of UHF Microwave Radiation R. M. Lebovitz Texas S. W. Med. School Dallas, Texas	915,2450M	2,7
Microwave Effects in Excitable Membrane Systems (algae & other cell systems) S. Cleary Medical College of Va. Richmond, Virginia	2-4G	7,8F,12

HEW/NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

RF/Microwave Teratogenic Effects Studies (rats) D. Conover, J. Lary	27.12M	1,9A
includes:		
Development of HF Absorbed Power Measurement System (six-port circuit) C. Hoer, H. Bussey National Bureau of Standards Boulder, Colorado	10-100M	

Development of a Criteria Document Containing a Recommended U. S. Occupational Standard for RF/MW Radiation Z. Glaser, NIOSH and R. Cleveland, J. Kielman Equitable Environmental Health, Inc. Rockville, Maryland	HF-MW	11C,12
Reproductive and Industrial Hygiene Study of Workers Exposed to RF Energy E. Egan	27M	1,4,5

ENVIRONMENTAL PROTECTION AGENCY

EM Dosimetry and Exposure Evaluation J. Ali, G. E. Anderson J. B. Kinn, C. M. Weil	100M-10G	9A,10
Effects of Microwave Radiation Functional Aberrations in Bio-polymers (membrane bound enzymes) J. W. Allis	1700,2450M	7,8C,8F,9A
The Effect of Nonionizing Radiation on the Immune Defense System J. A. Elder, EPA and A. T. Huang, Duke University Medical Center, Durham, N.C.	2450M	8E,8F,12
Neurobiological Effects of Exposure to MWR (rat) L. W. Reiter	100,425, 2450M	2,3
Radiofrequency Microwave Program (environmental measurements and assessment) D. Janes	20H-18G	9B,11 (A,B,C)
Mutagenic Effects of Microwave Radiation (bacteria, cells in culture) S. Dutta, Howard University, Washington, D. C. and C. Blackman, EPA	2450M,8.5-10G	1,12

Relative Effectiveness of Pulsed vs. CW Exposure on the Immune Defense System (mouse) R. Smialowicz	425M	8D,8F,12
Behavioral & Electroencephalographic (EEG) Responses of Squirrel Monkeys Exposed *in utero* to 2450MHz EMR J. N. Kaplan, P. Polson Stanford Research Institute Menlo Park, California	2450M	1,2,3,8C,8F
Interactions of Amplitude-Modulated (AM) Nonionizing EMR with Biological Systems (brain tissue & bacteria) C. Blackman	147M(3-30H mod) 2450M	1,2,7,8F
Define Specific Absorption Frequencies of Nonionizing EM Radiation in Biological Systems (molecules to tissues) J. Allis, C. Blackman C. Weil, J. Elder	100-2000M	7,9A
Mutagenic Effects of MW Radiation in the Rat E. Berman	100,425,980, 2450M	1
Relative Effectiveness of Short-Term vs. Long-Term EMR Exposure on Immune Defense (mice) R. J. Smialowicz, C. Liddle	2450M,9G	8F,12
Effects of Chronic Exposure to EMR on Band T Lymphocyte Function in Animals (rats) R. J. Smialowicz, C. Liddle	100,915M	1,8F,12
Effect of Nonionizing Radiation on Natural & Synthetic Membranes J. Allis	1000M (500-2000M)	7,8F
Teratologic Effects of MW in the Rat E. Berman	100,425,980, 2450M	1

Effects of Long and Short-Term Exposure to EMR on Specific Learned Behavior of Animals (monkeys, rats) M. I. Gage	100,980, 2450M	2,3
Neurochemical Analyes of Brains of Animals Exposed to Low-Level EMR (rat) S. J. Bursian	100,980M	2,8C
<u>DOD/U.S. ARMY</u>		
Development of RF-decoupled Tissue Electrodes L. E. Larsen, R. A. Moore, J. H. Jacobi, P. V. Brown	400M-10G	9(A&B)
Methodological Improvements for Tissue-Enzyme Inactivation (small mammals) P. V. Brown, L. E. Larsen, M. P. Toman, J. H. Jacobi	985,2450M	2,8C,9A
Dielectric Properties of Various Tissues J. H. Jacobi, L. E. Larsen, A. K. Frey	1M-4G	9A,10A&B
Biological Effects of Resonant EM Power Absorption in Rats (phantoms & human figurines) O. Gandhi University of Utah Salt Lake City, Utah	200-700M	8C,8D,10
Microwave Energy Absorption and Distribution (small animals & human models) L. Larson, J. Jacobi, E. Hunt	400M-10G	9A,10A&B
Modulated Microwave Bio-Effects: Behavior & Performance (rat) E. L. Hunt	400M-10G	3
<u>In vivo</u> Determination of Energy Absorption in Biological Tissues F. L. Cain, E. C. Burdette, J. Seals Georgia Inst. of Technology Atlanta, Georgia	100M-4G	9A,10

Stress Factors with Microwave Irradiation (e.g., latency to convulsions, adaptation) (rat) E. L. Hunt, J. F. Schrot, T. D. Hawkins	400M-10G	8D,8F,12
Quantification & Measurement of Internal EM Fields Induced in Finite Biological Bodies by Nonuniform EM Fields K. M. Chen Michigan State University East Lansing, Michigan	1-500M	9A,10A
Microwave Radiation Effects on CNS Excitability (rat) E. Hunt	400M-10G	2
MW Interrogation & Imaging of Biological Dielectrics L. E. Larsen, J. H. Jacobi, M. E. Swinnen	1-4G	9A,10,12
Neural Membrane Effects of MW Radiation P. V. Brown, L. E. Larsen	2450M	2,9A
EM Analysis of Cellular and Molecular Systems: Normal and Pathophysiological Attributes (e.g., DNA,RBC) L. E. Larsen, J. H. Jacobi, P. V. Brown, A. K. Krey	1-2450M	7,8E
Conditioned Taste Aversions Induced by MW Radiations G. R. Sessions	918M	3,8D
Improved Radiation Hazard Meter F. X. Reis, D. R. Belsher National Bureau of Standards Boulder, Colorado	3M-1G	9B

DOD/U.S. NAVY

An Evaluation of Possible Effect of 60 Hz & 75 Hz Electric Fields on Neurophysiology & Behavior of Monkeys R. Gavalas-Medici Brain Research Inst., UCLA Los Angeles, California	7,60,76H	2,3
A Physiological & Biochemical Study of the Effects of EM Fields Generated by (ELF) Naval Communications System on *Physarum polycephalum* E. Goodman Univ. of Wisconsin-Parkside Kenosha, Wisconsin	60,76H	1,7,8F
The Effects of Extremely Low Frequency (ELF) Radiation on Primates (monkey) J. D. Grissett	76H	4,8C,8F
Effects of MW Radiation on Physiological & Behavioral Factors in Laboratory Animals (mice) R. D. Phillips Battelle Memorial Inst. Pacific N. W. Labs Richland, Washington	2450,2880M	8E,8F
Effects of MW Radiation on the Central Nervous System (Chinese hamster, rat) E. N. Albert George Washington University Washington, D. C.	2-3G	2,8E,8F
Neurophysiological & Behavioral Effects Due to MW Fields (rat, phantoms) R. H. Lovely Univ. of Washington Seattle, Washington	915,2450M	2,3,7,8C,10 12
Ocular Effects of Microwaves (rabbit, other rodents, eye models) (jointly with BRH) R. C. Carpenter BRH, Northeast Labs Winchester, Mass.	2450,2890M, 10,16G	8A,8C,12

Effects on Biological Systems Due to MW Irradiation (rat CNS synaptosomes + receptor sites) C. M. Durney University of Utah Salt Lake City	960M	2,7,8F
Determination of EM Parameters that Affect the Brain and Behavior at Low Power Density (mouse, rat,) A. Frey Randomline, Inc. Huntingdon Valley, Pa.	1-3G, light	2,3,7,8F
Studies of the Effect of ELF Electric Fields on Rodents (mouse) A. Krueger Univ. of California at Berkeley Berkeley, California	45,76H	1,8F,12
X-ray & Microwave Radiation Interaction with Muscle Cells: Application to Protection and Treatment (frog & rat skeletal muscle) A. Portela Consejo Nacional de Investigaciones Cientificas y Tecnicas Inst. de Investicigaciones Biofisicas Buenos Aires, Argentina	S&X Bands	2,7,8F
Investigation of the Biological Effects of Pulsed Electromagnetic Fields Generated by Naval Operations (rabbit, artificial membranes, RBC's) S. F. Cleary Va. Commonwealth Univ. Medical College Richmond, Virginia	EMP(23.5M), 3G	7,8C,8F,12
Limiting Conditions for Effects of Navy Generated ELF Fields on Free Flying Migrant Birds in No. Wisconsin T. C. Williams Marine Biological Laboratory Woods Hole, Massachusetts	76H	3
Effects of Nonionizing Radiation on Biomembranes & Biological Macromolecules J. P. Sheridan	1-12G	7,8F,12

Biological Effects of EM Radiation (BEEMR) Quarterly Digest B. Kleinstein Franklin Institute Philadelphia, Pennsylvania	N/A	12
Studies of Biological Effects of Extremely Low Frequency (ELF) Electromagnetic Radiation in Rats F. Henry Armed Forces Radiobiology Research Institute Bethesda, Maryland	76H	1,4,8C,8F
Neurochemical Alterations in the CNS of Mammals Exposed to MW Radiation (rat) G. N. Catravas Armed Forces Radiobiology Research Institute Bethesda, Maryland	2450M	2,8C
A Study of Dendritic Spine Morphology in Rat & Rabbit Brain Following Chronic Exposure to Low Intensity Microwave Radiation A. McKee/J. L. Hosszu (Navy) and U.C.L.A. Los Angeles, California	2700,3700M	2,8E
Behavioral Characteristics of Monkeys and Rats Irradiated With Microwaves J. O. deLorge	2450M,6G	3
Biochemical Effects of Microwave Radiation (monkey) W. G. Lotz	1290M (1-12.4G)	2,8C
Reflection and Diffraction Aspects of Biological Microwave Dosimetry R. G. Olsen	1290M (1-12.4G)	10B
Biological Effects of Localized E-and H-Fields in the Standing Microwave Field (small organisms i.e., *Tribolium* pupae) R. G. Olsen	1.3,5.95,10G	1

Ultrastructural Studies of MW Cataractogenesis (rabbit) D. R. Simon	2450M	8A,12
Effects of MW Radiation on Behavioral Baselines (rat) J. R. Thomas	2450,2800M	2,3
Biomedical Effects of RF Radiation (mouse, human & mouse phantoms) J. C. Lin Wayne State University Dept. of Electrical Engineering Detroit, Michigan	148M (30-300M)	1,8E,8F,10B
Effects of Extremely Low Frequency (ELF) Electric & Electromagnetic Radiation on Tissue Cells (human cells *in vitro*) R. Wistar	76H	7,8C
Influence of MW Frequency and Power Level on Cumulative Teratogenesis (Beetle pupae) (jointly with BRH) F. Rosenbaum Washington University St. Louis, Missouri	9G	1,10
Behavioral Responses to a Chronic Microwave Environment (rats) R. Lebovitz Univ. of Texas Hlth. Sci. Cntr. Dallas, Texas	1300M	2,3,8E
Effect of Low-Dose Microwaves on the Immune Response of Mice C. J. Schlagel	2450M	7,8F,12
Effect of RF and MW Radiation on Nervous Systems (simple systems, rabbit brain) S. Takashimi University of Pennsylvania Philadelphia, Pennsylvania	1-100M	2,7

Experimental Development of Simulated Biotissues A. Cheung University of Maryland College Park, Maryland	1-18G, 2450M, 10G	10
MW Exposure Effects on Behavioral Actions of Pharmacological Agents J. Thomas	2450M	2,3,12
Ecological Studies in the Navy's Wisconsin Test Facility (ELF) (soil arthropods) B. Greenberg Univ. of Illinois Chicago, Illinois	76H	1
Effects of MW Radiation on Cells in Tissue Culture (DNA, various cells) K. C. Chen Wayne State University Detroit, Michigan	2450M	1,7,8C
Temperature Increase in Tissue Spheres Exposed to Microwaves from Naval Operations H. Kritikos, H. Schwan Univ. of Pennsylvania Dept. of Bioengineering Philadelphia, Pa.	300M-12G	8D,10
Microwave Spectroscopic Studies of DNA and Other Biomolecules R. W. Gammon Inst. of Science & Tech. Univ. of Maryland College Park, Maryland	various MW	7
Determination of Bound Water in Biological Tissue & Energy Dissipated in Bound Water by Low-Level Microwaves E. H. Grant Univ. of London London, England	10K-100M, 200M-4G, 4-70G	7
Effects of Pulsed Microwaves on Mammalian Blood Cells S. F. Cleary Va. Commonwealth Univ. Richmond, Virginia	7-11G	7,8F

Mechanisms of Microwave-Induced Blood-Brain Barrier Alterations J. C. Lin Wayne State University Detroit, Michigan	1200,2450M	2,7,8F
An Investigation of the Mechanism of Microwave Induced Changes in Membrane Permeability S. L. Gartner	2-3G	7,8F
Changes in Blood Brain Barrier in the Rat Following Exposure to MW Radiation S. P. Gruenau	2860M	7,8F
Effects of Acute Electromagnetic Radiation on the Central Nervous System: Morphological Study of Hypothalamic and Subthalamic Regions. A. E. McKee	1700,2450M	2,8E
Use of Synaptosomes as an Experimental Model for Evaluating the Effect of Electromagnetic Radiation (EMR) on Neural Membrane Function D. B. Millar	2860M	2,7,8F
Effects of Microwave Radiation on Development of Learning Process J. F. Schrot	2-3G	2,3

DOD/U. S. AIR FORCE

Development of Laser (& Holographic) Eye Measurement & Evaluation System (monkey) A. P. Bruckner University of Washington Seattle, Washington	N/A	8A,9A
Radio-Frequency Electromagnetic Environment Simulation and Measurement (phantom models, monkeys) S. J. Allen	10M-10G	9,10

Radiofrequency Radiation Interference with Medical Prosthetic Devices J. Mitchell	various/ specific systems (10k-30G)	11,12
RF Radiation Effects on Biochemical Systems in the Central Nervous System (rats & mice) J. Merritt	1-3G	2,8C,8D,8F
Comparison of Theoretical and Experimental Absorption of RF Power (human and animal models, monkeys, rodents) C. H. Durney University of Utah Salt Lake City, Utah	10K-100G	10(A&B)
RFR Effects on Cells (*in vitro*) A. W. Guy University of Washington Seattle, Washington	30,450M	7,8F,12
Effects of RF Radiation on Immune Systems (Mice) R. Liburdy	26,2600M, 4G	7,8F
Development of a Peak Pulsed Power Simulator W. Zarkower Cober Electronics, Inc. Stamford, Connecticut	2,2.8,5.6, 9.6G	9A
Effects of Multiple RF Radiation Exposures (Mice) J. H. Krupp	2600M	7,8F,12
Peak Power Effects of RF Radiation (rats) L. Heynick SRI International Menlo Park, California	1300,2900M	2,8F
Biological Consequences of Pulsed vs. Continuous Wave RFR (rabbits, rats, mice) A. W. Guy Univ. of Washington School of Medicine Seattle, Washington	915,918,2450M	2,3,8B,8F, 12

Biological Consequences of Pulsed vs. Continuous Wave RFR (mice) J. C. Toler Georgia Inst. of Tech. Biomedical Rsch. Group Atlanta, Georgia	450,2450M	8F,12
Behavioral Effects of RF Radiation (monkeys) G. C. Brown	1600M (16H mod.)	2,3
RF Radiation Effects on GI tract (cat) D. N. Erwin	10M-3G	2,7,8F
Development of an Electrothermia Monitor R. R. Bowman Vitek, Inc. Boulder, Colorado	N/A	9A
RFR Bioeffects-Mathmatical Models E. L. Bell, D. K. Cohoon	various	10A

DOD/DEFENSE NUCLEAR AGENCY/ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE

Studies of Biological Effects of Extremely Low Frequency (ELF) Electromagnetic Radiation in Rats (AFRRI for Navy) F. Henry	76H	1,4,8C,8F
Neurochemical Alterations in the CNS of Mammals Exposed to MW Radiation (rat) (for Navy) G. N. Catravas	2450M	2,8C

DOC/NATIONAL BUREAU OF STANDARDS

Probes for EMI/RF Radiation Measurements F. Reis, R. Bowman, M. Kanda	10K-100G	9
Broadband Radiation Probe (NBS for EPA) F. Ries, M. Kanda	50-1000M	9B

Development of HF Absorbed Power Measurement System (six-port circuit) (NBS for NIOSH) C. A. Hoer, H. E. Bussey	10-100M	9A
Improved Radiation Hazard Meter (for Army) F. Reis, D. R. Belsher	3M-1G	9B

NATIONAL SCIENCE FOUNDATION

Probes & Antennas in Biological Material S. S. Sandler, R. W. King Northeastern University Boston, Massachusetts	3-350M, 1-3G	8E,9A,10A&B
Electromagnetic Power Deposition In Man P. Barber University of Utah Salt Lake City, Utah	10M-10G	10
Interaction of EM Fields with the Human Body K. M. Chen Michigan State University East Lansing, Michigan	100-2500M	10(A&B)
Mechanisms of Pulsed MW Interaction with Human Auditory Systems (human & animal head models & theoretical studies) J. C. Lin, F. T. Yu Wayne State University Detroit, Michigan	900-3000M	2,7,10(A&B)

FEDERAL COMMUNICATIONS COMMISSION

Electromagnetic Radiation Measurements	50M-10G	11(A&C)

CENTRAL INTELLIGENCE AGENCY

Review of Published Foreign Scientific Literature on Biological Effects of Nonionizing Electromagnetic Radiation D. Meyers	N/A	12

U. S. VETERANS ADMINISTRATION

Biological Effects of Microwave Irradiation: Cataractogenic and Behavioral Effects of Chronic Irradiation of Monkeys R. MacAfee	2450M,9.3G	3,8A
Biopsychological Studies of MW Irradiation (small animals: mice, rats, guinea pigs, birds) (with BRH) D. R. Justesen	915,2450M	1,2,3,4,8C, 8D,8F,10,12

DEPARTMENT OF ENERGY

SPS (Satellite Power System) Microwave Impacts on Public Health and Safety; Program Coordination and Guidance D. Cahill EPA Research Triangle Park, N.C.	2450M	12
SPS Microwave Impacts on Public Health and Safety Overview Comments D. Cahill EPA Research Triangle Park, N.C.	2450M	11,12
Microwave Exposure Chambers for Assessment of Public Health Impact J. S. Ali, C. Weil, EPA Research Triangle Park, N.C.	2450M	9A
Assessment of SPS MW Radiation on Rectenna Site Energy S. Ballou Argonne National Laboratory Argonne, Illinois	2450M	11
Study of Biological and Ecological Effects of the SPS MW Power Transmission System on Behavior of Insects and other Terrestrial Invertebrates (honey bees) N. Gary U.C.L.A. Los Angeles, California	2450M	3,4

APPENDIX B

APPENDIX B

PUBLICATIONS AND PRESENTATIONS

The following are some reports, articles and presentations associated with the program which were published or presented in 1976, 1977 and early 1978. (A few earlier items, not cited in OTP's 1976 Report, are also included). Items are based on intramural and extramural activities grouped by agency program affiliation. Multiagency support of extramural activities is noted where information was available. This is not an all inclusive compilation nor does it correspond directly to work performed during Calendar Years 1976, 77, or FY 1978 due to normal phasing of reporting and publishing cycles. Many articles and reports based on activities during 1976, 1977 and FY 1978 are yet to be prepared, in preparation or have been submitted for publication and will appear in subsequent years. The Information referenced here reflects, in greater detail, activities and progress in some of the Agency programs and research areas discussed elsewhere in this report.

Sources aggregating a number of reports on various research include publications resulting from the 1975 and 1976 USNC/URSI conferences which are heavily referenced in this and OTP's 1976 report.

Biological Effects of Electromagnetic Waves, 1976:
Vol. I, (biological effects research) 494 pp. HEW Publication (FDA)77-8010 (or GPO 017-015-00124-5).

Vol. II, (dosimetry, measurements and exposure systems), 461 pp., HEW Publication (FDA) 77-8011, (or GPO 017-014-00125-3).

Biological Effects of Electromagnetic Radiation: Radio Science, Special Issue, 12(6S), p. 293, 1977.

(1977 USNC/URSI Conference, Airlie, Va., selected papers submitted for publication).

A source of current awareness of world literature, research and meetings, issued quarterly, is:

Biological Effects of Nonionizing Electromagnetic Radiation: A Digest of Current Literature (available from NTIS).

A comprehensive and periodically updated bibliography is:

Bibliography of Reported Biological Phenomena (Effects) and Clinical Manifestations Attributed to Microwave and

Radio Frequency Radiation: (Report including 7 supplements), 178 pp., 1976, Proj. No. MF51.524.015-0030, Naval Medical Research Institute, Bethesda, Md., (report and 8th and 9th supplements available through Navy or HEW/NIOSH).

Other publications of particular interest include:

(a) an extensive compilation of information on Federal Agency programs resulting from recent Senate hearings -

Oversight of Radiation Health and Safety, June 16, 17, 27, 28, 29, 1977, Senate Committee on Commerce, Science, and Transportation , 1224 pp., Serial No. 95-49, 1977.

(b) a recent review and statement of research needs/ priorities -

A Technical Review of Biological Effects of Nonionizing Radiation, Office of Science & Technology Policy, Executive Office of the President, 54+ pp., May 15, 1978.

HEW/BUREAU OF RADIOLOGICAL HEALTH

1976 Annual Report - Administration of the Radiation Control for Health and Safety Act of 1968, Public Law 90-602, U. S. Dept. of Health, Education and Welfare/Food and Drug Administration, April 1, 1977. (NTIS Acc. No. PB 265 793/AS)

1977 Annual Report - Administration of the Radiation Control for Health and Safety Act of 1968, Public Law 90-602, U. S. Dept. of Health, Education and Welfare/Food and Drug Administration, April 1, 1978. (NTIS Acc. No. PB 286 750/AS)

Bassen, H., Herchenroeder, P., Neuder, S., and Cheung, A., "Evaluation of an Implantiable Electric Field Probe within Finite Simulated Tissues," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 15-26, Nov. - Dec. 1977.

Bassen, H., Herman, W., and Hoss, R., "EM Probe with Fiber Optic Telemetry System," Microwave Journal, April 1977.

Bassen, H., Kantor, G., Ruggera, P., and Witters, D., "Leakage in the Proximity of Microwave Diathermy Applicators and Humans or Phantom Models." Presented at RTOG Meeting, Philadelpha, Pa., June 1978.

Bassen, H. and Peterson, R., Antenna with Electro-Optical Modulator. Patent No. 4,070,621, January 1978.

Bawin, S.M. and Adey, W.R., "Sensitivity of Calcium Binding in Cerebral Tissue to Weak Environmental Oscillating Electric Fields in Nature," Proc. Nat'l Acad. of Sciences, 73, pp. 1999-2003, 1976. (also supported by Navy)

Bawin, S.M., Kaczmarek, L. K., and Adey, W.R., "Effects of Modulated VHF fields on the Central Nervous Systems," Proc. of the New York Academy of Sciences, 247, pp. 74-81, 1975.

Bermant, R.I., Reeves, D.L., and Justesen, D.R., "Conditional Hyperthermia Induced by Microwave Irradiation or Footshock in Rats is Highly General and Resistant to Extinction," Presented at USNC/URSI International Meeting, Airlie, Virginia, Abstracts, p. 116, 1977. (also supported by VA)

Bruce-Wolfe, V., Mathews, M., and Justesen, D.R., "The Visually Evoked Electrocortical Response of the Guinea Pig After Microwave-Induced Hyperthermia." Presented at USNC/URSI International Meeting, Airlie, Virginia, U.S.A., Abstracts, p. 97, 1977. (also supported by VA)

Cetas, T.C., "A Birefringent Crystal Optical Thermometer for Measurements of Electromagnetically Induced Heating," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975. Published in Biological Effects of Electromagnetic Waves, Vol. II, HEW Publication (FDA) 77-8011, pp 338-348, 1976.

Cetas, T. and Kantor, G., "Infrared Emmitance of Electromagnetic Phantoms Materials and Infared Transmittance of Polyethelene," BRH Conference, February 1977. Published in Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves, HEW Publication (FDA) 77-8026, pp 152-169, July 1977.

Chernovetz, M.E., Justensen, D.R. and Oke, A.F., "Teratogenic Effects of Microwave Irradiation in the Laboratory Rat," Presented at 67th Annual Meeting of Southern Society for Philosophy and Psychology, New Orleans, Louisiana, 1975. (also supported by VA)

Chernovetz, M.E., Justesen, D.R., and Oke, A.F., "A Teratological Study of the Rat: Microwave- and Infrared-Radiations Compared," USNC/URSI Annual Meeting, Amherst, Ma., October 1976. In Radio Science (Special Issue), 12(6S), pp. 191-197, Nov.-Dec. 1977. (also supported by VA)

Chou, C.K. and Guy, A.W., "Quantitation of Microwave Biological Effects," BRH Conference, February 1977. Published in Symposium on Biological Effects and Measurement of Radiofrequency/Microwaves, HEW Publication (FDA) 77-8026, pp. 81-103, July 1977.

Chou, C.K., Guy, A.W., and Galambos, R., "Microwave-Induced Cochlear Microphonics in Cats," Presented at IMPI International Microwave Symposium, Leuven, Belgium, July 1976.

Clarke, R.L. and Justesen, D.R., "Behavioral Sensitivity of an Avian to 60-Hz AC and to DC Magnetic Fields," Presented at USNC/URSI International Meeting, Airlie, Virginia, U.S.A., Abstracts, p. 128, Oct.-Nov. 1977. (also supported by VA)

Carpenter, R.L., - (see Navy)

Ferri, E., - (see Navy)

Galloway, W., "Microwave Dose-Response Effects Upon Delayed Match to Sample Performance," Presented at IMPI International Microwave Power Symposium, Leuven, Belgium, July 1976.

Galloway, W.D. and Waxler, M., "Interaction Between Microwave and Neuroactive Compounds," BRH Conference, Published in Symposium on Biological Effects and Measurement of Radio-Frequency/Microwaves, HEW Publication (FDA) 77-8026, pp. 62-68, July 1977.

Grodsky, I.T., "Neuronal Membrane: A Physical Synthesis," Math. Biosciences, 28, pp. 191-291, 1976..

Guy, A.W. and Chou, C.K., "System for Quantitative Chronic Exposure of a Population of Rodents to UHF Fields," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975. Published in Biological Effects of Electromagnetic Waves, Vol. II, HEW Publication (FDA) 77-8011, pp. 389-410, December 1976.

Guy, A.W., Lin, J.C., and Chou, C.K., "Electrophysiological Effects of Electromagnetic Field on Animals," In Fundamental and Applied Aspects of Nonionizing Radiation, pp. 167-207. Ed. S.M. Michaelson & M.W. Miller, New York: Plenum Press, 1975.

Guy, A.W., Lehman, J.F., et al, "Development of a 915 MHz Direct Contact Applicator for Therapeutic Heating of Tissues," IEEE Trans. Microwave Theory Tech., 26(8), pp. 550-556, 1978.

Guy, A.W., Webb, M.D. and McDougall, J.A., "A New Technique for Measuring Power Deposition Patterns in Phantoms Exposed to EM Fields of Arbitrary Polarization - Example, the Microwave Oven," Presented at IMPI Microwave Power Symposium, Waterloo, Ontario, Canada, 1976.

Hazzard, D.G., editor, Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves, Proceedings of a BRH Conference, Rockville, Md., February 16-18, 1977, HEW Publication (FDA) 77-8026, (NTIS Acc. No. PB 272 906/AS), July 1977.

Henton, W., "Response Interactions During Simple and Concurrent Classical Conditioning Procedures Following Exposure to Microwave Radiation," Presented at Southeastern Psychological Association Annual Program, New Orleans, La., March 1976.

Ho, H., "Dose Rate Distribution in Triple-Layered Dielectric Cylinder with Irregular Cross Section Irradiation by Plane Wave Sources," J. Microwave Power, 10(4), pp. 421-432, December 1975.

Ho, H. "Energy Absorption Patterns in Circular Triple-Layered Tissue Cylinders Exposed to Plane Wave Sources" J. Health Physics Society, 31, pp. 97-108, August 1976.

Ho, H.S., "Design of Aperture Sources for Deep Heating Using Electromagnetic Energy," Presented at USNC/URSI International Meeting, Airlie, Virginia, Abstracts, p 146, Oct.-Nov. 1977. (submitted for publication to Health Physics)

Ho, H. and Edwards, W.P., "Oxygen Consumption Rate of Mice Under Differing Dose Rates of Microwave Radiation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 131-138, Nov.-Dec. 1977.

Ho, H.S. and McManaway, M., "Heat Dissipation Rate of Mice after Microwave Irradiation," J. Microwave Power, 12(1), pp. 93-100, 1977.

Ho, H.S. and Edwards, W.P., "Dose Rate and Oxygen Consumption Rate in Mice Confined in a Small Holder During Exposure to 2450 Megahertz Microwave Radiation," Radiation and Environmental Biophysics, 14, pp. 251-256, 1977.

Ho, H.S. and Faden, J., "Experimental and Theoretical Determination of Absorbed Microwave Dose Rate Distributions in Phantom Heads Irradiated by an Aperture Source," Health Physics, 33(1), pp. 13-21, 1977.

Ho, H., Pinkavitch, F., Edwards, W., and Monahan, J., "Altered Behavior of a Group of Mice Under Repeated Exposure to Low Level 915 MHz Microwave Radiation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976.

Justensen, D.R. and Bruce-Wolfe, V., "Microwave Hyperthermia and the Visually Evoked Potential: Preliminary Observations of the Guinea Pig," BRH Conference, February 1977. Published in Symposium on Biological Effects and Measurement of RF/Microwaves, HEW Publication (FDA) 77-8026, pp. 54-61, July 1977. (also supported by VA)

Justesen, D.R. and Guy, A.W., "Editorial: A New Radiobiology is Coming of Age But Faces an Uncertain Future," Radio Science (Special Issue), 12(6S), pp. i-ii, Nov.-Dec. 1977.

Justesen, D.R., Morantz, R.A., Clark, M., Reeves, D.L. and Mathews, M., "Effects of Handling and Surgical Treatment on Convulsive Latencies and Mortality of Tumor-Bearing Rats to 2450-MHz Microwave Radiation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 40, October 1976. (also supported by VA)

Kantor, G., "New Types of Microwave Diathermy Applicators-Comparison of Performance with Conventional Types," BRH Conference, Published in Symposium on Biological Effects and Measurements of Radiofrequency/Microwaves, HEW Publication (FDA) 77-8026, pp. 230-250, July 1977.

Kantor, G., "The Performance of a New Direct Contact Applicator for Microwave Diathermy," IEEE Trans., MTT 26(8), pp. 563-568, 1978.

Kantor, G. and Cetas, T.C., "A Comparative Heating Pattern Study of Direct Contact Applicators in Microwave Diathermy," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 111-120, Nov.-Dec. 1977.

Kantor, G. and Witters, D., "A Comparative Performance Study of Spaced Applicators in Microwave Diathermy," Presented at IMPI International Microwave Power Symposium, Leuven, Belgium, July 1976.

Kantor, G. and Witters, D., "A New 915 MHz Direct Contact Applicator with Reduced Leakage," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 58, June 1978, and RTOG Meeting, Philadelphia, Pa., June 1978.

Kantor, G., Witters, D.M., and Greiser, J.W., "The Design and Performance of Circularly Polarized Direct Contact Applicator for Microwave Diathermy," In 1977 IEEE MTT-S International Microwave Symposium, San Diego, Ca., June 1977, IEEE, (New York), pp. 364-367, 1977.

Leach, W., "Microwaves (2450 MHz) Stimulate Maturation of B Lymphoid Cells in Spleens of Exposed Mice" Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976.

Leach, W., "The Effects of Microwave (2450 MHz) on the Response of Mice to T Lymphoid Cell Dependent and T Lymphoid Cell Independent Antigens: Preliminary Results," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976.

Leach, W., "Induction of Chromosomal Aberrations by 2450 MHz Microwave Radiation," Presented at 1st International Congress on Cell Biology, Boston, Ma., September 1976.

Lebovitz, R.M. and Seaman, R.L., "Single Auditory Unit Response to Weak Pulsed Microwave Radiation," Brain Res., 126(2), pp. 370-375, 1977.

Lewis, K., We Want You to Know About Microwave Oven Radiation, HEW 78-805, 1978.

Lin, J.C. and Kantor, G., "A Class of New Microwave Diathermy Applicators," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 29, August 1978.

Magin, R.C. and Kantor, G., "Comparison of the Heating Patterns of Small Microwave (2450 MHz) Applicators," J. of Bioengineering, 1(5/6), December 1977.

Monahan, J. and Henton, W., "Microwave Absorption and Taste Aversion as a Function of 915 MHz Radiation," BRH Conference, February 1977, Published in Symposium on Biological Effects and Measurement of Radiofrequency/Microwaves, HEW Publication (FDA) 77-8026, pp. 34-40, July 1977.

Monahan, J. and Henton, W., "Free-Operant Advoidance and Escape from Microwave Radiation," BRH Conference, February 1977. Published in Symposium on Biological Effects and Measurement of Radiofrequency/Microwaves. HEW Publication (FDA) 77-8026, pp. 23-33, July 1977.

Monahan, J. and Henton, W., "The Effects of Psychoactive Drugs and Microwave Radiation on Operant Behavior," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 114, Oct.-Nov. 1977.

Monahan, J. and Ho, H. "The Effect of Ambrent Temperature on the Reduction of Microwave Energy Absorption by Mice," Radio Science (Special Issue), 12(6S), pp. 257-262, 1977.

Neuder, S., "A Finite Element Technique for Calculating Induced Internal Fields and Power Deposition in Biological Media of Complex Irregular Geometry, Exposed to Plane Wave Electromagnetic Radiation," BRH Conference, February 1977. Published in Symposium of Biological Effects and Measurement of Radiofrequency/Microwaves. HEW Publication (FDA) 77-8026, pp. 170-190, July 1977.

Neuder, S.M., Electromagnetic Fields in Biological Media-Part I: Dosimetry--A Primer on Bioelectromagnetics, HEW Publication (FDA) 78-8068, (NTIS Acc. No. PB 285 793/AS), 1978.

Peak, D.W., Herman, W.A., Shuping, R.E., and Conover, D.L., Measurement of Power Density from Marine Radar, (NTIS Acc. No. PB 247 765/AS), 1976.

Pickard, W.F., and Rosenbaum, F.J., "Biological Effects of Microwaves at the Membrane Level: Two Possible Athermal Electrophysiological Mechnisms and a Proposed Experimental Test," Math. Biosciences, 39, pp. 235-253, 1978.

Putthoff, D.L., et al.- (see VA)

Robinette, C.D. and Silverman, C., "Causes of Death Following Occupational Exposure to Microwave Radiation (RADAR) 1950-1974," In Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves, HEW Publ. No. (FDA) 77-8026, pp. 338-344, 1977.

Ruggera, P.S., "Near Field Measurements of RF Fields," BRH Conference, February 1977, Published in Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves, HEW Publication (FDA) 77-8026, pp. 104-116, July 1977.

Ruggera, P.S., "Measurement Techniques and Radiation Patterns Near CB Antennas," Presented at American Conference of Governmental Industrial Hygienists, Los Angeles, California, May 1978.

Rugh, R., "The Relation of Sex, Age, and Weight of Mice to Microwave Radiation Sensitivity," J. of Microwave Power, 11(2), June 1976.

Rugh, R., Ho, H., and McManaway, M., "The Relation of Dose Rate of Microwave Radiation to the Time of Death and Total Absorbed Dose in the Mouse," J. Microwave Power, 11(3), pp. 279-282, September 1976.

Rugh, R. and McManaway, M., "Are Mouse Fetuses Uniformily Sensitive to Microwave Radiation," Presented at Teratology Society Meeting, Carmel, Ca., June 1976.

Rugh, R. and McManaway, M., "Comparison of Ionizing and Microwave Radiations with Respect to Their Effects on the Rodent Embryo and Fetus," Presented at Congenital Anomalies Research Association of Japan Meeting, Nagoya City, Japan, September 1976.

Rugh, R. and McManaway, M., "Mouse Fetal Sensitivity to Microwave Radiation," Congenital Anomalies, 17, pp. 39-45, 1977.

Sandhu, T., Johnson, R., and Kowal, H., "Heating Patterns of a New Microwave Hyperthermia Applicator," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 57, June 1978.

Smith, R.F. and Justesen, D.R., "Effects of a 60-Hz Magnetic Field on Activity Levels of Mice," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 279-285, Nov.-Dec. 1977. (also supported by VA)

Taylor, L.S. and Cheung, A.Y., editors, The Physical Basis of Electromagnetic Interactions with Biological Systems- Proceedings of a Workshop Held at the University of Maryland, College Park, Maryland, June 15-17 1977, HEW Publication (FDA) 78-8055. (NTIS Acc. No. AD-A051218), 1978. (also supported by Navy)

Waxler, M. and Galloway, W., "Reduction in Behavior Output Following Combined Doses of Microwave and Serotonin-Depleting Drugs," Presented at Southeastern Psychological Association 1976 Annual Program, New Orleans, La., March 1976.

Wiktor-Jedrzejczak, W., Ahmed, A., Czerski, P., Leach, W., and Sell, K., "The Effects of Microwave (2450 MHz) on the Immune System in Mice--Increase in Complement Receptor Bearing Lymphocytes (CRL)," Exper. Hematol., 4, p. 73, 1976. (also Navy)

Yao, K., "Microwave Irradiation Effects on Eye Lens on Chromosomes of Corneal Epithelial Cells of Chinese Hamsters," Presented at IMPI International Microwave Power Symposium, Leuven, Belgium, July 1976.

Yao, K., "Cytogenetic Consequences of Microwave Incubation of Mammalian Cells in Culture," Presented at 45th Annual Meeting of the Genetics Society of America, Salt Lake City, Utah, August 1976.

HEW/NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES

Human Health and the Environment - Some Research Needs, Report of the Second Task Force for Research Planning in Environmental Health Science, HEW Publication (NIH) 77-1277, December 1976.

Adey, W.R., "The Sensorium and the Modulation of Cerebral States: Tonic Environmental Influences on Limbic and Related Systems," Ann. NY Acad. Sci., 290, pp. 396-420, 1977.

Adey, W.R., "Models of Membranes of Cerebral Cells as Substrates for Information Storage," BioSystems, 8, pp. 163-178, 1977.

Bawin, S.M., Sheppard, A. and Adey, W.R., "Mechanisms of Weak Electromagnetic Field Coupling in Brain Tissue," Presented at Navy (ONR)/BRH-University of Maryland Workshop, June 1977. Published in The Physical Basis of Electromagnetic Interactions with Biological Systems, HEW Publication (FDA) 78-8055, pp. 75-90, 1978.

Bawin, S.M., Sheppard, A., and Adey, W.R., "Possible Mechanisms of Weak Electrofield Coupling in Brain Tissue," Bioelectrochemistry and Bioenergetics, 1978.

Bawin, S.M., Sheppard, A., and Adey, W.R., "Models of Long-Range Order in Cerebral Macromolecules: Effects of ELF, VHF and UHF Fields on Calcium Binding," Presented at USNC/URSI International Meeting, Airlie, Virginia, Abstracts, p. 100, Oct.-Nov. 1977.

D'Andrea, J.A. and Gandhi, O.P., et al., "Behavioral and Physiological Effects on Rats of Chronic, Low-Level 915 MHz Microwave Radiation," Presented at USNC/URSI International Meeting, Airlie Virginia, Abstracts, p. 119, Oct.-Nov. 1977.

D'Andrea, J.A. and Gandhi, O.P., et al., "Behavioral and Physiological Effects of Chronic Low-Level 2450 MHz Microwave Radiation in Rats" Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 33, June 1978.

Hamrick, P.E. and Fox, S.S., "Rat Lymphocytes in Cell Culture Exposed to 2450 MHz (CW) Microwave Radiation," J. Microwave Power, 12(2), pp. 125-132, 1977.

Hamrick, P.E., McRee, D.I., Thaxton, J.P., and Parkhurst, C.R., "Humoral Immunity of Japanese Quail Subjected to Microwave Radiation During Embryogeny" Health Physics, 33(1), pp. 23-33, 1977.

Jensh, R.P., Ludlow, J. and Brent, R.L., "A Simple Cage Design for Containing Rats During Microwave Irradiation," (in preparation).

Jensh, R.P., Ludlow, J., Rudder, T., Vogel, W.H., Weinberg, I., and Brent, R.L., "Studies Concerning the Possible Non-Thermal Teratogenic Activity of Microwave Irradiation at 915 MHz," (in preparation).

Jensh, R.P., Ludlow, J., Rudder, T., Vogel, W.H., Weinberg, I., and Brent, R. L., "Neonatal and Adult Behavioral Modification Studies in the Rat Due to *in utero* Microwave Irradiation at 915 MHz," (in preparation).

Jensh, R.P., Ludlow, J., Weinberg,I., Vogel, W.H., Rudder, T., and Brent, R.L., "Teratogenic Effects of Rat Offspring of Non-Thermal Chronic Prenatal Microwave Irradiation," Teratology, 15(2), p. 14A, 1977.

Johnson, R.B., Mizumore, S., and Lovely, R.H., "Adaptation to Microwave Exposure as a Function of Power Density and Ambient Temperature in the Rat," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 30, June 1978.

Johnson, R.B., Mizumore, S., and Lovely, R.H., "Adult Behavioral Deficit in Rats Exposed Prenatally to 918 MHz Microwaves," Proceedings 17th Hanford Biology Symposium, (in press).

Lovely, R., Johnson, R., and Mathews, M., "Alterations of Behavioral and Biochemical Parameters During and Consequent to 500 uw/cm^2 Chronic 2450 MHz Microwave Exposure," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 34, June 1978.

McRee, D.I., "Potential Microwave Injuries in Clinical Medicine," Annual Review of Medicine, 27, pp. 109-115, 1976.

McRee, D.I. and Hamrick, P.E., "Exposure of Japanese Quail Embryos to 2.45 GHz Microwave Radiation During Development," Radiation Research, 71(2), pp. 355-366, 1977.

McRee, D.I. and Wachtel, H., "Microwave Effects on Nerve Vitality," Presented at USNC/URSI International Meeting, Airlie, Virginia, Abstracts, p. 96, Oct.-Nov. 1977.

McRee, D.I. and Wachtel, H., "Effects of 2.45 GHz Microwave Radiation on Nerve Vitality," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 79, August 1978.

McRee, D., Wyatt, R., Haseman, J., and Somjen, G., "The Transmission of Reflexes in the Spinal Cord of Cats During Irradiation with Microwaves," J. of Microwave Power, 11(1), pp. 49-60, March 1976

McRee, D.I., Elder, J.A., Gage, M.I., Reiter, L.W., Rosenstein, L.S., Shore, M.L., Galloway, W.D., Adey, W.R. and Guy, A.W., "Effects of Nonionizing Radiation on the Central Nervous System, Behavior and Blood: A Progress Report." In the Second US/USSR Environmental Health Symposium, Marineland, Florida, December 1976.

HEW/NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

Conover, D.L., "Measurement of Electric and Magnetic Field Strengths from Industrial Radiofrequency (15-40 MHz) Power Sources," Presented at AIH Meeting, Alanta, Ga., May 1976.

Conover, D.L., "RF/Microwave Monitoring Measurements and Instrumentation," Presented at Nonionizing Radiation Seminar, University of Cincinnati Medical Center, Cincinnati, Ohio, June 1976.

Conover, D.L., "Industrial RF (6-40 MHz) Personnel Exposure Problems-Initial Observation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976.

Conover, D.L., "RF (10-40 MHz) Personnel Exposure-Industrial Hygiene Problems," Presented at American Industrial Hygiene Conference, New Orleans, Louisiana, May 1977.

Conover, D.L., Lary, J.M., and Foley, E.D., "Induction of Teratogenic Effects in Rats by 27.12 MHz RF Radiation," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p 31, June 1978.

Dwyer, M.J. and Leeper, D.B., A Current Literature Report on the Carcinogenic Properties of Ionizing and Nonionizing Radiation -- Part II: Microwave and Radiofrequency Radiation HEW (NIOSH) Publication No. 78-134, March 1978.

Glaser, Z.R., Ninth Supplement to Bibliography of Microwave and RF Biologic Effects, HEW (NIOSH) Publication No. 78-126, November 1977.

Greene, F. M., Development of an RF Near-Field Exposure Synthesizer (10 to 40 MHz), HEW Publication No. (NIOSH) 76-160, 1976.

Greene, F.M., Measurement of RF Power-Absorption in Biological Specimens, HEW Publication No. (NIOSH) 77-146, February 1977.

Guy, A.W., RF Cell Culture Irradiation System With Controlled Temperature and Field Strength, HEW Publication No. (NIOSH) 77-182, June 1977. (also supported by AF)

Guy, A.W., Webb, M.D., and McDougall, J.A., RF Radiation Absorption Patterns: Human and Animal Modeling Data," HEW Publication No. (NIOSH) 77-183, September 1977.

Guy, A.W., Webb, M.D., and McDougall, J.A., Critical Comparison of RF Field Delivery Techniques and Measurable Results in Cell Culture of Whole Animals, U. Wash. Final Report on AF contract F41609-75-C-0021, June 1976.

Moss, C.E., Conover, D.L., Murray, W.E., and Kohre, A., "Estimated Number of United States Workers Potentially Exposed to Electromagnetic Radiation," Presented at American Industrial Hygiene Conference, New Orleans, Louisiana, May 1977.

Moss, C.E., Murray, W.E., Parr, W.H., Messite, J., and Karches, G.J., A Report on Electromagnetic Radiation Surveys of Video Display Terminals, HEW (NIOSH) Publication No. 78-129, December 1977.

Toler, J. and Seals, J., RF Dielectric Properties Measurement System: Human and Animal Data, HEW Publication No. (NIOSH) 77-176, July 1977.

ENVIRONMENTAL PROTECTION AGENCY

Radiation Protection Activities, 1976, EPA-520/4-77-005, EPA/ORP, August 1977.

Radiation Protection Activities, 1977, EPA-520/4-78-003, EPA/ORP, August 1978.

Radiation Quality of the Environment, EPA-520/1-76-010, EPA/ORP, May 1976.

Radiation Quality of the Environment in the United States, 1977, EPA-520/1-77-009, EPA/ORP, EPA/ORP, September 1977.

Allis, J.W., Blackman, C.F., Fromme, M.L., and Benane, S.G., "Measurement of Microwave Radiation Absorbed by Biological Systems: I. Analysis of Heating and Cooling Data," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp 1-8, Nov.-Dec. 1977.

Allis, J.W. and Fromme, M. L., "Activity of Membrane-Bound Enzymes Exposed to Amplitude Modulated 2450 MHz Radiaiton," Presented at 1977 Annual USNC/URSI Meeting, Airlie, Va., (submitted for publication in Radio Science).

Allis, J.W., Fromme, J.L., and Janes, D.E., "Pseudosubstrate Binding to Ribonuclease During Exposure to Microwave Radiation at 1.70 and 2.45 GHz," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves, Vol. 1, HEW Publication (FDA) 77-8010, pp. 366-376, December 1976.

Allis, J.W. and Weil, C.M., "Spectrofluorometric Measurements in Biochemical Samples During Simultaneous Microwave Exposures," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 25, August 1978.

Athey, T.W., Tell, R.A., Hankin, N.N., Lambdin, D.L., Mantiply, E.D., and Janes, D.E., Radiofrequency Radiation Levels and Population Exposure in Urban Areas of the Eastern United States, EPA-520/2-77-008, May 1978.

Berman, E. and Carter, H.B., "Observations on Mouse Fetuses Exposed to 2.45 GHz Microwave Radiation," 1978. (In press, Health Physics).

Blackman, C.F. and Black, J.A., "Measuremnt of Microwave Radiation Absorbed by Biological Systems, II. Analysis by Dewar-Flask Calorimetry," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 9-14, Nov.-Dec. 1977.

Blackman, C.F., Elder, J.A., Weil, C.M., Benane, S.G., and Eichinger, D.C., "Two Factors Affecting Radiation-Induced Calcium Efflux from Brain Tissue," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 101, Oct.-Nov. 1977. (submitted to Radio Science)

Blackman, C.F., Surles, M.C., and Benane, S.G., "The Effect of Microwave Exposure on Bacteria: Mutation Induction," Presented At USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Elctromagnetic Waves, Vol. 1, HEW Publication (FDA) 77-8010, pp. 406-413, December 1976.

Burdeshaw, J.A. and Schaffer, S., Factors Associated with the Incidence of Congenital Anomalies: A Localized Investigation, So. Res. Institute, EPA Report No. 600/1-77-016, (NTIS Acc. No. PB 266 184/AS) March 1976.

Dutta, S.K., Hossain, M.A., Ho, H.S. and Blackman, C.F., "8.6 GHz Electromagnetic Radiation Effect on Escherichia coli Repair Deficient Mutant Under Controlled Temperature," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 18, June 1978.

Elder, J.A., "Research Needs for Establishing an Environmental Microwave Radiation Safety Standard," In Human Health and the Environment - Some Research Needs, HEW Publication No. (NIH) 77-1277, pp. 137-142, 1977.

Elder, J.A., Ali, J.S., Long, M.D., and Anderson, G.E., "A Coaxial Air Line Microwave Exposure System: Respiratory Activity of Mitochondria Irradiated at 2-4 GHz," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves, Vol. I, HEW Publication (FDA) 77-8010, pp. 352-365, December 1976.

Environmental Radio-Frequency Strengths: Miami, Florida, EPA, ORP/EAD 76-5, 1976.

Gage, M.I., "Effects of Single Exposures to 2450 MHz Microwave Irradiation on Rat Behavior," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976.

Gage, M.I., "Learning and Memory in Rats Exposed to 2450 MHz," (submitted to Radio Science)

Gage, M.I., "Microwave Power and Ambient Temperature Interact to Alter Rat Behavior Following Overnight Exposure," 1977 USNC/URSI Meeting, (submitted to Radio Science)

Gage, M.I., "Operant Behavior of Rats Following Overnight Exposures to Microwaves," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 118, Oct.-Nov. 1977.

Gage, M.I., Berman, E., Kinn, J.B., and Anderson, G.E., "Videotape Observation of Rats During Exposure to 2450 MHz Microwave Radiation," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 115, Oct.-Nov. 1977. (submitted to Radio Science)

Gage, M.I. and Guyer, W.M., "Interaction of Ambient Temperature and Microwave Power Density on Schedule Controlled Behavior in the Rat," Presented at URSI Symposium on Biological Effects of Electromagneic Waves, Helsinki, Finland, Abstracts, p. 84, August 1978.

Galpin, F.L., Athey, T.W., Hankin, N.N., and Janes, D.E., "Results of the EPA Envionmental Radiofrequency Radiation Measurements Program," Presented at Annual Meeting of the Conference of Radiation Control Program Directors, Seattle, Wa., June 1977.

Hankin, N.N., Environmental Impact Analysis, Project PAVE PAWS - Otis AFB, Mass., EPA/ORP, December 1977.

Hankin, N.N., Radiation Characteristics of Traffic Radar Systems, ORP/EAD-76-1, (NTIS Acc. No. PB 257 077/AS), March 1976.

Huang, A.T., Engle, M.E., and Elder, J.A., "Lymphocyte Transformation Induced by Microwave Radiation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 21, October 1976.

Huang, A.T., Engle, M.E., Elder, J.A., Kinn, J.B. and Ward, T.R., "The Effect of Microwave Radiation (2450 MHz) on the Morphology and Chromosomes of Lymphocytes," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 173-177, Nov.-Dec. 1977.

Janes, D.E., "The EPA Environmental Radiofrequency Radiation Program," National Bureau of Standards Electromagnetic Interference Workshop, Gaithersburg, MD, July 1977 (in press). (also presented at the Region II-III Radiological Health Meeting, Lancaster, PA, October 1977)

Janes, D.E., "Background Information on High Voltage Fields," Environmental Health Perspectives, 20, pp. 141-147, October 1977.

Janes, D.E., "Current Status of Environmental Findings," Proceedings of the Tenth Annual National Conference on Radiation Control, Harrisburg, PA, HEW Publication (in press), April-May 1978.

Janes, D.E., Tell, R.A., Athey, T.W., and Hankin, N.N., "Nonionizing Radiation Exposure in Urban Areas of the United States," Proceedings IVth International Congress of the International Radiation Protection Association, Vol. 2, pp. 329-332, April 1977.

Janes, D.E., Tell, R.A., Athey, T.W., and Hankin, N.N., "Radiofrequency Radiation Levels in Urban Areas," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 49-56, Nov.-Dec. 1977.

Kaplan, J.N. and Polson, P., Study to Determine Neurophysiologic and Social Behavioral Response of Squirrel Monkeys Exposed to Electromagnetic Radiation, SRI, Final Report, EPA Contract No. 68-02-1778, June 1978.

Kaplan, J., Polson, P., Rebert, C., Lunan, K., and Gage, M., "Biological and Behavioral Effects of Pre- and Postnatal Exposure to 2450 MHz Electromagnetic Radiation in the Squirrel Monkey," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 64, August 1978.

Kinn, J.B., "Whole Body Dosimetry of Whole Animals: The Effect of Weight and Exposure Geometry." Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 61-64, Nov.-Dec. 1977.

Kinn, J.B., "The Number of Animals Simultaneously Exposed to Microwaves in a Free Field Affects the Dose Rate," Presented at USNC/URSI Symposium, Arlie, Va., Oct.-Nov. 1977. (submitted to Radio Science)

Lambdin, D.L., "A Comparison of Measurement Techniques to Determine Electric Fields and Magnetic Flux Under EHV Overhead Power Transmission Lines," EPA, ORP/EAD 78-1, 1978.

Smialowicz, R.J., "The Effect of Microwaves (2450 MHz) on Lymphocyte Blast Transformation *in vitro*," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves, Vol. I, HEW Publication (FDA) 77-8010, pp. 472-483, December 1976.

Smialowicz, R.J., Kinn, J.B., and Elder, J.A., "Exposure of Rats *in utero* Through Early Life to 2450 MHz (CW) Microwave Radiation: Effects on Lymphocytes," (submitted to Radio Science)

Smialowicz, R.J., Kinn, J.B., Weil, C.M., and Ward, T.R., "Chronic Exposure of Rats to 425 and 2450 MHz Microwave Radiation: Effects on Lymphocytes," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 140, Oct.-Nov. 1977.

Smialowicz, R.J., Riddle, M.M., Brugnolotti, .L., Ward, T.R., and Kinn, J.B., "Evaluation of Lymphocyte Function in Mice Exposed Repeatedly to 2450 MHz (CW) Microwave Radiation," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 27, June 1978.

Tell, R.A., A Measurement of RF Field Intensities in the Immediate Vicinity of an FM Broadcast Station Antenna, EPA, ORP/EAD-76-2, (NTIS Acc. No. PB 257 698/AS), January 1976.

Tell, R.A., An Analysis of Radar Exposure in the San Francisco Area, ORP/EAD-77-3, (NTIA Acc. No. PB 273 188/AS), March 1977.

Tell, R.A., An Analysis of the Radiofrequency and Microwave Absorption Data With Consideration of Thermal Safety Standards, ORP/EAD 78-2, April 1978.

Tell, R.A., "Field Strength Measurements of Microwave Oven Leakage at 915 MHz," IEEE Trans. on Electromagnetic Compatibility, EMC-20(2), pp 341-346, May 1978.

Tell, R.A., Near-Field Radiation Properties of Simple Linear Antennas With Applications to Radiofrequency Hazards and Broadcasting, ORP/EAD 78-4, (in press) 1978.

Tell, R.A. and Hankin, N.N., Measurements of Radiofrequency Field Intensity in Buildings with Close Proximity to Broadcast Stations, ORP/EAD 78-3, (in press) 1978.

Tell, R.A., Hankin, N.N., and Janes, D.E., "Aircraft Radar Measurements in the Near Field," In Operational Health Physics, Proceedings of the Ninth Midyear Topical Symposium of the Health Physics Society, pp. 239-246, Boulder, Co., February 1976.

Tell, R.A., Hankin, N.N., Nelson, J.C., Athey, T.W., and Janes, D.E., "An Automated Measurement System for Determining Environmental Radiofrequency Field Intensities: II," in Measurements for the Safe Use of Radiation, National Bureau of Standards Special Publication 456, Washington, D. C., pp. 203-213, November 1976.

Tell, R.A. and Janes, D.E., "Broadcast Radiation: A Second Look," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves, Vol. II, HEW Publication (FDA) 77-8011, pp. 363-388., December 1976.

Tell, R.A., Lambdin, D.L., and Mantiply, E.D., "Hospital Proximities to Nearby Broadcast Stations," in Proceedings of the 1978 International Symposium on Electromagnetic Compatibility, Atlanta, Ga., IEEE Publication 78-CH-1304-5 EMC, pp. 100-105, June 1978.

Tell, R.A. and Mantiply, E.D., Population Exposure to VHF and UHF Broadcast Radiation in the United States, ORP/EAD 78-5, June 1978.

Tell, R.A. and Nelson, J.C., "Broadcast-Signal Bandwidth Measurements Using Real-Time Data Averaging," IEEE Transactions on Broadcasting, BC-22(4), pp. 116-123, 1976.

Tell, R.A., Nelson, J.C., Lambdin, D.L., Athey, T.W., Hankin, N.N., and Janes, D.E., An Examination of Electric Fields Under EHV Overhead Transmission Lines, EPA-520/2-76-008, (NTIS Acc. No. PB 270 613), April 1977.

Tell, R.A. and O'Brien, P.J., An Investigation of Broadcast Radiation Intensities at Mt. Wilson, California, ORP/EAD-77-2, (NTIS Acc. No. PB 275 040/AS), April 1977.

Tripathi, V.K. and Lee, H., Electromagnetic Absorption By Prolate Spherioidal Models of Man and Animals, Final Report, under (EPA Grant No.: R804697-01-0), December 1978.

Weil, C.M., "Use of Mathematical Models in Nonionizing Radiation," Proceedings of the Conference on Environmental Modeling and Stimulation, Cincinnati, Ohio, April 1976, EPA Report No. 600/9-76-016, pp. 186-190, July 1976.

Weil, C.M., "Propagation of Plane Waves Through Two Parallel Dielectric Sheets," IEEE Transaction on Biomedical Engineering, BME-21, pp 165-168, 1974. See also Communications, IEEE Transactions on Biomedical Engineering, pp. 78-80, January 1977.

Weil, C.M., "Review of Exposure Techniques and Dosimetric Methods Employed in Microwave Bioeffects Research," Digest, IEEE Region 3 Meeting, Williamsburg, Va., (77CHO 1233-6 Region III), April 1977.

Whitcomb, E.R., Weil, C.M., and Blackman, C.F., "The Effect of Nonionizing E/M Energy on the Rate of Spontaneous Contraction of Smooth Muscle," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 36, Oct.-Nov., 1977.

Wilson, B.S., Joines, W.T., Casseday, J.H., Auditory Neural Response of Cats to Low Power Pulsed Microwave Irradiation: A Pilot Study, Final Report, EPA Contract No. 68-02-2231, (in publication, 1978).

DOD/U. S. ARMY

Balcom, G.L., Lenox, R.H., and Meyerhoff, J.L., "Regional Glutamate Levels in Rat Brain Determined After Microwave Fixation," J. Neurochemistry, 26, pp. 423-425, 1976.

Brown, P.V., Lenox, R.H., and Meyerhoff, J.L., "Microwave Enzyme Inactivation System: Electronic Control to Reduce Dose Variability," IEEE Trans. on Biomedical Engineering, BME-25(2), pp. 205-208, 1978.

Chen, K. and Guru, B.S., "Focal Hyperthermia as Induced by RF Radiation of Simulacra with Embedded Tumors and as Induced by EM Fields in a Model of a Human Body," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 27-37, Nov.-Dec. 1977.

Cleary, S.F. and Wangemann, R.T., "Effect of Microwave Radiation on Pentobarbital-Induced Sleeping Time," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975. Published in Biological Effects of Electromagnetic Waves, Vol. I, HEW Publication (FDA)77-8010, pp 311-322, December 1976.

D'Andrea, J.A., Ghandi, O.P., and Kesner, R.P., "Behavioral Effects of Resonant Electromagnetic Power Absorption in Rats," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves, Vol. I, HEW Publication (FDA)88-8010, pp. 257-273, December 1976.

D'Andrea, J.A., Gandhi, O.P.,and Lords, J.L., "Behavioral and Thermal Effects of Microwave Radiation at Resonant and Nonresonant Wavelengths," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp 251-256, Nov.-Dec. 1977.

Gandi, O.P., Sedigh, K., Beck, G.S. and Hunt, E.L., "Distribution of Electromagnetic Energy Deposition in Models of Man with Frequencies Near Resonance," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol. II, HEW Publication (FDA)77-8011, pp. 44-67, December 1976.

Gandhi, O.P., "Resonant Electromagnetic Power Deposition in Man and Animals," Presented at the International Microwave Symposium, Palo, Alto, California, May 1975.

Gandhi, O.P. and Hagmann, M.J., "Some Recent Results on the Deposition of Electromagnetic Energy in Animals and Models of Man," In The Physical Basis of Electromagnetic Interactions with Biological Systems, HEW Publication (FDA) 78-8055 (NTIS Acc. No. AD-A051218) pp. 243-259, 1978.

Gandhi, O.P., Hunt, E.L., and D'Andrea, J.A., "Deposition of Electromagnetic Energy in Animals and in Models of Man With and Without Grounding and Reflector Effects," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 39-48, Nov.-Dec. 1977.

Gandhi, O.P. and Sedigh, K., "Biological Phantom Materials for Simulating Man at Different Frequencies," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 40, October 1976.

Guru, B.S. and Chen, K.M., "Internal EM Field and Absorbed Power Density in Human Torsos Induced by 1 to 500 MHz EM Waves," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 39, October 1976.

Guru, B.S. and Chen, K.M., "Hyperthermia By Local EM Heating and Local Conductivity Change," IEEE Trans., BME 24(5), pp. 473-477, 1977.

Hagmann, M.J., Gandhi, O.P., and Durney, C.H., "Upper Bound on Cell Size for Moment-Method Solutions," IEEE Trans. on Microwave Theory and Techniques, MTT-25(10), pp. 831-832, 1977.

Hagmann, M.J. and Gandhi, O.P., "Radiators for Microwave Biological Effects Research - Waveguide Slot Array with Constant Radiation Intensity," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 97-102, Nov.-Dec. 1977.

Heynick, L.N., Polson, P. and Karp, A., "A Microwave Exposure System for Primates," Presented at USNC/URSI Annual. Meeting, Amherst, Ma., October 1976, Published in Radio-Science (Special Issue) 12(6S), p. 103-110, Nov.-Dec. 1977.

Jacobi, J.H. and Larsen, L.E., "Microwave Interrogation of Dielectric Targets (II) By Time Delay Spectrum," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 48, October 1976.

Larsen, L.E. and Jacobi, J.H., "Microwave Interrogation of Dielectric Targets (I) By Scattering Parameters," ibid., p. 47.

Larsen, L.E., Moore, R.A., Jacobi, H.H., and Halgas, F., "A Microwave Compatable Temperature Electrode," ibid., p. 68.

Larsen, L.E., Jacobi, J. and Krey, A.K., "Preliminary Observations with an Electromagnetic Method for the Non-invasive Analysis of Cell Suspension Physiology and Induced Pathology," IEEE Trans., MTT 26(8), pp. 581-595, 1978.

Lenox, R.H., Gandhi, O.P., Meyerhoff, J.L., and Grove, H.M., "A Microwave Applicator for in vivo Rapid Inactivation of Enzymes in the Central Nervous System," IEEE Trans. Microwave Theory and Techniques, 24, pp. 58-61, 1976.

Mousavinezhad, H., Chen, K.M., and Nyquist, D.P., "Implantable EM Field Probes in Finite Biological Bodies," Presented at Workshop on Electrically Small Antennas, Fort Monmouth, New Jersey, May 1976.

Oscar, K. and Hawkins, T.D., "Electromagnetic Radiation Effects on the Blood-Brain Barrier System of Rats," Presented at USNC/URSI Annual Meeting, Boulder, Co., Abstracts, p. 222, October 1975.

Oscar, K.J. and Hawkins, T.D., "Microwave Alteration of the Blood-Brain Barrier System of Rats," Brain Research, 126(2), pp. 281-293, 1977.

Schrot, J., and Hawkins, T.D., "Interaction of Microwave Frequencyand Polarization with Animal Size," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves, Vol. II, HEW Publication (FDA)77-8011, pp. 184-192, December 1976.

Wangemann, R.T. and Cleary, S.F., "The in vivo Effects of 2.45 GHz Microwave Radiation on Rabbit Serum Components and Sleeping Times," Radiation and Environmental Biophysics, 13, pp. 89-103, 1976.

DOD/U. S. NAVY

Albert, E., "Ultrastructural Pathology Associated with Microwave Induced Alterations of Blood-Brain Barrier Permeability," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 58, August 1978.

Albert, E., "Neuropathological Observations on Microwave Irradiated Hamsters," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 59, August 1978.

Albert, E.N., Grau, L., and Kerns, J., "Microwave Effects on the Blood-Brain Barrier of Hamsters,"Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 18, October 1976.

Baum, S.J., Ekstrom, M.E., Skidmore, W.D., Wyant, D.E., and Atkinson, J.L., "Biological Measurements in Rodents Exposed Continuously Throughout Their Adult Life to Pulsed Electromagnetic Radiation," Health Physics, 30, pp 161-166, 1976.

Bawin, S.M. and Adey, W.R., "Sensitivity of Calcium Binding in Cerebral Tissue to Weak Electromagnetic Fields in Nature," Proceedings of National Academy of Science USA, 73, pp. 1999-2003, 1976. (also supported by BRH)

Brainard, G., et al., "Rat Hypothalamic Temperatures During Whole Body Exposure to 2450 MHz and 2800 MHz Microwaves at Low Power Densities," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 4, June 1978.

Carpenter, R., "Histopathological Changes During Development of Microwave Cataracts," BRH Conference, February 1977, Published in Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves, HEW Publication (FDA) 77-8026, p. 351, July 1977. (also supported by BRH)

Carpenter, R., Hagan, G. and Donovan, G., "Are Microwave Cataracts Thermally Caused?", ibid., 352-379. (also BRH)

Catravas, G.N., Takenaga, J., Katz, J., and Abbott, J., "Effects of Low Power Density Microwaves on Macromolecular Constituents of the Brain of Rats," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 18, October 1976.

Catravas, G.N., Katz, J.B., Takenaga, J. and Abbott, J.R., "Biochemical Changes in the Brain of Rats Exposed to Microwaves of Low Power Density," J. of Microwave Power 11(12), pp. 147-148, 1976.

Catravas, G.N., Styrofoam Cages for Rats Used in Microwave Research: Coating With Quinine, AFRRI TN75-8, December 1975, and Health Physics 31, pp. 68-69, 1976.

Chen, K.C., "A System for Studying Effects of Microwaves on Cells in Culture," J. of Microwave Power, 13(3), pp. 251-256, 1978.

Chou, C.K. and Galambos, R., "Middle-Ear Structures Contribute Little to Microwave Hearing." Submitted for Publication in Radio Science (Special Supplement), 1978.

Chou, C.K. and Guy, A.W., Microwave-Induced Auditory Response-Cochlear Microphonics," Presented at USNC/URSI Annual Meeting Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol. I, HEW Publication (FDA)77-8010, pp. 89-103, December 1976.

Chou, C.K., Galambos, R., Guy, A., and Lovely, R., "Cochlear Microphonics Generated by Microwave Pulses," J. Microwave Power, 10(4), pp. 361-367, December 1975.

Chou, C.K.and Guy, A.W., "Threshold Energy for Hearing Microwave Pulses of 10-500 Microsecond Duration," (submitted to Radio Science (Special Supplement), 1978).

Chou, C.K., Guy, A.W., and Galambos, R., "Characteristics of Microwave Induced Cochlear Microphonics," Radio Science (Special Issue), 12(6S), pp. 221-228, Nov.-Dec. 1977.

Cleary, S.F., Investigation of the Biological Effects of Pulsed Electrical Fields, Annual Report Number 3, Office of Naval Research, Arlington, Virginia, December 1977.

Cope, F.W., "Superconductivity - A Possible Mechanism for Non-Thermal Biological Effects of Microwaves," J. of Microwave Power, 11(3), pp. 267-270, September 1976.

deLorge, J.O., Behavior and Temperature in Rhesus Monkeys Exposed to Low Level Microwave Irradiation, Naval Aerospace Medical Research Laboratory (NAMRL) TR No. (NAMEL) 1222, January 1976.

deLorge, J.O., Operant Behavior and Colonic Temperature of Squirrel Monkeys(Saimiri Sciureus) During Microwave Irradiation, Naval Aerospace Medical Research Laboratory Report No. NAMRL-1236, June 1977.

deLorge, J.O., and Grissett, J.D. "Behavioral Effects in Monkeys Exposed to Extremely Low Frequency Electromagnetic Fields," Int. J. Biometeor., 21(4), pp. 357-365, 1977.

deLorge, J., "Disruption of Behavior in Mammals of Three Different Sizes Exposed to Microwaves: Extrapolation to Larger Mammals," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 37, June 1978.

Durfee, W.K., et al., Extremely Low Frequency Electric and Magnetic Fields in Domestic Birds, Univ. Rhode Island, Final Report, ONR Contract N00014-68-A-0215-0009, December 1976.

Ferri, W., "Ascorbic Acid Levels in Rabbit Eyes After Single and Repeated Exposure to Microwave Radiation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 118, October 1976. (also supported by BRH)

Ferri, E.S.and Hagan, G.J., "Chronic Low-Level Exposure of Rabbits to Microwaves," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol I, HEW Publication (FDA) 77-8010, pp. 129-142, December 1976. (also supported by BRH)

Ferri, E.S., "Heat-Invoked Changes in Ascorbic Acid Levels on the Rabbit Eye," BRH Conference, February 1977, Published in Symposium on Biological Effects and Measurement of Radio Frequency/Microwaves, HEW Publication (FDA)77-8026, pp. 380-386, July 1977. (also supported by BRH)

Flanigan, W.F., Jr., Bowman, R., and Lowell, W.R., "A Non-Metallic Electrode System for Recording EEG and ECG in Electromagnetic Fields," Physiology and Behavior, 18(3), pp. 531-533, 1977.

Frey, A.H. and Gendleman, S., "Electromagnetic Energy Exposure Effects on Motor Coordination or Balance," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 19, October 1976.

Frey, A.H. and Spectro, J., "Irritability and Aggression in Mammals as Affected by Exposure to Electromagnetic Energy," ibid., p. 93.

Frey, A.H. and Cohen, E., "Holographic Evaluation of Hypothesized RF Hearing Mechanisms," ibid., p. 3.

Frey, A.H., "Behavioral Effects of Electromagnetic Energy," In Symposium on Biological Effects and Measurements of Radio Frequency/Microwaves, HEW Publication (FDA) 77-8026, pp. 11-22, 1977.

Gavalas-Medici, R., "Effects of Weak Electric Fields on Behavior and EEG of Laboratory Animals," Neurosciences Research Program Bulletin, 15(1), pp. 27-36, 1977.

Gavalas-Medici, R. and Day-Magdaleno, S., "Extremely Low Frequency, Weak Electric Fields Affect Schedule-Controlled Behavior of Monkeys," Nature, 261, pp. 256-259, May 1976.

Gavalas-Medici, R. and Sagan, P.M., "Behavioral Assays of Possible Weak ELF Effects: Comments and Recommendations," In Biological Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer. Report of the Committee on Biosphere Effects of Extremely-Low-Frequency Radiation, Division of Medical Sciences, Assembly of Life Sciences, National Research Council, National Academy of Sciences, 1977.

Goodman, E.M., et. al., "Effects of Extremely Low Frequency Electromagnetic Fields on Physarum polycephalum," Radiation Research, 66, pp. 531-540, May-June 1976.

Green, D.R., Rosenbaum, F.J., and Pickard, W.F., "Biological Effects of Microwaves on the Pupae of Tenebrio molitor," BRH Conference, February 1977, Published in Symposium on Biological Effects and Measurement of Radiofrequency/Microwaves, HEW Publication (FDA)77-8026, pp. 253-262, July 1977.

Greenberg, B. and Ash, N., "Metabolic Rates in Five Animal Populations After Prolonged Exposure to Weak Electromagnetic Fields in Nature," Radiation Research, 67, pp. 252-265, 1976.

Greenberg, B., Sanguine/Seafarer Extremely Low Frequency Fields: Effect of Long-term Exposure on Soil Anthropods in Nature, Univ. of Illinois, (NTIS Acc. No. AD A27513), 45 pp. 1976.

Grissett, J.D., "Chronic Exposure of Primates to Electric and Magnetic Fields Associated with ELF, Communications System," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 145, October 1976.

Grissett, J.D., Kupper, J.L., Kessler, M.J., Brown, R.J., Prettyman, G.D., Cook, L.L., and Griner, T.A., Exposure of Primates for One Year to Electric and Magnetic Fields Associated with ELF Communications Systems, Naval Aerospace Medical Research Laboratory Report, NAMRL-1240, November 1977.

Grissett, J.D., "Enhanced Growth in Pubescent Male Primates Chronically Exposed to ELF Fields," Presented at URSI Symposium on Biological Effects of Electomagnetic Waves, Helsinki, Finland, Abstracts, p. 52, August 1978.

Guillet, R. and Michaelson, S.M., "The Effect of Repeated Microwave Exposure on Neonatal Rats," Presented At USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 125-129, Nov.-Dec. 1977.

Hagan, F.J. and Carpenter, R.L., "Relative Cataractogenic Potencies of Two Microwave Frequencies (2.45 and 10 GHz)," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol. I, HEW Publication (FDA) 77-8010, pp. 143-155 December 1976. (also supported by BRH)

Hjersen, D.L. and Phillips, R.D., "Perception and Response to Pulsed Microwave Radiation by Rats," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 4, October 1976.

Houk, W.M., The Continuing Medical Surveillance of Personnel Exposed to Extremely Low Frequency Electromagnetic Fields, Naval Aerospace Medical Research Laboratory (NAMRL) TR No. (NAMRL) 1225, 1976.

Johnson, C.C., "The Role of Radio Science in Investigating Electromagnetic Biological Hazards," Radio Science, 12(3), pp. 349-354, 1977. (also supported by NSF & AF)

Kramer, P., et al., "Acute Microwave Irradiation and Cataract Formation in Rabbits and Monkeys," J. of Microwave Power, 13(3), pp. 239-249, 1978.

Kritikos, H.N., Foster, K.R. and Schwan, H.P., "Effect of Surface Cooling and Blood Flow on the Electromagnetic Heating of Tissue," In 1977 IEEE MTT-S International Microwave Symposium Digest, pp. 354-356, 1977.

Kritikos, H.N. and Schwan, H.P., "Formation of Hot Spot in Multilayered Sphere," IEEE Trans. Bioeng. BME 23, p. 168, 1977.

Kritikos, H.N. and Schwan, H.P., "Potential Temperature Rise Induced by Electromagnetic Fields in Brain Tissues," IEEE Trans. BME, March 1978.

Krueger, A.P. and Reed, E.J., "A Study of the Biological Effects of Certain ELF Electromagnetic Fields," International J. Biometeorology, 19(3), pp. 194-201, 1975.

Lin, J.D. and Wu, C.L., "Scattering of Microwaves by Dielectric Materials Used in Laboratory Animal Restrainers," IEEE Trans. Microwave Theory and Techniques, April 1976.

Lin, J.C., Bassen, H.J. and Wu, C.L., "Perturbation Effects of Animal Restraining Materials on Microwave Exposure," IEEE Trans. Biomed. Eng., 24, pp. 80-83, 1977.

Lin, J.C., Nelson, J.C., Ekstrom, M., and Nam, S.H., "Effects of Radio Waves on Growth, Hematology and Histology of Mice," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 137, Oct.-Nov. 1977.

Lovely, R.H., Myers, D.E., and Guy, A.W., "Irradiation of Rats by 918 MHz Microwaves at 2.5 mW/cm^2: Delineating the Dose-Response Relationship," Radio Science (Special Issue), 12(6S), pp. 139-146, Nov.-Dec. 1977.

Lovely, R.H., Myers, D.E., Johnson, R.B., and Guy, A.W., "Behavioral and Physiological Effects on Rats of Chronic Square-wave Modulated Microwave Radiation," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 120, Oct.-Nov. 1977.

Lu, S.T., Pettit, S., and Michaelson, S.M., "Effect of Repeated Microwave Exposure and Environmental Temperature on Body Growth of Neonatal Rats," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 69, Oct.-Nov. 1977.

Lu, S.T., Lebda, N., Michaelson, S.M., et al., "Thermal and Endocrinological Effects of Protracted Irradiation of Rats by 2450 MHz Microwaves," Radio Science (Special Issue), 12(6S), pp. 147-156, 1977.

Mattsson, J.C. and Olivia, S.A., "Effect of Electromagnetic Pulse on Avoidance Behavior and Electroencephalogram of a Rhesus Monkey," Aviation Space and Environmental Medicine, 27(6), pp. 644-648, 1976.

McArther, G.R., Lords, J.L. and Durney, C.H., "Microwave Radiation Alters Peristaltic Activity of Isolated Segments of Rat Gut," Radio Science (Special Issue), 12(6S), pp. 157-161, Nov.-Dec. 1977.

Michaelson, S.M., Guillet, R., and Heggeness, F.W., "The Influence of Microwave Exposure on Functional Maturation of the Rat," Proceedings of the 17th Hanford Biology Symposium, Department of Energy Symposium Series, (in press).

Michaelson, S.M., "Radio Frequency and Microwave Energies and Electric Field," In Foundation of Space Biology, 2, pp. 409-452, NASA, 1975.

Miller, M.W. et al., "Lack of Effect of Extremely Low Frequency Electric and Magnetic Fields on Roots of Vicia faba," Environmental and Experimental Botany, 16, pp. 83-88, 1976.

Moe, K.E., Lovely, R.H., Myers, D.E., and Guy, A.W., "Physiological and Behavioral Effects of Chronic Low-Level Microwave Radiation of Rats," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol. I, HEW Publication (FDA)77-8010, pp. 248-256, December 1976.

Oliva, S.A. and Catravas, G.N., Microwave Exposure Array: Improved Field Measurements, Armed Forces Radiobiology Research Institute, AFRRI TN77-1, April 1977.

Oliva, S.A.and Catravas, G.N., "A Multiple-Animal Array for Equal Power Density Microwave Irradiation," IEEE Trans. on Microwave Theory and Techniques, MTT-25, pp. 433-436, May 1977.

Oliva, S.A. and Catravas, G.N., Microwave Exposure Facility: Multiple Animal Exposure at Equal Power Density, Armed Forces Radiobiology Research Institute Scientific Report No. AFRRI SR76-12, April 1976.

Olsen, R.G., "Insect Pupae Teratogenisis in a Standing Wave Irradiation System," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 199-207, Nov.-Dec. 1977.

Olsen, R.G., "Thermographic Analysis of Waveguide-Irradiated Insect Pupae," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 62, August 1978.

Olsen, R.G., "Constant Dose Microwave Irradiation of Insect Pupae," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 61, August 1978.

Olsen, R.G., Lords, J.L. and Durney, C.H., "Microwave-Induced Chronotopic Effects in the Isolated Rat Heart," Annals Biomed. Eng., 5(4), pp. 395-409, 1977.

Philips, R.D., Hjersen, D.L. and Sheldon, R.L., "Audiogenic Seizure Sensitivity of Mice After Repeated Exposures to 2.88 GHz Pulsed Microwaves," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 19, October 1976.

Rabinowitz, J.R. and Olcerst, R.B., "The Effect of Microwaves on Transport of Ascorbic Acid in the Rabbit Lens," Radiation Research, 62, p. 594, 1975. (also supported by BRH)

Ragan, H.A. and Phillips, R.D., "Hematologic Effects in Mice Exposed to Pulsed and CW Microwaves," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 48, August 1978.

Reed, J.R., Lords, J.L., and Durney, C.H., "Microwave Irradiation of Isolated Rat Hearts Treated with ANS Blocking Agents," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 161-165, Nov.-Dec. 1977.

Reno, V.R. and deLorge, J.O., "A Primate-Restraint Device For Use in Microwave Biological Research," IEEE Trans. on Biomed. Engineering (Communications), 24, pp. 201-203, March 1977.

Sanza, J.N. and deLorge, J.O., "Fixed Interval Behavior in Rats Exposed to Low Power Density Microwaves," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 273-277, Nov.-Dec. 1977.

Schwan, H.P. and Foster, K.R., "Microwave Dielectric Properties of Tissue: Some Comments on Rotational Mobility of Tissue Water," Biophys. J., 17, p. 193, 1977.

Sheridan, J.P., et al., "Techniques of Raman Spectroscopy Applied to Study the Effects of Microwaves Upon Synthetic and Naturally Occuring Phospholipid Membranes," Presented at NAVY (ONR)/BRH University of Md. Workshop, June 1977. Published in The Physical Basis of Electromagnetic Interactions with Biological Systems, p. 145, June 1977.

Takashima, S. and Kritikos, H.N., "Investigation of the Effects of RF and Microwave Radiations on Isolated Nerve Preparations," IEEE Trans. Biomed. Eng., (to be published).

Thomas, J.R., Yeandle, S.S., and Burch, L.S., "Modifications of Internal Discriminative Stimulus Control of Behavior by Low Levels of Pulsed Microwave Radiation," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol. I, HEW Publication (FDA)77-8010, pp. 201-214, December 1976.

Tinney, C.E., Lords, J.L., and Durney, C.H., "Rate Effects in Isolated Turtle Hearts Induced by Microwave Irradiation," IEEE Trans. on Microwave Theory and Techniques, MTT-24(1), January 1976.

Wiktor-Jedrzejczak, W., Ahmed, A., Czerski, P. Leach, W.M., and Sell, K.W., "The Effect of Microwaves (2450 MHz) on the Response of Mice to T Lymphoid Cell Dependent and T Lymphoid Cell Independent Antigens: Preliminary Results," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, October 1976. (also BRH)

Wiktor-Jedrzejczak, W., Ahmed, A., Czerski, P., Leach, W.M., and Sell, K.W., "Increase in the Frequency of Fc Receptor (FcR) Bearing Cells in the Mouse Spleen Following a Single Exposure of Mice to 2450 MHz Microwaves," Biomedicine, 27(7), pp. 250-252, 1977. (also BRH)

Wiktor-Jedrzejczak, W., Ahmed, A., Czerski, P., Leach, W.M., and Sell, K.W., "The Effect of Microwaves (2450 MHz) on the Immune System in Mice--Increase in Complement Receptor Bearing Lymphocytes (CRL)," Exp. Hematol., 4, p. 73, 1976. (also BRH)

Wiktor-Jedrzejeczak, W., Ahmed, A., Sell, K.W., Czerski, P., and Leach, W.M., "Microwaves Induce an Increase in the Frequency of Complement-Receptor Bearing Lymphoid Spleen Cells in Mice," J. Immunol., 118(4), pp. 1499-1502, 1977. (also BRH)

Wiktor-Jedrzejczak, W., Ahmed, A., Czerski, P., Leach, W.M., and Sell, K.W., "Immune Response of Mice to 2450 MHz Microwave Radiation: Overview of Immunology and Empirical Studies of Lymphoid Splenic Cells," Radio Science (Special Issue), 12(6S), pp. 209-219, 1977. (also BRH)

Williams, T.C. and Williams J.M., A Radar Investigation of the Effects of Extremely Low Frequency Electromagnetic Fields on Free Flying Migrant Birds, Final Report, ONR Contract N00014-75-00341, 1976.

DOD/U. S. AIR FORCE

Allen, S.J., et al., Comparison of Theoretical and Experimental Absorption of Radiofrequency Power, USAF Shcool of Aerospace Medicine TR-75-52, December 1975.

Allen, S.J., Hurt, W.D., Krupp, J.H., Ratliff, J.A., Durney, C.H., and Johnson, C.C., "Measurement of Radiofrequency Power Absorption in Monkeys, Monkey Phantoms, and Human Phantoms Exposed to 10- to 50-MHz Fields, USAF School of Aerospace Medicine TR-76-5, February 1976.

Allen, S.J. and Hurt, W.D., "Development and Use of Calorimeter to Measure Specific Absorption Rates in Small Laboratory Animals," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 61, Oct.-Nov. 1977.

Allen, S.J., Durney, C., and Johnson, C.C., "Implications of the Radiofrequency Dosimetry Handbook (Second Edition)," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 70, June 1978.

Barber, P.W., "Electromagnetic Power Deposition in Prolate Spheroid Models of Man and Animals at Resonance," IEEE Trans., MTT-24(6), pp. 513-521, 1977.

Barber, P.W., "Resonance Electromagnetic Absorption by Nonspherical Dielectric Objects," IEEE Trans., MTT-25(5), pp. 373-381, 1977.

Barnes, F.S., and Hu, C.L.J., "Model for Some Nonthermal Effects of Radio and Microwave Fields on Biological Membranes," IEEE Trans., MTT-25(9), pp. 341-351, 1977.

Bell, E.L., Cohoon, D.K., and Penn, J.W., MIE: A Fortran Program for Computing Power Deposition in Spherical Dielectrics Through Application of MIE Theory, USAF Shcool of Aerospace Medicine TR-77-11, August 1977.

Bell, E., and Cohoon, D., "A Model of the Thermal Response of the Head to Radiofrequency Electromagnetic Radiation," (Abs) Notices of the American Mathematical Society, 187, August 1978.

Bruckner, A.P., "Picosecond Light Scattering Measurements of Cataract Microstructure," Applied Optics (In Press).

Chamness, A.F., Scholes, H.R., Sexauer, S.W., and Frazer, J.W., "Metal Ion Content of Specific Areas of the Rat Brain After 1600-MHz Radiofrequency Irradiation," J. of Microwave Power, 11(4), pp. 33 -338, 1976.

Chou, C.K., Guy, A.W. Spackman, D., and Riley, V.T., Biological Consequences of Pulsed Versus Continuous Wave Radiofrequency Radiation, Quarterly Interim Report, Air Force Contract F33615-77-C-0623, November 1977.

Chou, C.K., Guy, A.W., Sparks, T., Lovely, R.H., and Riley, V.T., RF Radiation Effects on Cells, Quarterly Interim Report, Air Force Contract F33615-77-C-0617, December 1977.

Chou, C.K., et. al., Biological Consequences of Pulsed Versus Continuous Wave Radiofrequency Radiation, Quarterly Interim Report Under Air Force Contract F33615-77-C-0623, January 1978.

Chou, C.K., et. al., Biological Consequences of Pulsed Versus Continuous Wave Radiofrequency Radiation, Quarterly Interim Report, Air Force Contract F33615-77-C-0623, April 1978.

Chou, C.K., Guy, A.W., McDougall, J., and Han, L.F., "Effects of Continuous and Pulsed Chronic Radiation on Rabbits," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 96, August 1978.

Cody, C.A., Modestino, A.J., Miller, P.J., and Klainer, S.M., The Detection of RF Damage to High Molecular Weight Biopolymers by Raman Spectroscopy, Final Comprehensive Report, Air Force Contract F41609-75-C-0043, (NTIS Acc. No. AD-A027049), January 1976.

Durney, C.H., Barber, P.W., Johnson, C.C., and Mossoudi, H., Comparision of Theoretical and Experimental Absorption of Radiofrequency Power, Utah Univ. Interim Reports, April, July, and October 1976, and Final Report, December 1976.

Durney, C.H., Barber, P.W., Johnson, C.C., Massoudi, H., and Iskander, M., Comparison of Theoretical and Experimental and Absorption of Radiofrequency Power, Interim Technical Reports, Air Force Contract F41609-76-C-0025, August and October 1977.

Durney, C., et. al., Comparison of Theoretical and Experimental Absorption of Radiofrequency Power, Final Report, Air Force Contract F41609-76-C-0025, February 1978.

Durney, C.H., et. al., "Long-Wavelength Analysis of Planewave Irradiation of a Prolate Spheroid Model of Man," IEEE Trans., MTT-23(2), pp. 246-254, 1975.

Durney, C.H., et. al., Radiofrequency Radiation Dosimetry Handbook (Second Edition), USAF School of Aerospace Medicine TR-78-22, May 1978.

Durney, C.H., Iskander, H., Massoudi, H., and Johnson, C., "An Empirical Formula for Calculating the SAR of Prolate Spherioidal Models of Humans and Animals Irradiated by Plane Waves," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 74, June 1978.

Emery, A.F., Short, R.E., Guy, A.W., Kraning, K.K., and Lin, J.C., "The Numerical Thermal Simulation of the Human Body When Undergoing Exercise or Nonionizing Electromagnetic Irradiation," J. of Heat Transfer, 98(2), pp. 285-290, May 1976.

Farrer, D.N., Yochmowitz, M.G., Jaeger, R.J., Allen, S.J., and Wolfle, T.L., Primate-Performance Assessment Following 3.2-GHz Exposures, USAF School of Aerospace Medicine TR-76-15, March 1976.

Frazer, J.W., et. al., Thermal Responses to High-Frequency Electromagnetic Radiation Fields, USAF School of Aerospace Medicine TR-76-20, September 1976.

Greene. F.M., Measurement of RF Power Absorption in Biological Specimens (10 to 100 MHz), National Bureau of Standards TN 687, November 1976.

Guy, A.W., "A Method for Exposing Cell Cultures to EM Fields Under Conditions of Controlled Temperature and Field Strength," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12(6S), pp. 87-96, Nov.-Dec. 1977, and Final Report, Air Force Contract F41609-75-C-021, April 1976; revised May 1976.

Guy, A.W., Webb, M.D., and McDougall, J.A., Critical Comparison of RF Field Delivery Techniques and Measurable Results in Cell Culture of Whole Animals, Final Report, AF Contract F41609-75-C-0021, June 1976. (also supported by NIOSH)

Guy, A.W., Webb, M.D., and Sorensen, C.C., "Determination of Power Absorption in Man Exposed to High-Frequency Electromagnetic Fields by Thermographic Measurements on Scale Models," IEEE Trans., BME-23(5), pp. 361-371, 1976.

Guy, A.W., RF Cell Culture Irradiation System with Controlled Temperature and Field Strength, HEW Publication (NIOSH) 77-182, June 1977.

Guy, A.W., Webb, M., Emery, A., & Chou, C.K., Measurement of Power Distribution at Resonant and Nonresonant Frequencies in Experimental Animals and Models, Final Report, Air Force Contract F41609-76-C0032, March 1978.

Guy, A.W. and Chou, C.K., "Studies on the Effects of High Energy Microwave Pulse Exposure on the Brain of the Rat," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 73, August 1978.

Hamill, D.A., Donahue, M.E., and Krupp, J.H., Comparative Whole Body Heating from Exposure to RFR or Warm Moist Air. SAM-TR (In Press)

Hamill, D.A., Experimental Results from Heating Rats by Exposure to 1.2 GHz RFR Compared to a Theoretical Model. In preparation.

Han, L.F., Chou, C.K., and Guy, A.W., "Effects of Low Level Microwave Radiation on Heart Rate," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 65, August 1978.

Hoer, C.A. and Roe, K.C., Six-Port Analysis, Progress Report, NBS/USAFSAM Memorandum of Agreement, Project Task 7757-01-43, February 1976.

Hurt, W.D., Dewar Calorimetry Technique for Determining Specific Absorbed Power of Rodents in Radiofrequency Fields, USAF School of Aerospace Medicine TR-77-39, December 1977.

Iskander, M., Durney, C., Massoudi, H., and Johnson, C., "Approximate Analysis of Plane Wave Irradiation of a Man Near a Ground Plane," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, 75, June 1978.

Iskander, M., Barber, P., Durney, C.H., and Massoudi, H., "Near Field Irrdiation on Prolate Spheroidal Models of Humans and Animals," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 14, August 1978.

Johnson, C.C., et. al., Radiofrequency Radiation Dosimetry Handbook, USAF School of Aerospace Medicine TR-76-35, September 1976.

Krupp, J.H., Radar and Migrating Birds, USAF School of Aerospace Medicine Aeromedical Review 3-76, July 1976, USAF/SAM TR-76-24, March 1976.

Krupp, J.H., Thermal Response in Macaca mulatta Exposed to 15- and 20-MHz Radiofrequency Radiation, USAF School of Aerospace Medicine TR-77-16, September 1977.

Krupp, J.H., "The Relationship of Thermal Stress to Immune System Response in Mice Exposed to 2.6-GHz Radiofrequency Radiation," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 143, Oct.-Nov. 1977.

Krupp, J.H., "Long-Term Follow-up of Macca mulatta Exposed to High Power Levels of 15-, 20-, and 26-MHz Radiofrequency Radiation," Presented at 1977 USNC/URSI International Meeting, Airlie, Va., and USAF School of Aerospace Medicine TR-78-3, January 1978.

Liburdy, R.P., "Effects of Radiofrequency Radiation on Murine Peripheral White Blood Cell Population," American Association of Immunologists Meeting, FASEB, 1977.

Liburdy, R.P., "Effects of Radiofrequency Radiation on Peripheral Vascular Permeability," Presented at USNC/URSI Annual Meeting, Amherst, Ma., Abstracts, p. 117, October 1976.

Liburdy, R.P., "Further Characterization of Differential Effects of RF Radiation on Murine Lymphocyte Subpopulations," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 139, Oct.-Nov. 1977.

Liburdy, R.P., "Differential Effects of RF Radiation on Murine Lymphocyte Subpopulations," Federation Proceedings, 36, p. 1089, 1977.

Liburdy, R.P., "Effects of Radiofrequency Radiation on Inflamation," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in Radio Science (Special Issue), 12 (6S), pp. 179-183, Nov.-Dec. 1977.

Liburdy, R.P., "Suppression of Murine Allograft Rejection by Whole-Body Microwave Hyperthermia," Federation Proceedings, 37(6), p. 1281, 1978.

Liburdy, R.P., "Alteration of in vivo Lymphocyte Migration by Whole-Body Microwave Hyperthermia," Presented at IMPI Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, Abstracts, p. 28, June 1978.

Liburdy, R.P., "Effects of Radiofrequency Radiation on the Immune System: Modulation of T- and B-Lymphocyte Levels and of Cell-Mediated Immunocompetence by Thermogenic Microwave Radiation," Radiation Research (In Press), 1978.

Lovely, R.H., Sparks, T.J., and Guy, A.W., in vitro Response of Lymphocyte Cultures Exposed to RF Radiation, Final Report, (Part 2), AF Contract F41609-75-C-0021, April 1976.

Lovely, R.H., Sparks, T.J., and Guy, A.W., Measurement of Power Distribution at Resonant and Nonresonant Frequencies in Experimental Animals and Models: Immune Responses of Animals, Interim Report, Air Force Contract F41609-76-C-0032, April 1977.

Lovely, R.H., Johnson, R., Chou, C.K., and Guy, A.W., "Induction of Retrograde Amnesia for Classically Conditioned Fear by a Single Microwave Pulse," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 78, August 1978.

Massoudi, H., Durney, C.H., and Johnson, C.C., "Long-Wavelength Analysis of Plane Wave Irradiation of an Ellipsoidal Model of Man," IEEE Trans., MTT-25(1), pp. 41-46, 1977.

Massoudi, H., Durney, C.H., and Johnson, C.C., "Long-Wavelength Electromagnetic Power Absorption in Ellipsoidal Models of Man and Animals," IEEE Trans., MTT-25(1), pp. 47-52, 1977.

Massoudi, H., et. al., "Geometrical-Optics and Exact Solutions for Internal Fields and SARs in a Cylindrical Model of Man as Irradiated by an Electromagnetic Plane Wave," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 49, Oct.-Nov. 1977.

Merritt, J.H., Hartzell, R., and Frazer, J.W., The Effect of 1.6 GHz Radiation on Neurotransmitters in Discrete Areas of the Rat Brain, USAF School of Aerospace Medicine TR-76-3, February 1976.

Merritt, J.H. and Frazer, J.W., "Microwave Fixation of Brain Tissue as a Neurochemical Technique--A Review," J. of Microwave Power, 12(2), pp. 133-139, 1977.

Merritt, J.H., Chamness, A.F., Hartzell, R.H., and Allen, S.J., "Orientation Effects on Microwave-Induced Hyperthermia and Neurochemical Correlates," J. of Microwave Power, 12(2), pp. 167-172, 1977.

Merritt, J.H., Mitchell, J.C., and Chamness, A.F., "Some Biologic Effects of Microwave Energy Directed Toward the Head," 1977 Conference on Undesirable Electromagnetic Effects, sponsored by the DOD Electromagnetic Compatibility Analysis Centar (ECAC), Annapolis, MD, April 1977.

Merritt, J.H., Chamness, A.F., and Allen, S.J., "Some Studies on Blood-Brain Barrier Permeability after Microwave Radiation," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 164, Oct.-Nov. 1977.

Mitchell, J.C., and Hurt, W.D., The Biological Significance of Radiofrequency Radiation Emission on Cardiac Pacemaker Performance, USAF School of Aerospace Medicine TR-76-4, January 1976.

Mitchell, J.C., "Radiofrequency Radiation Health Hazards Control in Perspective, AFR 161-42," Eleventh Bioenvironmental Engineering Symposium, USAF School of Aerospace Medicine, March 1976.

Mitchell, J.C., Hurt, W.D., and Steiner, T.O., "EMC Design Effectiveness in Electronic Medical Prosthetic Devices," In Fundamental and Applied Aspects of Nonionizing Radiation, (Eds.) Michaelson, et al., NY, Plenum Press, February 1976.

Mitchell, J.C., "USAF Exposure Standards for Radiofrequency/ Microwave Hazards Control," AGARD Paper B4, AGARD-CPP-202, NATO, 8 pp., September 1976.

Riley, V., and Spackman, D., "Simulation of Some RF and Microwave Biological Effects by Handling and Housing Induced Stress of Experimental Animals," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 63, August 1978.

Riley, V., et. al., "Neoplastic Cells as Sensitive Targets for Examining the Biological and Pathological Effects of RF and Microwave Irradiation," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 93, August 1978.

Scholl, D.M. and Allen, S.J., "Skilled Performance in RFR Environments," Presented at USNC/URSI International Meeting, Airlie, Va., Abstracts, p. 111, Oct.-Nov. 1977.

Spackman, D.H., Riley, V., Guy, A.W., and Chou, C.K., "Studies of RF Radiation Effects on Blood-Brain Barrier Permeability Using Fluorescein and Amino Acids," Presented at URSI Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, Abstracts, p. 75, August 1978.

Toler, J., Seals, J., and Burdette, C., Biological Consequences of Pulsed Versus Continuous Wave Radiofrequency Radiation Study, Interim Report, Air Force Contract F33615-77-C-0619, October 1977.

Toler, J., et. al., Biological Consequences of Pulsed Versus Continuous Wave Radiofrequency Radiation Study, Interim Report under Air Force Contract F33615-77-C-0619, January 1978.

U. S. Air Force, Biologic Judgments in Support of PAVE PAWS Environmental Assessment, Prepared for Congressman Gerry E. Studds, March 1978.

U. S. Air Force, Radiofrequency Radiation Survey, North Truro Air Force Station, Massachusetts, June 1978.

DOC/NATIONAL BUREAU OF STANDARDS

Baird, R.C. and Sanders, A.A., "Non-Ionizing Electromagnetic Standardizaiton," In Measurements for the Safe Use of Radiation, pp. 417-425, 1976.

Measurements for the Safe Use of Radiation, Proceedings of NBS 75th Anniv. Symposium, Gaithersburg, Md., March 1976.

Roe, K.C. and Hoer, C.A., A Microwave Vector Voltmeter System, NBS Final Report No. NBSIR 76-844, August 1976.

NATIONAL SCIENCE FOUNDATION

Barber, P., "Numerical Study of Electromagnetic Power Deposition in Biological Tissue Bodies," Presented at USNC/URSI Annual Meeting, Boulder, Co., October 1975, Published in Biological Effects of Electromagnetic Waves Vol.II, HEW Publication (FDA)77-8011, pp. 119-134, December 1976.

Chen, K.M., Livesay, D., and Guru, B.S., "Induced Current in and Scattered Field from a Finite Cylinder With Arbitrary Conductivity and Permittivity," IEEE Trans. on Antennas and Propagation, May 1976.

Chen, K.M. and Guru, B.S., "Induced Electromagnetic Field and Absorbed Power Density Inside a Human Torso," Proceedings of IEEE, 1976.

Chen, K.M., and Guru, B.S., Induced EM Field and Absorbed Power Density Inside Human Torsos, NSF Technical Report, Division of Engineering Research, Michigan State University 1976.

Chen, K.M., Interaction of EM Field With Human Body, NSF Annual Report, Division of Engineering Research, Michigan State University 1975.

Chen, K.M., "Internal EM Field and Absorbed Power Density in Human Torsos Induced by 1-500 MHz EM Waves," IEEE Trans. Microwave Theory and Techniques, 25(9), pp. 746-756, 1977.

Chen, K.C., Guru, B.S. and Nyquist, D.P., "Quantification and Measurement of Induced Fields Inside Finite Biological Bodies," In Biological Effects of Electromagnetic Waves, HEW Publication (FDA) 77-8011, pp. 19-43, 1976.

Guru, B.S. and Chen, K.M., "Experimental and Theoretical Studies on Electromagnetic Fields Induced Inside Biological Bodies," IEEE Trans., MTT-24(7), pp. 433-440, July 1976.

Guru, B.S., Chen, K.M. and Hoopingarner, R., "Microwave Effects on Human Tissues Culture Chromosomes," In 1975 USNC/URSI Meeting - Digest, p. 102, 1975.

Guru, B.S., "Experimental and Theoretical Studies on the Interaction of Electromagnetic Field with Biological Systems," Ph.D. Dissertation, Michigan State University, June 1976.

King, R.W.P. and Smith, G.S., "A Comparison of Electrically Short, Bare and Insulated Probes and Their Application in EMC," Presented at EMC International Symposium, Montreux, Switzerland, May 1975.

Kritikos, H. and Takasahima, S., "Non-Thermal Effects of Electromagnetic Fields on the Central Nervous System," Presented at USNC/URSI Annual Meeting, Boulder, Co., Abstracts, p. 223, October 1975.

Kritikos, H., Takashima, S., and Schwan, H.P., "Effects of RF Fields on Nervous Activities," Presented at IMPI Symposium, Waterloo, Canada, 1975.

Lin, J.C., "Microwave Induced Hearing: Some Preliminary Theoretical Observations," J. of Microwave Power, 11(3), pp. 295-298, September 1976.

Lin, J.C. and Lam, C.K., "Coupling of Gaussian Electromagnetic Pulse into Muscle-bone of Biological Structure," J. of Microwave Power, 11(1), pp. 67-75, March 1976.

Lin, J.C., "Microwave Auditory Effect-A Comparision of Some Possible Transduction-Mechanisms," J. of Microwave Power, 11(1), pp. 77-91, March 1976.

Lin, J.C., "Further Studies of the Microwave Auditory Effect," IEEE Trans., MTT-25(11), pp. 938-943, 1977.

Livesay, D., Guru, B.S., and Chen, K.M., "Scattering from Finite Biological and Metallic Cylinders," 1975 International Symposium on Antennas and Propagation Digest, pp. 161-164, June 1975.

Livesay, D., "Electromagnetic Fields Induced in and Scattered by Biological Systems Exposed to Nonionizing Electromagnetic Radiation," Ph.D. Dissertation, Michigan State University, June 1975.

Nyquist, D.P., Chen, K.M. and Guru, G.S., "Coupling Between Small Thin-Wire Antennas and a Biological Body," IEEE Trans. Antennas and Propagation, 25(6), pp. 863-866, 1977.

Sandler, S. and Smith, G.S., "Electromagnetic Effects in Nerve Tissue," Presented at the EMC International Symposium, Montreaux, Switzerland, May 1975.

Takashima, S., Yanlorno, R., and Pal, N.C., "Electrical Properties of Squid Axon Membranes," Biochemica et Biophysica Acta. pp. 15-27, 1975.

CENTRAL INTELLIGENCE AGENCY

The following are translations of some recent foreign research literature by the U.S. Joint Publication Research Service (JPRS). They are Available from the National Technical Information Service (NTIS), Dept. of Commerce, Washington, D.C., using the JPRS numbers.

JPRS#L/5232(11 Mar 76)-transl. of: Kholodov, YU.A., "Reactions of the Nervous System to Electromagnetic Fields," Reaktsii Nervnoy Sistemy Na Elektromagnitynne Polya (Moscow), pp. 1-207, August 1, 1975.

JPRS#L/6791(12 Jan 77)-JPRS title: Effects of Nonionizing Electromagnetic Radiation contains:

- Gabovich, R.D., and Zhukovskiy, O.M., "Effect of Radio Frequency Electromagnetic Waves on Humans," Gigiyena Truda I Professional'Nyye Zabolevaniya (Moscow), No. 10, pp. 26-29, 1976. (Russian)

- Pasynkov, Ye.I., et. al., "Therapeutic Use of a Variable Magnetic Field in Chronic Diseases of the Veins of the Lower Extremities," Voprosy Kurotologii Fizioterapii I Fizicheskoy Kultry (Moscow), No. 5, pp. 16-19, 1976. (Russian)

- Kapustin, A.A., et. al., "Cytogenetic Effect of a Variable Electromagnetic Field in the Super High Frequency Range," Tsitologiya I Genetika (Kiev), No. 5, pp. 400-402, 1976. (Russian)

- Yevtushenko, G.I., et. al., "Morphofunctional State of the Hypophysis-Gonad System With Exposure of the Organism to Different Ranges of Electromagnetic Fields," Gigiyena Truda I Professional' Nyye Zabolevaniya, (Moscow), No. 6., pp. 52-54, 1976. (Russian)

- Udintsev, N.A., et. al., "Dynamics of Lactate Dehydrogenase Activity in Skeletal Muscle and Myocardium Following Single Exposure to Alternating Current Magnetic Field," Byulleten' Eksperimental' Noy Biologii I Meditsiny (Moscow)

- Sevast'yanova, L.A., et. al., "Changes in Cellular Composition of Bone Marrow Under the Influence of of Superhigh Frequency Radiation Combined with Imifos," Biologicheskiye Nauki (Moscow), No. 7, pp. 36-39, 1976. (Russian)

- Klimovskaya, L.D. and Smirnova, N.P., "Changes in Evoked Potentials of the Brain Under the Influence of a Steady Magnetic Field," Byulleten' Eksperimental' Nov Biologii I Meditsiny (Moscow), No. 8, pp. 906-909, 1976. (Russian)

- Sorkin, E., "Effects of Electromagnetic Fields on Man," Tekhnika I Nauka, (Moscow) No. 9, pp. 30-32, 1976. (Russian)

- Antimoniy, G.D., et. al., "Changes in the Self-stimulation of Rats Under the Action of a Modulated Electromagnetic Field," Byulleten' Eksperimental' Noy Biologii I Meditsiny (Moscow), No. 10, pp. 1163-1165, 1976. (Russian)

- Artoamonova, V.G., et. al., "Ophthalmologic Changes in Persons Exposed to Microwaves," Gigiyena Truda I Professional'Nyye Zabolevaniya (Moscow), No. 10, pp. 24-26, 1976. (Russian)

JPRS#L/6983(24 March 77)-JPRS title: Effects of Nonionizing Electromagnetic Radiation contains:

- Udinesev, N.A. and Moroz, V.V., "Mechanism of Reaction to the Hypophyseo-Adrenal System to the Stress of Exposure to an Alterating Magnetic Field," Patologicheskaya Fiziologiya I Eksperimental'Naya Terapiya (Moscow), No. 6, pp. 72-74, 1976. (Russian)

- Medvedev, M.A., et al., "Effects of Static and Low-Frequency Magnetic Fields on Behavioral and Autonomic Reactions of a Human Operator," Zhurnal Vysshey Nervnoy Deyatel' Nosti, (Moscow), No. 6, pp. 1131-1136, 1976. (Russian)

- Sorkin, E., "Biological Effects of Electromagnetic Fields," Tekhnika I Nauka, (Moscow), No. 7, pp. 34-36 and pp. 30-32, 1976. (Russian)

- Sevast'yanova, L.A., et al., "Characteristics of Millimeter Wave Effects in Combination with Fluorafure of the Hemopoietic System," Biologicheskiye Nauki (Moscow), No. 12, pp. 27-31, 1976. (Russian)

- Mandrugin, A., "Use of Magnetophores In Medicine, Industry," Tekhnika I Nauka (Moscow), No. 12, pp. 7-10, 1976. (Russian)

- Medvedev, V.P., "Human Cardiovascular System Under the Influence of a Superhigh-Frequency Electromagnetic Field," Gigiyena Truda I Professional' Nyye Zabolevaniya (Moscow), No. 1, pp. 18-21, 1976. (Russian)

- Sartayev, Zh.N., "Effects of Ultrahigh Frequency Electromagnetic Fields on Contractile Activity of the Heart (Experimental Study)" Zdravookhraneniye Kazakhstana (Alma-Ata), No. 1, pp. 71-72, 1977. (Russian)

- Gurevich, Z.S., "Effect of Exposure of the Thorax to Superhigh Frequency Electromagnetic Fields on Contractile Function of the Heart," (Experimental Study) Zdravookhraneniye Kazakhstana (Alma-Ata), No. 1, p. 73, 1977. (Russian)

JPRS#L/7298(3 August 77)-JPRS title: Effects of Nonionizing Electromagnetic Radiation contains:

- Sadchikova, M.N., et al., "Arterial Pressure as Related to Exposure to Low-Intensity Microwaves and High Temperature," Gigiyena Truda I Professional'Nyye Zabolevaniya, (Moscow) No. 2, pp. 17-20, 1977. (Russian)

- Obukhan, E.I., "Reactivity of Bone Marrow Megakaryocytes in Albino Rats Exposed to Microwave Low-Intensive Electromagnetic Field," Tsitologiya I Genetika, (Kiev), No. 1, pp. 27-29, 1977. (Russian)

- Pokutsa, P.I., "Contraction Function of the Myocardium in Patients Suffering from Rheumatoid Arthritis with Microwave Therapy (According to Polycardiography Data)," Voprosy Kurortologii Fizioterapii I Lechebnoy Fizicheskoy Kul'Tury (Moscow) No. 1, pp. 65-68, 1977. (Russian)

- Shandala, M.G., et al., "Effect of Different SHF Energy Levels on the Functional State of the Body," Vrachebnoye Delo (Moscow) No. 12, pp. 113-116, 1976. (Russian)

- Kozyarin, I.P., et al., "Effects on the Organism of Brief Daily Exposure to Low-Frequency Electromagnetic Fields," Gigiyena I Sanitariya (Moscow) No. 4, pp. 18-21, 1977. (Russian)

- Kalyuzhnyy, V.F. and Mikhaylov, M.I., " The Influence of the Electrical Field of an Electrical Power Transmission Line on Communications Lines Service Personnel," Elektrosvyaz'(Moscow), No. 3, pp. 30-34, 1977. (Russian)

- Bresler, S.Ye., "Electric and Magnetic Properties of Biological Membranes," Priroda (Moscow), No. 3. pp. 68-75, 1977. (Russian)

- Prosr, V., "Electromagnetic Ecology and Compatibility," Ceskoslovenska Standardizace (Prague), No. 9, pp. 355-358, 1976. (Russian)

- Zalyubovskaya, N.P., "Biological Effect of Millimeter Radiowaves," Vrachebnoye Delo (Kiev), No. 3., pp. 116-119, 1977. (Russian)

- Murav'yeva, K., "Effect of the Earth's Magnetic Field on Some Regulatory Functions in Healthy Persons," Referativnyy Zhurnal, Meditsinskaya Geografiya (Moscow) No. 3., (Abstracts) 1976. (Russian)

- Murav'yeva, K., "Heliogeomagnetic and Meteorological Factors in the Process of Adaption," Referativnyy Zhurnal, Meditsinskaya Geografiya (Moscow) No. 3, (Abstract), 1976. (Russian)

JPRS#L/70101(7 November 77)-JPRS title: Effect of Nonionizing Electromagnetic Radiation contains:

- Adriyenko, L.G., "Experimental Study of Effects of Industrial Frequency Electromagnetic Fields on Reproductive Function," Gigiyena I Sanitariya (Moscow), No. 6, pp. 22-25, 1977. (Russian)

- Kozyaryn, I.P., et al., "Influence of an Electric Field of Commercial Frequency and Different Intensity on the Balance and Metabolism of Copper, Molybdenum and Iron in the Organisms of Laboratory Animals," Fiziologichnyy Zhurnal (Kiev), No. 3, pp. 369-372, 1977. (Ukrainian)

- Zhgun, A.A., et al., "Experience with Decimeter Wave Therapy as Part of Comprehensive Treatment for Patients with Peptic Ulcer," Voprosy Kurortologii, Fizioterapii I Lechebnoy Fizicheskoy Kul'Tury (Moscow), No. 3, pp. 38-41, 1977. (Russian)

- Aleksandrov, N.N., et al., "Applications of Local Electromagnetic Hyperthermia in Oncology," Voprosy Onkologii (Leningrad), No. 5, pp. 3-13, 1977. (Russian)

- Ismailov, E.Sh. and Zubkova, S.M., "Physico-chemical Mechanisms of the Biological Activity of Microwaves," Biologicheskiye Nauki (Moscow), No. 6, pp. 5-17, 1977. (Russian)

- Zalyubovskaya, N.P., et al., "Effects of Electromagnetic Waves of the Millimetric Range on the Energy Metabolism of Liver Mitochondria," Biologicheskiye Nauki (Moscow), No. 6, pp. 133-134, 1977. (Russian)

- Popovich, V.M. and Kozyarin, I.P., "Effects of Electromagnetic Energy of Industrial Frequency on the Human and Animal Nervous System," Vrachebnoye Delo (Kiev), No. 6, pp. 128-131, 1977. (Russian)

- Gabovich, R.D., et al., "Metabolism and Distribution of Iron, Copper, Molybdenum, Manganese, and Nickel in the Organs of a Body Exposed to Industrial and Superhigh Frequency Electromagnetic Fields," Gigiyena I Sanitariya (Moscow) No. 7, pp. 26-33, 1977. (Russian)

- Demokidova, N.K., "The Nature of Changes in Some Metabolic Indices in Response to Nonthermal Intensity Radiowaves," Gigiyena I Sanitariya, (Moscow) No. 7, pp. 34-38, 1977. (Russian)

- Prokhvatilo, Ye.V., "Reduction of Functional Capacities of the Heart Under Conditions of Effect of Electromagnetic Feild of Industrial Frequency on the Body," Vrachebnoye Delo (Kiev) No. 7, pp. 141-143, 1977. (Russian)

- Parsadanyan, A.Sh., et al., "Technique for Deriving Electrograms of the Heart of the Intact Frog During Exposure to Superhigh Frequency Field," Biologicheskiy Zhurnal Armenii (Yerevan), No. 7, pp. 50-53, 1977. (Russian)

- Pas, A.H., "Effects of UHF Magnetic Fields on Development of Arterial and Lymphatic Collaterals (an Experimental Study)," Voprosy Kurortologii, Fizioterapii I Lechebnoy Fizicheskoy Kul'Tury (Moscow), No. 4, pp. 65-68, 1977. (Russian)

JPRS#L/7467(15 November 77)-JPRS title: Effects of Non-ionizing Electromagnetic Radiation conains:

- Sudakov, K.V., "A Modulated Electromagnetic Field As a Factor of Selective Influence Upon the Mechanisms of Goal-Oriented Behavior in Animals," Zhurnal Vysshey Nervnoy Deyatel'Nosti (Moscow), No. 5, pp. 899-909, 1976. (Russian)

- Faytel'berg-Blank, V.R. and Perevalov, G.M., "Selective Action of Decimeter Waves on Central Structures of the Brain," Fiziologicheskiy Zhurnal SSSR (Leningrad), pp. 668-672, 1977. (Russian)

- Sudakov, K.V. and Antimoniy, G.D., "Hypnogenic Effects of a Modulated Electromagnetif Field," Byulleten' Eksperimental' NoyBiologii I Meditsiny (Moscow), No. 8, pp. 146-149, 1977. (Russian)

JPRS#L/7629(24 February 78)-JPRS title: Effects of Non-ionizing Electromagnetic Radiation contains:

- Gershuni, G.V., "Reactions to Unperceived Stimuli in the Presence of Functional Disturbances of Sense Organs," Sovreminnyye Tendentsii V Neyrofiziologii (Leningrad), pp. 68-81, 1977. (Russian)

- Slonim, A.D., "The Role of Isolation, Environmental Deprivation and Enrichment in Formation of Behavior," Sovremennyye Tendentsii V Neyrofiziologii (Leningrad), pp-304-316, 1977. (Russian)

DOT/FEDERAL AVIATION ADMINISTRATION

Larsen, E.B. and Shafer, J.F., Surveys of Electromagnetic Field Intensities Near Representative Higher-Power FAA Transmitting Antennas, FAA-RD-77-179, Final Report, I.A.A. DOT-FA73WAI-388 (NBS), December 1977. (AD A051717)

Markey, G.J., ARSR-3 Electromagnetic Radiation Survey, Oklahoma City, Oklahoma, FAA Academy, April 1978.

Markey, G.J., Electromagnetic Assessment of Typical FAA Long Range Radars on the Environment, August 1978.

<u>VETERANS ADMINISTRATION</u>

Bermant, R.I. and Justesen, D.R., "Pavlovian Conditioning of Microwave-Induced Hyperthermia," Presented at USNC/URSI Annual Meeting, Amherst, Ma., <u>Abstracts</u>, p. 4, October 1976. (also supported by BRH)

Chernovetz, M.E., Justesen, D.R., and Oke, A.F., "A Teratological Study of the Rat: Microwaves-and Infrared-Radiations," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in <u>Radio Science (Special Issue)</u>, <u>12</u>(6S), pp. 191-198, Nov.-Dec. 1977. (also supported by BRH)

Justesen, D.R., "Classical and Instrumental Conditioning of Licking: A Review of Methodology and Data," In <u>Drinking Behavior: Oral Stimulation, Reinforcement and Preference</u>, pp. 115-144, New York, Plenum, 1977.

Justesen, D.R., "Diathermy-Versus the Microwaves and Other Radiofrequency Radiations: A Rose by any other Name is a Cabbage," <u>Radio Science</u>, <u>12</u>(3), pp. 355-364, May-June 1977.

Levinson, D.M., Justesen, D.R., and Ward, L.B., "Hyperthermal Response to Salicylate as a Function of Species, Pigmentation and Gender," (abstracts), <u>Bulletin of the Psychonomic Society</u>, <u>6</u>, p. 443, 1975.

McAfee, R., et al., "Microwave Irradiation Behavioral and Ocular Effects on Rhesus Monkeys," <u>Biophysical J.</u>, <u>17</u>, p. 145, 1977.

Putthoff, D.L. and Justesen, D.R., "Reversible Ectothermal Response of Rodents to Steroid," (abstract), <u>Bulletin of the Psychonomic Society</u>, <u>8</u>, p. 255, 1976. (also supported by BRH)

Putthoff, D.L., et al., "Drug-Induced Ectothermia in Small Mammals: The Quest for a Biological Dosimeter," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in <u>Radio Science (Special Issue)</u> <u>12</u>(6S), pp. 73-80, Nov.-Dec. 1977. (also supported by BRH)

Smith, R. and Justesen, D.R., "Effects of a 60 Hz Magnetic Field in Activity Levels of Mice," Presented at USNC/URSI Annual Meeting, Amherst, Ma., October 1976, Published in <u>Radio Science (Special Issue)</u>, <u>12</u>(6S), pp. 279-286, Nov.-Dec. 1977. (also BRH)

FEDERAL COMMUNICATIONS COMMISSION

Wang, J.C.H., Power Density in Near Field of Small Linear Antennas, FCC Technical Memorandum No. 1, 1975.

Wang, J.C.H. and Linthicum, J.M., RF Field Intensity Measurements in Selected Broadcast Facilities, FCC Technical Memorandum No. 3, August 1976.

Wang, J.C.H. A Study of Environmental Electromagnetic Radiation Levels, FCC Technical Memorandum No. 4, December 1977.

DEPARTMENT OF ENERGY (DOE)/NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Biological Effects of High Strength Electric Fields on Small Laboratory Animals, Annual Report, April 1977 to March 1978, HCP/T1830-03, Contract No. EY-76-C-06-1830, April 1978.

Justesen, D.R., et al., Compilation and Assessment of Microwave Bioeffects: A Selective Review of the Literature on Biological Effects of Microwaves in Relation to the Satellite Power System, Batelle Pacific Northwest Lab., Doc. No. PNL-2634/UG41, 90 pp., 1978.

Newsom, B.D., Research Plan for Study of Biological and Ecological Effects of the Solar Power Satellite Transmission System, NASA Contractor Report 3044, (Contract NAS2-9655, 354 pp., August 1978.

Phillips, R.D. and Kaune, W.T., Biological Effects of Static and Low Frequency Electromagnetic Fields: An Overview of United States Literature, Battelle Pacific N.W. Lab. Report No. BNWL-2262, ERDA Contract No. EY-76-C-06-1830, April 1977.

Satellite Power System (SPS) Concept Development and Evaluation Program Plan, July 1977 - August 1980, DOE/ET-0034, Prepared by NASA and DOE, February 1978.

OTHER

Adey, W.R. and Bawin, S.M., "Brain Interactions with Weak Electric and Magnetic Fields," Based on a Neurosciences Research Program Work Session, Boston, Ma., Neururosci. Res. Prog. Bull., 15(1), 129+pp., January 1977.

Baranski, S. and Czerski, P., Biological Effects of Microwaves, Stroudsburg, Pa., Dowden, Hutchinson, & Ross Inc., 231 pp., 1976.

Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer, Report of the Committee on Biosphere Effects of Extremely-Low-Frequency Radiation, Assembly of Life Sciences, National Research Council, National Academy of Science, 1977.

Biological Effects of Nonionizing Electromagnetic Radiation, A Digest of Current Literature, A Quarterly Publication produced for NTIA/NAVY, The Franklin Institute Research Laboratories, Philadelphia, Pa, (Available through NTIS).

Bridges, J.E., Bibliography on Biological Effects of Electric Fields, IITRI, Final Report under Electric Power Research Institute Contract EPRI-381-1, 190 pp., Nov. 1975.

Cleary, S.F., "Biological Effects of Microwave and Radio Frequency Radiation," CRC Critical Reviews in Env. Control, 7(2), June 1977.

Conference on Undesirable Electromagnetic Effects, Abstracts, Sponsored by the DOD Electromagnetic Compatibility Analysis Center (ECAC), Annapolis, Md., April 5-7, 1977.

Dodge, C.H. and Glaser, Z., "Trends in Nonionizing Electromagnetic Radiation Research and Related Occupational Health Aspects," J. Microwave Power, 12(4), pp. 319-334, 1977.

Health Aspects of Radio Frequency and Microwave Radiation Exposure, Part 1, Environmental Health Criteria Document, 77-EHD-13, Information Directorate, Dept. of National Health and Welfare, Brook Claxton Bldg, Ottawa, Canada, K1A 0K9, November 1977.

Lee, H.K., Falk, H.L., and Murphy, S.D., editors, American Physiological Society Handbook of Physiology - Section 9: Reactions to Environmental Agents, Baltimore, Md.: Williams and Wilkins, 1977.

Lin, J.C., Microwave Auditory Effects and Applications, Springfield, Ill.: Charles C. Thomas Publishers, 227 pp., 1978.

McConnell, D.R., editor, "Special Issue: Microwave Ovens," J. of Microwave Power, 13(1), pp 1-52, March 1978.

Open Symposium on the Biological Effects of Electromagnetic Waves, Abstracts, held at the XIX General Assembly of the International Union of Radio Sciences, Helsinki, Finland, Aug. 1-8, 1978 (Selected papers to be published in 1979 Special Issue of Radio Science).

Oversight of Radiation Health and Safety, June 16, 17, 27, 28,29, 1977, Senate Committee on Commerce, Science and Transportation, 224 pp., Serial No. 95-49, 1978.

Overviews on Nonionizing Radiation, Report of the International Radiation Protection Association (IRPA) Study Group on Criteria, Standards, and Measurements for Protection Against Nonionizing Radiation, (HEW), April 1977.

Phillips, A.D., et al., Effects of Electric Fields on Large Animals, Interim Report under Electric Power Research Institute Contract EA-331, December 1976.

The Physical Basis of Electromagnetic Interactions With Biological Systems, Taylor, L.S. and Cheung, A.Y. (eds.), Proceedings of a Workshop sponsored by the Navy and BRH, University of Maryland, College Park, Md., June 1977, HEW Publication (FDA) No. 78-8055, 1978.

Proceedings of the 9th Annual National Conference on Radiation Control; Meeting Today's Challenges, Seattle, Wash., June 1977, Conference of Radiation Control Program Directors, Inc., cosponsored by the EPA/ORP, U. S. NRC, FDA/BRH, HEW Publication (FDA) 78-8054, April 1978.

Sheppard, A.R. and Eisenbud, M., Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency, New York: New York University Press, 1977.

A Technical Review of the Biological Effects of Nonionizing Radiation, Office of Science and Technology Policy, Executive Office of the President, 54+ pp., May 1978.

APPENDIX C

APPENDIX C

SUMMARY OF THE ERMAC WORKSHOP/SEMINAR ON EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION ON IMMUNOLOGIC SYSTEMS AND RESPONSES

On December 15, 1976, the Office of Telecommunications Policy (OTP) held a workshop/seminar at 1800 G Street, N.W., Washington, D.C., with the Electromagnetic Radiation Management Advisory Council (ERMAC). The purpose of the workshop was to exchange information and review the state of knowledge, progress, and current and planned research into immunologic effects of nonionizing electromagnetic fields--an important emerging subject of research in the multi-agency program to assess the biological consequences of radiofrequency fields. The meeting was open to the public and was attended by approximately 50 people, including: the ERMAC, invited experts in immunology and related disciplines, investigators, agency observers, and other interested parties from the scientific community and the general public. The meeting was chaired by Mr. S.E. Probst, Acting Assistant Director for Spectrum Management. Attachment 2 is an agenda for this meeting; Attachment 3 lists projects being conducted on this subject; and Attachment 4 lists those who attended the meeting.

I. INTRODUCTORY OVERVIEW AND DISCUSSION

In view of the complexity and highly specialized nature of the subject matter, the first session was devoted to an introductory overview. It was opened with an invited summary exposition on immunology by Dr. Thomas P. Stossel, Chief of the Oncology Division, Massachusetts General Hospital. Dr. Stossel reviewed the functions of the various cellular components and humoral substances of the immune system and their known or postulated origins, including T and B lymphocytes, phagocytes (neutrophils), monocytes, macrophages, antibodies, and complement proteins. He described the conditions under which these defenses are activated, the various response mechanisms and interactions involved, and the roles of antibody and complement proteins in recognizing and neutralizing antigens released in the blood stream by invaders. He stressed that subtle perturbations of the immune system or its responses are most likely to occur at the cellular level, and especially at the cell membrane. Attachment 1 summarizes his presentation.

Following Dr. Stossel, Capt. Kenneth W. Sell, Commanding Officer of the Naval Medical Research Institute, provided a number of important amplifying remarks regarding the types of lymphocytes (such as the subclasses of T and B cells) and other components of the immune system, and the detailed properties of the cell membrane surface that contribute to the activation and recognition processes. Dr. Sell also reviewed the laboratory techniques for determining whether, and to what extent, the functioning of the immune system has been perturbed by an external agent (such as an electromagnetic field), and techniques for distinguishing among the several types of lymphocytes. Specifically, he described the use of mitogens in blood cultures to enhance the detectability of an activation or perturbation of the immune system. In essence, mitogens are substances that can stimulate mitosis (cell division) and hence, the growth of lymphocytes in blood cultures, thereby permitting better quantification of differences in lymphocyte counts between exposed and control subjects. Moreover, mitogens have different degrees of selectivity for T and B lymphocytes, so that the use of several mitogens provides a means for ascertaining the nature of the immune-system response.

Prof. W. Ross Adey, of the Brain Research Institute, UCLA (and a member of ERMAC), then elaborated on the functioning and mechanisms involved in cell-membrane phenomena and the central role of the membrane in immune responses. He described the intramembrane particles (IMPs) that bridge the inner and outer lipid (fat) layers of the membrane and indicated that the mobility of the IMPs within the membrane is a possible basis for coding of specific cellular responses to external stimuli. He reviewed the relationship of calcium ions to binding centers on the membrane surface and stated that the electrical impedance characteristics of cells are measures of resistance to current-flow along the surface of the membrane rather than through it.

Dr. Adey then generalized to other cell membrane phenomena -- e.g., in the nervous system. He pointed out that changes in the electric field of the order of 10^{-8}V/cm in water surrounding marine vertebrates at extremely low frequencies ($\sim$5 Hz) can be detected and used by such animals for navigation, searching for food, attack and avoiding predators. In mammalian brain tissue, behavioral effects, neurophysiological responses and neurochemical effects have been reported for ELF fields inducing gradients within tissue of 10^{-7}V/cm. At VHF and UHF frequencies, fields modulated at ELF elicit these changes with 1-10 mV/cm gradients in brain tissue. Altered calcium binding induced by modulated VHF and UHF fields in chick brain in Dr. Adey's laboratory has recently been confirmed in experiments by Dr. Carl Blackman at EPA. Indicent field intensities in these experiments ranged from 0.1-5 mW/cm^2. Increased calcium efflux was observed only at intensities between 0.1 and 1 mW/cm^2 in these experiments indicating the existence of an "amplitude window" for this effect.

A question and discussion period concluded this session. A significant point raised concerned how information coded on the outer surface of a cell membrane (as an immune-system response) is transferred through the cell membrane to the cell nucleus (e.g., to effect mitosis). It was acknowledged that the transfer process is not yet well understood.

II. RESEARCH PRESENTATIONS

The second session consisted of presentations and discussion of representative research into possible immunologic effects of radiofrequency electromagnetic fields. Abstracts are as follows. Informal questions and discussions relative to each presentation are summarized after each abstract. The views and conclusions expressed are those of the investigators, based on the present state of knowledge and, in many cases, research still in progress. As such they do not necessarily represent their final results or conclusions, or the views of any agency or institution.

Chronic Microwave Irradiation and Its Effect on Lymphocyte Function: A Preliminary Study

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Investigators in the Soviet Union and Eastern European countries have suggested that the immune system of man may be affected by nonionizing electromagnetic radiation. Changes in the metabolic and functional integrity of lymphocytes obtained from microwave exposed animals have been reported. In light of this we have initiated studies to determine if chronic microwave exposure of rats affects lymphocyte function. We have employed a chronic regimen of exposure in an attempt to mimic the type of experiments performed by Soviet and Eastern European investigators.

The *in vitro* phytohemagglutinin (PHA)-lymphocyte stimulation test is widely used as an indicator of cell-mediated immune competence. This technique was used to assess the proliferative capacity of blood and lymph node T-lymphocytes obtained from rats chronically exposed to microwave radiation. The incorporation of ^{3}H-thymidine into newly synthesized DNA was used to follow PHA-stimulated lymphocyte blastogenesis.

Time-bred rats were exposed, in a temperature-controlled environment, to either 2450 MHz or 425 MHz microwave radiation. One group of pregnant rats was exposed at an incident power density of 5mW/cm^2 to 2450 MHz(CW) in an anechoic chamber. Another group was exposed to 425 MHz(CW) in a Crawford cell transmission line at an incident power density of approximately 10 mW/cm^2. The pregnant rats were irradiated for four hours a day seven days a week until parturition. The subsequent offspring were then irradiated, following the same regime, through 40 days of age. At 20 or 40 days of age, rats were sacrificed and lymphocytes from blood and lymph nodes were cultured. Exposure of rats to either frequency resulted in little change in the percentage of lymphocytes or in the number of leukocytes circulating in blood compared to sham irradiated controls. The PHA-response of lymph node lymphocytes from rats irradiated at 425 MHz was consistently found to be significantly increased over the control response in several experiments. Furthermore, blood lymphocytes in one experiment with animals exposed to 425 MHz microwaves gave an increased PHA-response compared to controls. Changes in the PHA-response of lymph node lymphocytes from rats irradiated at 2450 MHz was also observed.

The results of this preliminary study suggest the chronic *in vivo* exposure to microwaves affects the mitogen-stimulated lymphocyte response. The means by which these changes occur and the implications of these changes are not known at this time. Studies are presently in progress to verify these observed changes and to investigate the possible effects of microwaves on the functional integrity of the immune system.

Discussion

In response to a question whether the power densities used constituted significant thermal stresses for the animals, Dr. Smialowicz reiterated that the mean energy absorption rates corresponding to 5 mW/cm^2 at 2450 MHz and to 10 mW/cm^2 at 425 MHz were less than the average basal metabolic rate for the animals. However, he did not preclude the existence of local internal regions of relatively high energy-absorption rate ("hot spots").

Reference was made to the relatively large intercontrol group variability that was found and the use of one plate for controls and experimentals. Dr. Smialowicz then indicated that the results presented were preliminary, that the research is to be repeated, and that reevaluation of the protocols and test procedures would be an important aspect in the replication of this research.

Effects of Microwaves on Antibody Production in Rodents

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Studies are being conducted to evaluate the circulating antibody (B cell) response of animals exposed to microwaves during the period of antibody response. Six groups of four mice each were innoculated with *Streptococcus pneumonae* and irradiated for 2 hours a day with 9 GHz pulsed (1 sec pulse width, 1 kHz pulse repetition rate) microwaves at an incident average power density of 10 mW/cm^2. Antibody titers and hemotological parameters (red blood cell, white blood cell, hemoglobin, hematocrit, differential) were measured on the day following irradiation. The titers in the irradiated animals were significantly higher (p=.04) than in the sham irradiated animals, but there were no significant alterations of any of the hematological parameters. Also, three groups of fifteen mice each were irradiated with 2450 MHz CW microwaves at an incident power density of 10 mW/cm^2 in a similar manner. There was no difference in antibody titers between irradiated and sham irradiated animals.

A preliminary study of twenty-four rats exposed *in utero* from day six of gestation until twenty days postnatally (5 mW/cm^2, 4 hours daily) was conducted using 2450 MHz CW microwaves. The antibody titers in the irradiated animals were somewhat higher than in the controls (p=.10).

Discussion

A comment was made that if blood samples had been drawn at times when the rate of antibody production was rising rapidly towards its maximum, as appeared to be the case in these experiments, then the results could be affected tremendously, especially if the sampling times were spread over a 6 to 12 hour period. Dr. Liddle responded that the sampling time used in the experiments was selected to correspond approximately to the time of maximum antibody production, based on preliminary measurements, and that an effort was made to minimize sampling-time errors. A suggestion was made that one of the best ways to measure antibody production is not to determine the amount of antibody produced, but to count the number of cells producing antibody. The so-called plaque-forming assays give very precise measures of how many cells are turned on to produce antibody, which removes the additional variable of how much antibody each cell produces. Dr. Liddle stated that the results were preliminary, that perhaps there may be more variation inherent in the methodology than anticipated, and that the research should be repeated if possible.

Lymphocyte Transformation Induced by Microwave Radiation

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The primary objective of this research was to investigate whether chromosomal aberrations are caused by irradiating cell cultures from hamsters at 2450 MHz CW, as reported by Everett and coworkers for a power density of 29 mW/cm^2. The lymphocyte system was selected since it is readily amenable to such studies. Dr. Huang was also concurrently interested in any possible lymphocyte effects.

Effects of microwave radiaton have been examined in blood lymphocytes from Chinese hamsters irradiated for 15 minutes on 5 consecutive days at 2450 MHz (CW) with power densities of 5, 15, 30 and 45 mW/cm^2. Absorbed dose measurements were determined by twin-well calorimetry. Rectal temperatures were taken immediately before and after irradiation and blood lymphocyte samples were obtained from orbital hemorrage within 1 hour after irradiation. In addition, bone-marrow cultures were studied. For power densities up to 30 mW/cm^2, morphological examinations of cultures from irradiated and control animals showed no indication of radiation-induced chromosomal aberrations in either peripheral-blood lymphocytes or bone marrow cells. Also, DNA synthesis or repair, as indicated by tritiated-thymidine uptake, was not evident.

Dr. Huang then described his *in vivo* results on the effects of radiation on lymphocyte transformation, citing earlier reports from East Europe that *in vitro* radiation induced mitosis and increases in lymphocyte size. Cells were cultured for one day if unstimulated or for three days if stimulated with phytohemagglutinin (PHA) to induce mitosis. After termination, lymphocytes were processed for morphological and cytogenetic analyses with a brief colchicine treatment to arrest cells in metaphase. His data indicated that the ratio of blast cells from irradiation and control animals increased approximately linearly with power density up to 30 mW/cm^2, but was lower at 45 mW/cm^2. The effect was both transient and reversible. However, in looking for radiation-induced increases in mitotic index by use of PHA stimulation and tritiated-thymidine uptake, he found a decrease in the frequency of cell divisions in irradiated samples. Both effects were evident at 5 mW/cm^2. The measured increases of rectal temperature with power density (0.2°C for 5 to 15 mW/cm^2, 0.8°C for 30 mW/cm^2, and 1.4°C for 45 mW/cm^2) did not correlate well with these results.

Autoradiography of cells labeled with [^{3}H] -thymidine showed no evidence of radiation-related DNA repair. Cytogenetic analysis of the irradiated samples demonstrated no significant chromosomal aberrations within these power densities.

He then summarized additional preliminary experiments on mitotic index changes. Without mitogen stimulations, the cultures from the irradiated animals exhibited twofold higher tritiated-thymidine uptake than thos from the controls, whereas the uptake for PHA-stimulated cultures from irradiated animals was lower by a factor of 2.5 than for the controls. Similar work is currently being performed with mice.

Another topic presented by Dr. Huang was the effort of microwaves on the use of methotrexate as a treatment for leukemia in mice. He indicated that when L 1210 leukemia cells were injected into mice, the mice all died between 8 and 9 days later, whereas if methotrexate was added to the leukemia cells and the culture injected into the animals, their lives were prolonged about 3 days. In the microwave experiments, the leukemia-methotrexate culture was irradiated *in vitro* for 20 minutes and then injected into the animals. The results indicated that the irradiation had neutralized the life prolongation by the methotrexate, i.e., that the animals died within 8 to 9 days. Dr. Huang ascribed these results to a microwave effect on the cell membrane, and is currently studying several possible mechanisms related to whether the radiation inhibits methotrexate influx or enhances its efflux through the cell membrane, or whether the leukemia cells are altered to prevent entry of the drug.

Discussion

It was commented that the L 1210 leukemia cells are B-lymphoblasts, i.e., that the reported effects are on B-lymphocytes. In response to a question pertaining to the leukemia experiment, Dr. Huang stated that *in vivo* experiments performed subsequently yielded the same results as the *in vitro* experiments. In these *in vivo* experiments, injection of the leukemia-methotrexate culture followed by irradiation of the animals negated the 3-day life prolongation due to methotrexate injection alone.

Studies at NIEHS Relating to the Effect of Microwave Radiation on Immunity

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Fertile Japanese quail eggs were exposed to continuous wave microwave radiation at an intensity of 5 mW/cm^2 (50 Wm^2) and a frequency of 2450 MHz. The absorbed power density was determined to be 4.03 W/kg. The eggs were exposed throughout the first twelve days of the normal incubation period of 17.5 days. Non-exposed control eggs were incubated in a chamber identical to the exposure chamber. In our first series of experiments, the quail were carefully examined and sacrificed at the time of hatching. Major organ weights (heart, liver, pancreas, adrenals) and blood parameters were compared between exposed and control birds. The only significant differences found were in the hemoglobin concentration (4% increase) and in the monocyte percentage (decrease). The birds appeared normal in all other respects.

In our next series of experiments on the quail, the exposure conditions were as before but after hatching the exposed and control quail were not sacrificed but were reared in the conventional laboratory manner. Weekly body weight measurements were made to compare the growth patterns of exposed and control quail. The weights of the exposed male at the ages of four and five weeks were 12 and 7 percent, respectively, less than the control males. This difference approached statistical significane (P 0.05). At five weeks of age the quail were challenged with sheep red blood cells (SRBC) and the levels of the anti-SRBC antibodies, determined four days after antigen challenges, were of the same magnitude for both the exposed and control quail. Following this assessement of humoral immunity, the quail were sacrificed and the bursa of Fabricus and spleen were removed and a comparison was made of exposed and control birds. The weights of the bursa of Fabricus and spleen were not altered significantly by the microwave exposure.

In our most recent series of experiments (not completed), the quail were exposed as in the prvious tow series but were allowed to develop to 22 weeks of age. At this time the birds were sacrificed and organ weights compared and some histological sections taken. Although the studies are not complete, there appears to be some changes in the liver and in the bursa of Fabricus of exposed females that are not observed in control females.

In addition to the above _in vivo_ study relating to immunological function, rat lymphocytes have been exposed _in vitro_ to continuous wave 2450 MHz microwave radiation at intensities of 5, 10, and 20 mW/cm^2. The corresponding absorbed power densities were determined to be 0.7, 1.4 and 2.8 mW/gm. The lymphocytes were exposed for 4 hours, 24 hours or 44 hours eigher with or without the addition of the mitogen phytohemagglutinin. The transformation of lymphocytes into lymphoblasts was monitored by the addition of tritiated thymidine. No signficant differences (P=.05) were found in the uptake of tritiated thymidine between exposed and control cultures under the conditions tested.

Discussion

It was asked whether any decrease in hatchability was observed as a result of irradiation. Dr. Hamrick responded that no decrease was evident unless the irradiation produced a significant temperature rise in the egg. He cited the case where irradiation of 5 mW/cm^2 at an incubator temperature of 37°C increased the egg temperature to the range 39-41°C, for which very few eggs hatched. However, he also said that control eggs held at an incubator temperature of 40°C did not hatch either.

In response to a question regarding effects of the temperature gradients observed in the eggs due to irradiation, Dr. Hamrick indicated his opinion that such gradients are not significant.

Responses of Lymphocytes in-Vitro to 30 MHz Radio Frequency Exposure

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Freshly obtained primate lymphoctyes (M. mulatta) are suspended in culture media and stimulated with PHA mitogen immediately prior to a 2 minute exposure to 30 MHz RF fields. The preparations were exposed to electric field strengths of 5 V/cm with a magnetic field strength of 3.77 A/m (within the media) at a controlled temperature of approximately 36.5°C ($\pm$ 0.08 SE) in the exposure system described by Guy (Ref.) The exposed cultures are then routinely incubated in a 5% CO_2 environment for a period of time from 48 hours up to 96 hours for different cultures obtained from the primate population. Stimulated cells are blocked at metaphase with colcemid and harvested 30 minutes later. Following staining with Giesma, slides are then examined for the percentage of blast cells present and for the mititic figures to determine what if any, effects relative to standards, sham-exposed and other culture controls, the RF exposure has had. Expressing either the percentage of blast cells or the mitotic index (percentage cells blocked at metaphase) as difference scores from the appropriate control cultures, we have found no significant differences between RF exposed cells or control cultures in terms of peak mitotic figures or in terms of the distribution in time of peak mitotic index. Similarly, we have found no significant differences in the blast cell data, although these are much more variable. These findings appear to hold both within and across primates tested.

On the other hand, it has taken us nearly a year to collect a rather minimal amount of data. Re-evaluation of our culture outcomes in terms of success rate (obtaining viable cultures from which the appropriate data can be garnered) has revealed that a significantly higher number of lymphocyte cultures fail to grow following 30 MHz RF exposures, i.e., when harvested at different points in time there are simply not enough viable cells in the RF exposed group to make the appropriate determinations relative to the various control groups--which do produce viable outcomes.

More recently, we have had a higher success rate in obtaining viable lymphocyte cultures from the RF exposed groups, but preliminary evidence still suggests that the total number of cells available for evaluation is far less than the number available in the control groups, and that this is the case immediately following RF exposure when stimulated first by the PHA mitogen.

Discussion

With reference to the lower viability of irradiated cultures, a question was asked regarding the total numbers of cells noted in the irradiated and control cultures, on the basis that transformed cells tend to adhere to a culture dish much more strongly than untransformed cells. It was also asked whether the types of cells present were macrophages or other kinds of lymphoid cells. Dr. Lovely stated that he did not know.

In response to a question regarding specific dose rate, Dr. Lovely reiterated that the electric and magnetic field values cited for 30 MHz correspond to 350 W/kg (350 mW/g).

References

Guy, A.W., "A Method for Exposing Cells to EM Fields under Controlled Conditions of Temperature and Field Strength," URSI Proceedings, Radio Science, Special Issue, 12,6(S), p.87, 1977.

Some Effects of Electromagnetic Radiation on the Immune System

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Relatively high values of specific absorbed radiation (SAR) have been found in the extremities of animals exposed to frequencies below their geometric resonance frequency with electric field vectors paralleling the extremity. In other instances, the close apposition of the base of the brain to the dielectric discontinuity offered by the floor of the cranium insures higher than average SAR in this region also. Both of these circumstances predict some effect on the maturation and liberation of bone marrow elements, as well as effects on release of pituitary hormones with secondary effects on the reticuloendothelial system.

Frequencies utilized in the series of experiments reported range from 25 kHz to 26 MHz. Fields employed were sufficient to produce appreciable in-tissue fields, but insufficient to produce measurable hyperthermia except at 26 MHz.

In 25 kHz, 15 kV/m fields, it was found that tritiated thymidine incorporation into DNA of animals exposed for 1 hour a day, continuously increased over a period of approximately three months. Littermate controls showed no such increase. A survey for parasite infestation revealed no qualitative differences between the groups of animals, though both groups were extensively infested with round worms present at the time of arrival. Cells tested were removed from marrow and cultured so that most cells were marrow lymphocytes.

In another series of experiments, it was found that lymphocytes removed from field monkeys (Macaca mulatta) 3 days following a single exposure to 10, 19, or 26 MHz fields, (5880 V/m, 17% duty cycle) responded to addition of phytohemagglutinin 3-5 times as much as pair handled controls. Culture of cells extended 96 hours after removal from the animal. Lymphocytes were cultured in the presence of RBC. Hyperthermia, measured by rectal temperature and by radio-meter surface scan, was only produced at 26 MHz.

Rats exposed daily to 19 MHz fields in the near-field synthesizer with electric and magnetic vectors coincident at

8 kV/m and 50 A/m had a depressed lymphocyte count when sampled on the 4th day of exposure, and demonstrated a small increase in plasma alpha 2 globulin content. No significant changes were found in plasma cortisol, serum aldosterone, or 24 hour excretions of 17 hydroxy or 17 ketosteroids or aldosterone. Animals brought to the same rectal temperature by exposure for a similar period of time to a warm environment demonstrated an increased aldosterone excretion as expected.

Rats given a single acute exposure to 19 MHz, 3400 V/m fields responded with a decrease in circulating lymphocytes reaching minimum 7-12 hours post exposure and returning nearly to normal in 24 hours. Another group exposed to 1700 V/m showed no such response.

A large series of molecules was exposed in solution to frequencies ranging from 10 MHz to 100 MHz. Evidence of alteration in molecular structure was obtained from Raman or Fourier transform infrared spectrometry. Molecular species ranged from glycine, through several nucleotides, t-RNA, chymotrypsin to calf thymus DNA. Lower molecular weight compounds did not demonstrate alterations in structure under the carefully thermostatted conditions used. E.coli t-RNA gave evidence of hydrogen bond disruption and increased P-O stretching amplitudes. Chymotrypsin behaved as if there was a "stiffening" of the peptide chain. DNA showed little evidence of perturbation, other than equivocable evidence of change in hydration.

We believe the data indicate, though do not prove, the existence of two effects of the application of the fields utilized. One is a response similar to that expected from hyperthermia; i.e., a transient gluco-corticoid release and lymph depression with a time course similar to that shown to occur in higher frequency fields by Michaelson, and whose consequences to lymphocytes was demonstrated many years ago as part of the "alarm" reaction.

The other effect is more subtle, depending on direct interaction with a set of macromolecules either in the releasing sequences, or in the lymphocyte itself. This effect is expected to occur at low fields, and should be investigated in pulsed fields.

Discussion

The discussion following Dr. Frazer's presentation was directed toward a number of aspects of the experimental observations and the basic mechanisms postulated. He stressed that despite the large fields used, the effects observed were non-thermal up to frequencies of about 19 MHz. He stated, for example, that at 19 MHz, the dose-rate corresponding to 5000 V/m was only about 10% of the basal metabolic rate of the rat. In essence, the fields were sufficient to perturb long macromolecules because of their larger moments and could cause hydrogen bond disruption by flexing, whereas such fields would not affect water molecules to an appreciable extent. He then suggested that similar experiments on immune-system responses be performed with pulsed fields at higher frequencies, to obtain comparable field strengths in macromolecules without significant energy absorption by water.

He also indicated the need for measuring polarization responses of large molecules to high fields and the utility of techniques such as nuclear magnetic resonance (NMR) and Raman spectroscopy in elucidating effects on marcomolecular structures.

Lymphocytic Response in Mice Exposed to 2450 MHz Radiation

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Lymphocytosis of the peripheral blood has been reported in guinea pigs exposed to 2950 MHz fields (1) and in monkeys exposed to 10.5, 19.27, and 26.6 MHz fields (2). Lymphoblastoid cell effects in body organs (thymus, spleen, liver, and lymph nodes) have been reported after exposure of mice to 3.105 MHz (3), and to 2950 MHz (4). Lymphoblastoid transformation of human lymphocytes exposed _in vitro_ to 2950 MHz has also been described(5). A parameter common to most of these cited studies is that multiple repetitive exposures were employed.

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The present studies were undertaken to explore the dose-response relationships of the lymphoblastoid response in mice. Adult CF 1 male mice, weighing between 21-35 g, were exposed individually to a 2450 MHz field in an environmentally controlled waveguide apparatus, described elsewhere(6). For one-time exposures, 116 mice were used; for three-time exposures, 107 mice were used. Untreated control animals were used with each experiment to establish a normal blood picture; sham-irradiated animals were used as controls. At intervals after exposure, blood was taken from the tail vein of mice and routine hematological tests were performed, including microhematocrit and total and differential white blood cell counts on Wright's stained smears.

Results from the studies on mice exposed one time are summarized as follows:

- Exposure of mice in the range of whole-body absorbed average power(W-B AAP) of 10-35 mW/g resulted in appearance of lymphoblastoid cells, defined as cells which correspond morphologically to lymphoblastoid cells induced _in vitro_ by mitogenic substances, 6-8 days after microwave exposure.

- At 10 mW/g W-B AAP, a 5 minute microwave exposure resulted in the blastoid response in approximately 50 percent of animals, and a 20 minute exposure resulted in the response in 100 percent of animals. At 20 or 35 mW/g W-B AAP, 100 percent of animals showed the blastoid response.

- Lymphoblastoid cells may be observed as early as 2 days after microwave exposure, but the data indicated that the response was not consistent.

- Transient neutropenia and neutrophilia was observed during the first 5 days after both microwave and sham exposure of some animals, particularly after exposures to microwaves in the range of 40-95 mW/g W-B AAP.

The results from the studies of mice exposed for 30 min. on 3 occasions to 10 mW/g W-B AAP are summarized as follows:

- o Mice exposed on days 0, 3, and 6 showed lymphoblastoid responses similar to those following a single exposure, in that the first appearance of the lymphoblastoid cell was about 6 days after the last exposure.

- o Mice exposed on days 0, 2, and 5 consistently show lymphoblastoid cells by 24 hours after the last exposure and a peak of the cells about 2 to 2.5 times higher than that of animals exposed on days 0, 3, and 6.

- o Amplitude modulation (12 Hz) by a 3310A Hewlett Packard function generator failed to affect the results.

In neither of the studies were lymphoblastoid cells observed in control or sham-irradiated mice. One of the points stressed by Dr. Leach was that mitogens were not used to detect lymphoblast transformation in the peripheral blood of irradiated animals, but that the transformations seen were morphologically similar to those induced *in vitro* by mitogens.

Discussion

Dr. Leach was asked if he had any hypothesis regarding why there were such significant differences between the results for the 0,2,·5-day multiple exposures and those for the 0, 3, 6-day exposures. His reply was negative.

When asked about comparing the timing for DNA repair and glucocorticoid receptor sites in the strain of mice used, he responded that the time periods required did not exceed 24 hours, whereas the maximum lymphoblast transformations occurred well beyond 24 hours after irradiation.

A comment was made that lymphocytes do not perform their basic functions in peripheral blood, but are in transit therein, so that it would be preferable to investigate lymphoid physiology. Dr. Leach agreed.

References

1. Baranski, S., "Effect of Chronic Microwave Ireadiation on the Blood Forming System of Guinea Pigs and Rabbits," Aerospace Med., 43, p. 1196, 1971.

2. Prince, J.E., L.H. Mori, J.W. Frazer and J.C. Mitchell, "Cytologic Aspect of Radiation in the Monkey," Aerospace Med., 43, p. 759, 1972.

3. Miro, L., R. Loubiere and A. Pfister, "Effects of Microwave on the Cell Metabolism of the Reticulo-Histocytic System," In: Biological Effects and Health Hazards of Microwave Radiation. Proceeding of an International Symposium. Warsaw 15-18, Oct. 1973. Polish Medical Publishers, Warsaw, 1974, p. 89.

4. Czerski, P., "Microwave Effects on the Blood-Forming System With Particular Reference to the Lymphocyte," Annals New York Acad. Sci., 247, p. 323, 1974.

5. Stodolnik-Baranska, W., "The Effect of Microwaves on Human Lymphocyte Cultures," In: Biological Effects and Health Hazards of Microwave Radiation. Proceedings of an International Symposium, Warsaw, 15-18 Oct. 1973, Polish Medical Publishers, Warsaw, 1974, p. 189.

6. Ho, H.S., E.I. Ginns and C.L. Christman, "Environmentally Controlled Waveguide Irradiation Facility," IEEE Trans on Microwave Theory and Techniques, Vol. MTT-21, p. 837, 1973.

Effect of Low Dose Microwaves on the Immune Response of Mice

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CBA/J male adult mice were exposed to 2450 MHz microwaves (amplitude modulated 12 Hz) at a forward power of 0.6 watts for 30 minutes in an environmentally controlled waveguide facility. The absorbed dose rate was computed from measurements of forward, reflected, and transmitted power and was about 14 mW/g body weight of the animal for each exposure. The experiments were carried out with two groups of mice. One group received a single exposure for 30 minutes, the other group a total of three exposures of 30 minutes each at three day intervals. Sham exposed animals served as controls.

A single exposure to microwaves in such conditions produced a significant increase in the frequency of a subpopulation of B lymphoid cells bearing a receptor for complement (CR^+). Triple exposures not only enhanced this effect, but also significantly increased the total frequency of Ig + B cells in spleens of exposed mice. The effect was pronounced seven days after exposure and was independent of cell proliferation since the total number of spleen cells and the incorporation of 3_H- TdR(DNA precursor), 3_H-Uridine(RNA-precursor) and 3_H-Leucine (protein precursor) by spleen bone marrow, and peripheral blood lymphoid cells of the exposed mice remained unchanged. This effect could not be related to the arrest of further maturation of B cells in CR^+ stage, since seven days after a single exposure the number of cells spontaneously forming IgM antibody also increased as evaluated by the plaque assay. Moreover, the functional immune capacity of these mice was evaluated by the response of their spleen cells *in vitro* to B cell-specific mitogens: dextran sulphate lipopolysaccharide, poly I.D. and PPD-tuberculin. While there was no significant increase in their ability to respond to dextran sulphate (which stimulates neonatal B cells), there was a significant increase in their ability to respond to the other B cell mitogens used.

The proportion of T lymphoid cells (theta-positive) remained unaltered as did their functional capacity, evaluated by response of spleen cells in vitro to the T cell specific mitogens, phytohemagglutinin and concanavalin A, and to allogenic stimulator cells in mixed lymphocyte cultures.

Groups of CBA/J male adult mice were injected on day "0" with 0.5 ml of saline, or 0.2 ml of T lymphoid cell-dependent antigen (i.e., requiring the cooperation of T cells for the production of antibody)--sheep red blood cells (SRBC) or 100 μg of synthetic T cell independent antigen (i.e., B cells produce antibody without cooperation with T cells)--DNP-lysine-Ficoll. On days 1, 2, and 3 the experimental groups, consisting of four animals each, were exposed to 2450 MHz microwaves. Controls consisted of mice which were sham-exposed. Exposures were performed in an environmentally controlled waveguide facility with a forward power of 0.6 watts to the average absorbed dose rate of about 12 mW/g body weight for each exposure. On day 4, mice were sacrificed and their spleen cells were assayed for antibody by the modification of the direct plaque assay of Jerne. Cells from SRBC immunized animals were assayed using SRBC as indicator cells, while cells from DNP-lysine-Ficoll immunized mice were plaqued against SRBC coated with appropriate antigen determinant-trinitrobenzene sulfonic acid. Cells from saline injected animals were assayed against both these indicators.

While the number of IgM antibody secreting cells increased in non-immunized (saline) microwave-exposed mice as compared to non-immunized sham animals, the ability to form specific antibody against both T-dependent and T-independent antigen decreased in microwave exposed animals. The difference was, however, statistically significant only in the case of their response to the T-independent antigen.

These results suggest that while microwaves stimulate non-specific reactivity of B lymphoid cells, they simultaneously decrease the number of antigen reactive cells specific for both thymus dependent and independent antigens. These exposure conditions of microwaves in vivo seem to be weakly immunosuppressive. Further studies on the mechanism of this reaction are currently in progress.

Dr. Sell emphasized that the tests were performed on spleen cells (rather than on cells from peripheral blood samples), and that significant differences between irradiated and control animals were observed only in their B-lymphocyte responses. Such responses are evident 4 days after exposure, persist near their maximum values for about 5 days, and then subside gradually until they completely disappear about 18 days after exposure. He also pointed out that the results exhibited large scatter, and suggested that variations in animal orientation relative to the RFR, and hence in doses, are an important factor in such scatter.

Discussion

It was asked whether the effects might be responses to endotoxin release in the gut due to the RFR, rather than to RFR-caused changes in the immune system. Dr. Sell indicated that this is possible because if you inject endotoxin into an animal, you would get an increase in complement receptor cells. He was also asked whether any animal temperature increases were seen. He said that no increases were seen.

Dr. Sell was also asked whether any clinical effects were observed in the animals, or whether the immune-system responses were essentially transient. He replied that no clinical effects were evident. Dr. Lovely (one of the previous speakers) then presented some very preliminary evidence of longer persistence of an immune-system response to chronic exposure. In the experiments described, rabbits were exposed to 2450 MHz at 10 mW/cm^2 for 23 hours per day for about 6 months. Three months after the animals were exposed, spleen cultures exhibited some degree of suppression of response to pokeweed-mitogen stimulation (but not to other mitogens).

III. GENERAL DISCUSSION AND COMMENTS

Mr. Probst opened this session by calling on Dr. Stossel for his comments regarding the information presented and for his recommendations. Dr. Stossel made the following points:

The research presented indicates the existence of changes in immunologic function in response to microwaves but we do not know whether such effects are direct or indirect. He noted that much speculation was presented (including his own) regarding possible mechanisms of microwave action on lymphocytes at the molecular level, but he believes that the data presented are not evidence that microwaves do anything directly to lymphocytes. However, he did feel that the methotrexate effect (described by Dr. Huang) was most interesting. He then went on to recommend research which might help to pin down whether RFR does anything directly to lymphocytes and discussed the use of some of the methodologies described.

Dr. Stossel then commented on the importance of determining whether RFR does anything to the immunologic responses of animals and people. He remarked that it would be very difficult to get meaningful data from epidemiological studies because of the multitude of uncontrolled variables involved, coupled with how little is known about immune-system responses. Rather, he advocated investigating effects on animals that are known to develop neoplasms, or are susceptible to infection, and determining whether they become more susceptible to neoplasia or infection, using graded RFR doses and challenges of tumor or microorganisms.

Mr. Probst made a general comment regarding the tendency of the participants to use descriptive adjectives such as "low" to characterize RFR levels used in their research. As an example of how this can be ambiguous and create confusion, he stated that 10 mW/cm^2 is, in fact, an usually "high" level relative to the environments normally encountered by general segments of the population and particularly, in a radiofrequency interference context. He noted that such "high" levels are encountered only in some few occupational situations. Moreover, he noted that most of the research is being done at such levels, and virtually none at levels more comparable to those encountered by the general population.

Dr. Tyler responded to Mr. Probst's comment agreeing that most of the RFR research to date was done at basically "high" levels, and went on to say that very few studies have yet been done to find the threshold level for an effect and to determine the effects of long-term exposures. Dr. Dr. Pollack also commented that in most of the investigations, exposures were for durations of a few minutes, hours, or days at mW/cm^2 levels, whereas general populations can be exposed more or less continuously to W/cm^2 or lower levels, and that it is essential to determine the relationship between these different exposure situations. He also stressed the importance of conducting epidemiological studies of populations undergoing more or less continuous exposures. It was generally agreed that implementation of experiments involving exposures of several months duration is a good next step, possibly leading to even longer exposures at lower levels in an effort to simulate real-world conditions, and that it is important to determine the actual health significance of any established effect.

Dr. Koslov remarked that the Navy spends considerable effort in studying the effects of various stresses, such as high pressure and high temperature and asked Dr. Sell whether the Navy looks at the kinds of immunological or hematological phenomenology discussed here. Dr. Sell responded that such parameters are studied only superficially because in the Navy's investigations of diving high pressure and heat stress, the personnel show no evidence of greater susceptibility to infections, i.e., that there is no clinical problem requiring the employment of an immunologist or indicating such studies.

Mr. Sacher asked what kind of routine clinical hematology studies have been done on fairly large exposed populations, because workers in ionizing radiation environments were so examined for many years and the first finding was depression of blood counts, and evidence of no elevations, but of dividing peripheral lymphocytes, appeared early in populations where there was no presumption of radiation damage. Dr. Pollack responded that there are no such studies in the nonionizing radiation literature.

INTRODUCTORY OVERVIEW/TUTORIAL ON IMMUNOLOGY

by

Thomas P. Stossel, MD
Chief, Oncology Division
Massachusetts General Hospital

at the

ERMAC Workshop Seminar on Nonionizing Electromagnetic Radiation Effects on Immunologic Systems and Responses
December 15, 1976

[Summary]

I've been commissioned to review modern concepts of immunology in half an hour, which is impossible, so I can say I've had easier assignments. I'm taking seriously the information I was given that many people here are not biologists, so I'm going to try to keep it quite simple.

The purpose of the immune system is to act as an adversary in a game called survival. The adversaries in this game are a whole variety of pathogenic microorganisms; the defense is the immune system. Part of this defensive system are our mucosal barriers in the skin. However, what is generally considered to be the true immune system consists of (1) certain cells that are specialized for defense; these cells can be broadly classified into lymphoid cells and phagocytic cells (that is, cells that digest other cells); and (2) a series of humoral substances in the blood and body fluid, such as antibodies and complement. Other measures can also be applied to help the immune system: antisepsis, antibiotics, and vaccines, but the pathogens have their own very powerful weapon too -- the ability to adapt very quickly to any sort of innovations that we can concoct.

We can divide the pathogens into two major camps. First are the so-called "facultative intracellular parasites", which include the viruses, most fungi, protozoa, and certain bacteria such as the tubercle bacillus. The other pathogens are the pyogenic microorganisms, which include most other bacterial species.

Most active against facultative intracellular parasites is a kind of lymphocyte called the "T lymphocyte". The T lymphocyte responds to these types of pathogens by becoming activated against them. In contrast, the principal agent active against the pyogenic organisms or most bacterial species is the phagocyte, particularly the neutrophil or polymorphonuclear leukocyte which is differentiated from the lymphocyte by having a polymorphous or multilobulated nucleus. This phagocyte is the most aggressive cell against pyogenic infection. It acts immediately in case of invasion, and rapidly crawls to and digests the invading pathogens.

Helplng out this phagocyte against pyogenic infection are the substances: antibody and complement. Antibody is produced by the progeny of another kind of lymphocyte the "B lymphocyte" or B cell, which differentiates into a plasma cell that produces antibody, a type of serum protein. Finally, another set of serum proteins called complement, a complex cascade of proteins, are involved in the system, and are produced from several sources. One is the liver and another is this other cell type that I'm finally going to talk about.

Taking an intermediate position between the T cells and the phagocytes mentioned above (neutrophils) are the monocytes and macrophages (which are actually types of phagocytes). The monocyte is also a blood cell (i.e., a mononuclear leukocyte). While it is a phagocyte it is not as quick as the neutrophils. It moves slowly into an invaded area and then differentiates into a "microphage". As phagocytes, these cells are not only active against pyogenic infections, but are also active in helping out the T lymphocyte in its activity against the facultative intracellular parasites. So they are in a very important central position in the armamentarium of cells devoted to host defense.

The T cell and the B cell are both lymphocytes and are called lymphocytes because old morphologists looked at them and defined them as lymphocytes. It's a pattern diagnosis, and you cannot tell the difference between a T cell and a B cell by looking at it, although they are quite different in their functional characteristics. (There are certain special tests that one can do to differentiate these, which I won't have time to discuss today.)

It is currently believed that the lymphocytes come from hypothetical "stem" cells originating in the bone marrow; hypothetical because no one can say really for sure to have seen a stem cell. The stem cell, during early development, in the fetus and early neonatal life, is "educated" by either of two sources.

One source is the thymus. A stem cell that is educated by the thymus becomes a T cell. The basis for that knowledge comes from a classical experiment in which you remove the thymus from a neonatal mouse, and it will not have T cells. This classic experiment is the basis for the idea that the thymus is absolutely essential for the education of lymphocytes and their differentiation into T cells, which then go on to be active against facultative intracellular parasites, in what is often called cell-mediated immunity. (By the way, an activated T cell is called a "blast").

The stem cell can also be educated by another source or another system, and in the chicken it is a structure called the bursa of Fabricius. If you take the bursa of Fabricius out of a chicken, the chicken will not make B cells, and will therefore not be able to make antibodies. In man we don't know what the equivalent of the bursa of Fabricius is. We reason that there must be a bursa equivalent and believe it is the bone marrow.

This is the sort of classic background from which the knowledge of T cells and B cells comes, and it would be very nice for students if it were that simple. Man's response is more complicated. For certain types of antigens or pathogens, we cannot respond and make antibodies just with B cells. The B cell has to interact with the T cell, so we end up with thymus-dependent and thymus-independent antibody responses. That is, we have certain responses for which only B cells are required and some for which both B and T cells are required. To make this even more complicated, we don't only have one kind of T cell and we probably don't even have one kind of B cell either. The T-cell system is now further subdivided into various subclassifications.

How does the T cell inactivate viruses and protozoa and fungi? We really don't know. Macrophages are involved, but it appears now that a certain subclass of T cells called "killer cells" or "K cells" are the ones that really do the work. We also have another class of T cells called "suppressor cells", which act as checks and balances to the killer T cells. The picture becomes more and more complicated, and rather than try to get into that, let me pass on back to the other side of the coin and talk about the defense against pyogenic infection, against the bacteria, and the role of the B cells.

If we are going to use phagocytes to defend against pyogenic infection, we've got to find the invaders, and that's done by what we call "chemotaxis." Invasion or infection elicits a response from the body, and certain fluid humors are released, which then attract polymorphonuclear leukocytes or neutrophils and monocytes to this invaded area. Now there are innumerable chemotactic factors (the term simply means to be attracted to a chemical source), so that this response is probably a relatively nonspecific one.

Having found their way to the invaded area by means of chemotaxis, the phagocytes have to differentiate between the invading particles and host cells, the red cells and the platelets. The chemical basis of that differentiation is not well understood, but what is clear is that the invading pathogens have surfaces that resist differentiation. The body's response is to coat pathogens with the serum or humors, so as to render them attractive to phagocytic cells. This serum phenomenon was discovered around the turn of the century, and since people were classical scholars in those days, they termed this process "opsonization", which comes from the Greek word meaning "to prepare for dining". The substances or opsonins that coat bacteria and other particles and render them interesting to the phagocytes are, very simply, antibody and complement. Coating the pathogens with antibody renders them very interesting and recognizable, and complement can amplify that response. In certain circumstances, complement can act independently of its opsonizing potential. It can act by directly lysing or breaking the pathogen, by boring a hole in the pathogen. This is probably of relatively minor importance in most aspects of host defense against infection.

In summary, we are dealing with the fact that the defending organism must respond initially to a pathogen, even if it has not seen that pathogen before. This is what we would call non-specific recognition. As it proceeds to process that initial encounter with the invading microorganism, it retains a memory. Memory is encased in both the T cells and B cells that have proliferated as a result of the initial encounter, and continue to circulate in the system. In response to a second encounter with the invading microorganism, they are able to produce specific recognition. Complement coating a microorganism, rendering it interesting to a phagocyte, would be an example of non-specific recognition, whereas memory-activated antibody directed against the surface of the microbe would be an example of specific recognition.

If we're going to look at the subtle effects of environmental agents on the immune response, we're going to have to know what is going on at the cellular level and how these cells work. In the case of a phagocyte such as a neutrophil, the stereotypic response is movement toward an invader because of the chemotactic gradient set up by the invader and sensed at some level by the phagocyte. This sensation at the plasma membrane is transduced into the motor activity involved in extending a pseudopod toward the source.

The way that this type of cell crawls, as do lymphocytes responding to viruses or anything else, is similar to the way you and I crawl in that it uses muscle proteins. However, the organization of the proteins in the cell is quite different from that in our musculature.

The immune system is susceptible to dysfunction at various levels. At its most blatant, in man, we can have complete deficiency of the stem cells, or non-function of the stem cells. Non-functioning stem cells produce no T cells or B cells and hence there are no lymphocyte-mediated immune functions. In man, this is called severe combined immune deficiency. Babies who are born with this genetic trait are unable to mount an immune response at all, because they don't make either B or T cells.

In keeping with the thymus-excised mouse analogy, we can have pure T-cell deficiency wherein the thymus is congenitally absent, so the stem cells are there, the lymphocytes are there, but they simply never get educated by the thymus, and children who are born with congenital thymic aplasia are not able to mount a cell-mediated immune response.

Similarly, in an analogy with the bursa-excised chicken, if whatever normally educates a stem cell to become a B cell is missing, B cells are not produced. This is a disorder called agammaglobulinemia, and no antibody is produced. These are the most clear-cut experiments of nature, if you will, where one can clearly define the role of the various parts of the immune response in man, and they are dramatic in terms of their clinical presentation. People who are born with these deficiencies are dramatically deficient in their ability to cope with infection.

Somewhat equally dramatic clinically, but more complicated in terms of understanding the pathogenesis is, for example, Hodgkin's disease, in which T cells are there but don't work because of something going on in the pathologic process at this neoplasm, this cancer. Another example is myeloma. This is a neoplasm, a tumor of plasma cells where normal antibody is not produced, and even though the cells are basically there, the immune response is not able to be mounted. These are some clear-cut clinically impressive examples involving lymphocytes.

A clinically impressive disorder involving phagocytes is exemplified by a baby from New Hampshire afflicted since birth with chronic, severe infections characterized by collections of bacteria in the tissues, but an inability to make pus. This baby's neutrophils, those mobile phagocytes that eliminate the bacteria, were unable to crawl or eat. The reason was that there was a deficiency in one of the muscle proteins relevant to cell movement.

So we have dramatic examples of disorders of the immune system that are clinically impressive and relatively easy to pin down at the laboratory level, but what do we do when it comes to trying to track down more subtle effects? And there I think we have a problem. If we come back to our scheme of immune response, let's look at what we could do in terms of analyzing the response of an individual or a population to some environmental agent. Take, for example, ionizing radiation. It's quite clear that ionizing radiation has effects primarily on dividing cells, so we see a change in the number of cells that are produced. Ionizing radiation is responsible for decreased numbers of neutrophils and monocytes, and therefore decreased numbers of macrophages. There will be an impairment in the ability of activations such as chemotaxis and opsonization to occur, because they involve a dividing response of the cell to the pathogens or antigens. In this case it is fairly easy, by conventional techniques, to pin down an effect of an environmental insult on the immune response. Conversely, when we come to more subtle effects, to effects where functions may be deranged, we have a problem. Because, even if detected in the laboratory, or put in another way, even if change in one or more aspects of the functions of these cells can be seen, it doesn't mean that such a change would be immediately translated into a clinically significant defect.

Let me indicate one area where I think a subtle target exists for various types of insults in the entire immune response. It is thought now that the cell membrane is a bi-layer of lipid molecules. The initial response of pre-activation of a cell to an invader is a perturbation that probably involves sugar molecules stuck on the outside that to all the way through the membrane. Then, if a virus or an opsonite bacterium or chemotactic factor perturbs this sugar, some kind of a signal passes through that then activiates the cell for that whole series of poorly understood occurrences comprising the overall immune response. If cells become involved with some environmental agent that chronically perturbs this recognition mechanism, they will possibly be diverted from what they're supposed to be doing because they are involved with that pre-existent activation. Even though we have a variety of techniques, I'm not sure that we're going to be able to detect such perturbations. For example, suppose that because of such a perturbation, a neutrophil has been coated with antibody. If you test this neutrophil with all of the tests that we have at our disposal, it will check out as normal. It can crawl, eat, and seems to be perfectly fine, but a nearby macrophage proceeds to eat it because it is coated with antibody. Thus very subtle degrees of perturbation or alteration of the surfaces of cells could lead to changes in those very important cell-cell interactions that are involved in the entirety of the immune response.

However, having discussed many things that can affect the immune response, one must keep the following points in mind: (1) there is a tremendous "overkill" (e.g., adaptability, redundancy) in the immune system, so we can, and do, survive a lot of perturbations of the immune response; (2) it's all speculation; and (3) it's going to be very hard to document what perturbations are clinically significant. The point is that, in terms of what the consequences of derangement of immunity are, don't just concentrate on the host. It's not just the intactness of the immune mechanism, the cells, the humors, the mucosal barrier, that count; it depends on what is encountered, i.e., the ecology of the flora, or the ecology of the insults to which the host is exposed.

For example, an individual can have a severe immune deficit that you can measure, and if he is never exposed to pathogens, he'll never know about his deficit because he'll never be tested. Compare this with another individual who is exposed to more severe, more pathogenic organisms. He is more likely to be afflicted.

I apologize if I bored the experts and confused the novices. Thank you.

APPENDIX C
ATTACHMENT 2

OFFICE OF TELECOMMUNICATIONS POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20504

ELECTROMAGNETIC RADIATION MANAGEMENT ADVISORY COUNCIL

AGENDA FOR

WORKSHOP/SEMINAR ON NONIONIZING ELECTROMAGNETIC RADIATION EFFECTS ON IMMUNOLOGIC SYSTEMS AND RESPONSES

DECEMBER 15, 1976
8:30 A.M.

OFFICE OF TELECOMMUNICATIONS POLICY
1800 G Street, N.W., Room 730
Washington, D.C.

MORNING

I INTRODUCTORY OVERVIEW EXPOSITION AND DISCUSSION

OVERVIEW:

Dr. Thomas P. Stossel
Chief, Oncology Division
Massachusetts General Hospital
Fruit Street
Boston, Massachusetts

Discussion:

Capt. Kenneth W. Sell, MC, USN
Commanding Officer
Naval Medical Research Institute
Bethesda, Maryland

Dr. W. Ross Adey, Professor
Departments of Anatomy and Physiology
and Brain Research Institute
University of California, Los Angeles
Los Angeles, California

II. RESEARCH PRESENTATIONS

	AGENCY PROGRAM ASSOCIATION
Dr. Ralph Smialowicz Experimental Biology Division Environmental Protection Agency Research Triangle Park, NC	EPA
Dr. Charles Liddle Experimental Biology Division Environmental Protection Agency Research Triangle Park, NC	EPA
Dr. Andrew T. Huang Duke University Medical Center Durham, NC	EPA
AFTERNOON	
Dr. Philip E. Hamrick National Institute of Environmental Health Sciences P. O. Box 12233 Research Triangle Park, NC	NIH
Dr. Richard H. Lovely University of Washington Seattle, WA	AFSC/AMD
Dr. James W. Frazer USAF School of Aerospace Medicine Radiobiology Division Brooks AFB, TX	AFSC/AMD & NIOSH
Dr. William Leach* FDA/BRH Bureau of Radiological Health Division of Biological Effects Rockville, MD	- Dr. P. Czerski Institute of Mother and Child Warsaw, Poland (visiting scientist/BRH)
Capt. Kenneth W. Sell, MC,USN* Naval Medical Research Institute Bethesda, MD	- Dr. W. Wiktor-Jedrzejczak Military Institute of Post-Graduate Medical Education Warsaw, Poland (visiting scientist/NMRI)

*Presenting

III GENERAL DISCUSSION AND COMMENTS

ERMAC MEMBERS

Dr. W. Ross Adey
Professor, Anatomy and Physiology
University of California, Los Angeles
Director Space Biological Laboratory,
Brain Research Institute

Professor Merril Eisenbud
Professor and Director, Laboratory for
Environmental Studies
Institute for Environmental Medicine
New York University Medical Center

Harold Gauper, Jr.
Electrical Engineer, Electromagnetic
Compatibility
Corporate Research and Development
General Electric Company
Schenectady, New York

Dr. William T. Ham, Jr.
Professor and Chairman
Department of Biophysics
Medical College of Virginia
Virginia Commonwealth University

H. Janet Healer
Consultant, Bioscience Programs
Office of Telecommunications Policy
Washington, D.C.

Dr. Samuel Koslov
Special Assistant for Research
Office of Assistant Secretary of Navy
The Pentagon

William W. Mumford
Engineering Consultant
Morris Plains, New Jersey

Dr. Herbert Pollack
Professor Emeritus of Clinical Medicine
George Washington University
Washington, D.C.
Medical Consultant

Dr. Charles Susskind
Professor, College of Engineering
University of California at Berkeley

Dr. George A. Sacher
Senior Biologist, Biology Division
Argonne National Laboratory
Argonne, Illinois

Dr. Arthur C. Upton
Professor, Department of Pathology
The University of New York at Stony Brook
Stony Brook, New York

INVITED SPECIALISTS

Dr. Thomas P. Stossel
Chief, Oncology Division
Massachusetts General Hosptial
Fruit Street
Boston, Massachusetts

Capt. Kenneth W. Sell, MC, USN
Commanding Officer
Naval Medical Research Institute
Bethesda, Maryland

IMMUNOLOGIC STUDIES

FY 1976 SUMMARY: 6 Agencies - 9 Relevant Projects as follows:

	Relevant Projects	Total Projects
EPA	2	17
HEW:NIEHS	2	6
BRH	1	19
NIOSH	(see Air Force)	2
DOD:AIR FORCE	3	13
NAVY	1	43
	9	

PROJECTS

PROJECT	INVESTIGATOR	TITLE/FREQUENCY
EPA(2)		
E-3	J. Elder(EPA) A. Huang(Duke Univ)	Effect of Exposure of Chinese Hamsters in the Radio and Radar Frequency Range on Chromosome Anomalies in Circulating Lymphocytes (2.45, 9 GHz)
E-15	R. Smialowicz C. Liddle C. Blackman (EPA)	Effect of MW Radiation on Immune Defense Mechanisms (2.45, 9 GHz)
HEW/NIEHS(2)		
NE-5	D. McRee(NIEHS)	Effects of 2.45 GHz on Embryonic Development and Immunological Response (2.45 GHz)
NE-6	P. Hamrick(NIEHS)	Effects of 1-10 GHz MW Radiation on Cell Systems (2.45, 5, 10 GHz)
HEW/BRH(1)		
---	P. Czerski(Poland) W. Leach(BRH)	Effect of MW on the response of Mice to T Lymphoid Cell Dependent and Independent Antigens (2.45 GHz)
HEW/NIOSH(see Air Force 9 and 18)		
NO-5	--	--

PROJECT	INVESTIGATOR	TITLE/FREQUENCY
DOD/AIR FORCE(3)		
AF-9 (jointly w/NO-5)	S. Klainer(Block Engineering)	Effects of RF on Biological Macromolecules: Mechanisms of Injury (100 MHz)
AF-18 (jointly w/No-5)	J. Frazer(AF)	Biological Effects of RF Transmitter Fields (25 kHz - 100 GHz)
AF-22	A. Guy/R. Lovely (U. of Washington)	Comparison of RF Field Delivery Techniques and Measurable Results in Culture and Whole Animals (20 - 500 MHz)
COMPLETED		
(AF-6)	J. Bollinger (Southwest Res. Inst.)	Biological Effects of VLF Band EMR (25 kHz)
(AF-8)	F. Barnes (U. of Colorado)	Effects of MW on the Growth Development and Behavior of Biological Systems (2.76GHz)
DOD/NAVY(1)		
N-81	W. Wiktor-Jedrzejczak(Poland)	MW Stimulation of B Cells in Spleens of Exposed Mice (2.45 GHz)

APPENDIX C
ATTACHMENT 4

LIST OF ATTENDEES

NAME	AGENCY/AFFILIATION
B. Appleton	Walter Reed Army Hospital
W. Athey	EPA
R. Butenhoff	ERDA
J. Bailey	BRH/FDA
D. Conover	NIOSH
J. Cole	Navy Medical Research Inst.
R. Frazier	Dept. of Commerce/OT
A. Friend	Navy Medical Research Inst.
W. Godden	USAF/AMD
R. Green	Columbia Broadcasting Sys.
Z. Glaser	NIOSH
L. Heynick	Stanford Research Inst.
E. Hunt	Walter Reed Army Research Inst.
O. Hunter	State Department
L. Hamilton	BRH/FDA
F. Henry	Navy Medical Research Inst.
H. Johnson	RCA
D. Janes	EPA
A. Kranich	Science Trends
P. Labyak	OTP
M. Little	BRH/FDA
J. Lords	Univ. of Utah
S.E. Probst	OTP
P. Polson	Stanford Research Inst.
E. Postow	Navy Medical R&D Command
T. Rozzell	Ofc Naval Research
M. Shore	BRH/FDA
J. Silva	Naval Electronic Labs.
J. Tolar	Georgia Tech.
P. Tyler	Navy Medical R&D Command
J. Wang	FCC
C. Watkins	Navy Electronics Command
R. Winston	Navy Medical Research Inst.

APPENDIX D

APPENDIX D

STATEMENT OF

THE OFFICE OF TELECOMMUNICATIONS POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
(William J. Thaler, Acting Director)

Before The

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
U. S. SENATE
JUNE 29, 1977

OVERSIGHT ON RADIATION HEALTH AND SAFETY

It is a pleasure to be here today to discuss the Government's program to assess the biological effects of nonionizing electromagnetic radiation.

OTP's involvement in electromagnetic radiation research stems from the dependency of telecommunications on the use of the radio frequency spectrum. The Director of OTP is responsible for advising the President on national telecommunications policy and on the Federal government's use of telecommunications. An important component of these responsibilities is OTP's mission to coordinate telecommunications activities and associated research and to develop programs which will promote the use of telecommunications in the public interest. Ensuring that the use of nonionizing electromagnetic (EMR) energy does not harm man or his environment is an integral part of this responsibility.

OTP oversees a valuable national resource -- the EMR spectrum -- and is also interested in seeing that the vital services the spectrum makes possible are not unnecessarily curtailed or impaired.

The Federal program, coordinated by OTP, is designed to develop a sound scientific understanding of the interaction of EMR energy with living systems. This will serve as a basis for evaluating possible biological risks of various levels and conditions of EMR and for developing appropriate controls which may be warranted to ensure safe and effective use of the spectrum. Since its formation, this Office has had a vital interest in a strong Federal research program in this area. We recommended five years ago and undertook the coordination of a cooperative multi-agency program to investigate biological effects of this energy so that there would be no unintended or unknown effects.

Our efforts involve radio frequency radiation (i.e., 0-300GHz). Like visible light and infrared, these radiowaves are nonionizing radiation. Regrettably, the use of the term" radiation" often elicits confusion between this energy and ionizing radiation such as x-rays and nuclear radiation. However, there are important differences which determine how these different radiations interact with the body and their potential for causing harm. For example, a quantum, or individual bundle, of radio frequency energy contains far less (i.e., approximately a million times less) energy than a quantum of ionizing radiation which can break molecular bonds, produce ionization and do significant biological damage.

The use of radio frequency energy has been growing rapidly. Today the radio spectrum is a widely used and integral part of modern society. It supports such telecommunications services as radio and TV broadcasting, citizen band radio, radars, air and marine navigation and safety systems, and emergency medical services. The spectrum also is used in industrial processing, medical equipment, and consumer products.

We have been working with nonionizing electromagnetic radiation since the days of Hertz in 1890. The first two decades of the 1900's saw the commercial and military uses of this radiation become a reality. The development of more powerful and diverse emitters using a wide range of frequencies during World War II stimulated further advances in this technology and its applications - thus increasing the potential for exposure to EMR. Yet, by the mid-1960's, our knowledge of the biomedical activity of nonionizing radiation was still very limited.

The major U. S. effort to increase that knowledge between 1957 and 1961 was a Tri-Service Program supported by the Department of Defense. It had been known for some time that radio frequency radiation at sufficiently high levels could cause harmful effects through energy absorption and heating. Studies were conducted in the Tri-Service Program which demonstrated some of these harmful effects at power density levels around and above 100 mW/cm^2. Effects of thermal stress on the body's heat dissipating capability were also studied. These studies contributed to the acceptance of 10 mW/cm^2, based primarily on thermal considerations, as a permissible exposure limit below which harmful effects would not be expected to occur. This level has since become the basis for present standards in the U. S. and most Western countries.

Following the Tri-Service Program, nonionizing EMR research came to a near standstill in the U. S., with the exception of a few isolated studies which included some investigation of bilogical effects at lower radiation levels. In this period, there was an increasing awareness of apparent differences between U. S. and Soviet concepts of the levels at which hazards from nonionizing radiations occurred. While our literature showed harmful effects from short exposures at high milliwatt levels, the Eastern literature claimed harmful effects in the range of several milliwats/cm^2, and in some cases, even microwatt/cm^2 levels. Also, the Eastern countries had established standards with maximum permissible exposures considerably lower than ours. They reported a wide range of observations (for example, effects on the nervous system and behavior), differences between various frequencies and waveforms (e.g., pulsed vs. continuous wave), and effects from lengthy exposures to levels below those generally associated with measurable or significant heating. We had no comparable research or basis for comparison and evaluation. Their publications frequently did not contain full information nor has there been a clear statement of the basis for their standards. However, our interest has led us to make a principal focus of our research since the mid-1960's the question of whether or not biological effects can be caused by EMR mechanisms of interaction with the body other than heating (nonthermal). Also, regardless of the mechanism involved, we want to know whether harmful effects can occur over a wide range of EMR conditions including lower radiation levels that we had previously anticipated. The Soviet research has been used to provide some initial guidelines in determining our present research priorities.

Toward the end of the 1960's there was a convergence of attention and concern by the Government, the scientific community, professional groups and industry on the biological effects of nonionizing radiation. In 1966, for example, the ANSI standard was issued; in 1968 a major industry report pointed to the need for a "central interdisciplinary coordinating body" in the "side effects" area, and P.L. 90-602 was enacted.

In 1967 the Office of Telecommunications Management, the predecessor to OTP, held discussions with academia, industrial and government personnel and initiated efforts to provide a central focus and review in this area. As a first step, the Electromagnetic Radiation Management Advisory Council (ERMAC) was established. It was made up of individuals with expertise in the various pertinent technical disciplines -- biomedical and physical sciences and e ngineering -- to advise and make recommendations on the adequate control of undesirable "side effects" associated with the use of the spectrum. The Council conducted an extensive review of scientific knowledge, requirements, and the status of research programs and funding. They recommended guidelines, initial research priorities, a framework for studies, and increased funding for a coordinated program of investigation among responsible Federal departments and agencies.

The 1971 ERMAC report reviewed the background and rationale for this research and emphasized its importance with remarkable foresight, for it has continued to provide valuable and comprehensive guidelines for research in this area. As a basis for determining future research requirements, the ERMAC continually reviews program activities on the growing state of knowledge of health effects. The Council is now in the process of reviewing its first five year plan in light of more recent research and is preparing updated guidelines for future efforts.

The research program was structured to take advantage of existing agency responsibilities and capabilities -- although no single agency has this area as a principal mission, several departments and agencies do have relevant missions. Agency missions and operational needs were viewed as incentives to utilize their technical capabilities to conduct research. However, research was fragmented, funding was limited, and there was little, if any, interagency interaction. In order to use available resources effectively without distorting the priority of this research, ERMAC recommended that OTP, as an independent and impartial entity in the Executive Office, serve as an overview and coordinating body, with assistance from the Council. The OTP role includes emphasizing the importance of this research priority among other competing agency priorities, and attempting to ensure that the overall program goals are being adequately addressed.

At its inception, the ERMAC recommended program expenditures of approximately $10-15 million/year over a five-year period for a coordinated Government-wide research effort. This recommendation was coordinated with OMB and the heads of departments and agencies for implementation by FY 1974 or earlier to the extent practicable.

The basic program objectives continue to be:

- o To determine what biological effects radio frequency radiations cause under different conditions of exposure. For example, what are the effects of various frequencies, waveforms, energy levels, electric and magnetic field components, and exposure durations, and what is the possible influence of such biological considerations as age, sex, and health?

- o To determine the health and biological significance of any effects and to evaluate risk with reference to realistic exposure environments.

- o To establish a sound scientific basis for any remedial and/or control measures which appear needed.

- o And, of course, to ensure that U. S. safety criteria provide an adequate margin of safety.

Where do we stand today? In many ways this program represents a unique approach to interdepartmental responsibility. I would like to touch briefly on our view of some of its accomplishments, its current status, and its problems. Additional information is contained in four summary reports issued by OTP.

Let me emphasize first that the research program, to date, has identified <u>no</u> positive evidence of <u>harmful</u> effects to man at the levels of exposure normally encountered by the general population. No crisis has been found to exist; no cause for public alarm has been identified, no specific mechnisms of interaction other than heating have been demonstrated. We must, however, be <u>absolutely sure</u> that nothing has been overlooked and we recommend continued and accelerated pursuit of the necessary research.

Mr. Chairman, I am pleased to be able to tell you that there have been some real accomplishments since this Committee's hearings in 1973. We do not yet have all the answers, but we have laid a solid foundation for developing them -- in terms of the research capabilities that have been developed, the advances in the research itself, and the establishment of mechanisms for coordinating and pursuing this research.

We have succeeded in creating an Executive Office focal point and central forum for Government activities related to the biological effects of radio frequency radiation. This coordinated effort has given the additional identity to individual agency activities of being part of a larger program. It has also stimulated communication and exchange of information and interaction among the responsible government entities.

Each agency has designated representatives who meet with the ERMAC and serve as members of an interdepartmental working group. These individuals are identifiable and knowledgeable points of contact for activities in this area within their own agencies as well as with other agencies and the private sector.

Relevant research has been identified at the work unit level and organized to facilitate analysis and coordination of research efforts. This information is exchanged and available to all agencies, including those not actively engaged in research. It serves as a basis for technical reviews and for individual agency program planning and possible collaboration or mutual support of work which may be beyond the available resources of a single agency.

This, of course, is still a developing field of scientific endeavor without a large number of trained and highly skilled practioners ready to undertake research. Moreover, it involved highly complex technical problems and requires multidisciplinary skills. Since this Committee's previous hearings, there has been a considerable increase in both the level of technical sophistication and the numbers of investigators active in this research. Nonetheless, there is still a need to attract new investigators from various disciplines into this field.

There has also been an increase in exposure facilities available to conduct research over the wide range of frequencies and waveforms of interest. These facilities, including associated equipment and animal holding capabilities, are costly and required a considerable portion of the available research dollars, particularly at the outset. However, there remains a need for additional investment in facilities, particularly for studies involving long-term continuous or near continuous exposures.

In the actual conduct of the research, substantial progress has also been made. Better instrumentation and techniques have been developed for determining radiation dose and for measuring electromagnetic fields. These advances are critical to our ability to associate biological responses with exposures and to permit the extrapolation of animal experiments to man.

I am not going to elaborate here on specific research or results since I believe you have had the opportunity to hear from some of the agencies and investigators actually carrying out the work. However, I would like to point out that nonionizing EMR research is far more complex than ionizing radiation. There are difficulties in relating absorbed energy to the incident radiation or "exposure." It is even more difficult to determine the distribution of that energy within the body. The body has different properties than air. It consists of different layers and structures of complex geometries and differing electrical properties which affect the internal distribution of absorbed energy. Frequency is very important as the degree of energy penetration is a function of the frequency; also there are questions about frequency dependent effects and resonances. We must also consider the effects of continuous wave emitters, pulsed emitters, and various other modulations and frequency combinations.

In the course of this research, biological effects have been observed and reported in experiments with small laboratory animals at levels around and even below 10 mW/cm^2 (e.g., in the range of 1-20 mW/cm^2). These effects include changes in learned behavior or task performance, radiation perception, and apparent alterations in electrophysiological measurements of nervous system activity.

While reports of such biological changes evoke considerable interest because of the level of current safety standards, they do <u>not necessarily</u> imply hazards to man for many reasons. For example, differences in size, geometry and physiology between humans and laboratory animals with respect to frequency and power density, and the nature of an effect are among many factors which need to be taken into consideration in assessing or interpreting this research. Nevertheless, systematic study must continue to be vigorously carried out to determine under what conditions any biological effects occur and what their significance is to man.

In assessing the impact of this radiation on man, one must develop a realistic picture of actual exposure environments and the populations which are involved. The EPA, DOD and other agencies have been conducting programs in this regard. While their work is still in progress, and actual measured data is somewhat limited, it appears that radiation levels in most environments normally encountered by the general public are well below 10 mW/cm^2, although levels of a few $milliwatts/cm^2$ do occur in some occupational situations. In fact, the EPA has estimated that approximately 99% of the general population is not normally exposed to levels exceeding 1 $microwatt/cm^2$ (which is 10,000 times less than 10 mW/cm^2).

Further hallmarks of a maturing effort include an increase in research in areas which have evolved out of EMR research itself and more studies to replicate observations. Studies are now being conducted with longer radiation exposures, although we need more work with still longer exposure periods. Also, the U. S. and USSR have recently established an agreement to conduct collaborative research in the microwave area.

Our experience over the past few years has also made it possible for us to identify some of the problems and deficiencies in this effort. In our opinion, the major problem is that nonionizing radiation research requires greater priority.

Sufficient and stable funding is needed to attract new investigators, to develop exposure facilities and instrumentation, and to permit timely follow-up of project findings, experiments with long-term exposures, and studies of people who encounter nonionizing radiation in occupational situations. Current funding is approximately $9 million per year. HEW, EPA and DOD account for approximately 90% of these funds.

Let me illustrate some of the problems:

- o EMR research has had to compete for resources within each agency against many other priorities, some with greater agency or public interest priority.

- o Research requiring relatively large and stable funding, such as experiments with long-term chronic exposures and large epidemiological studies, is beyond the particular resources of any individual agency for nonionizing radiation research.

o Certain types of research, for example, basic research, are not being funded at a high enough level because of the mission orientations of some of the agencies.

We are all aware of the increased attention and apprenhension over the question of the safety of microwaves and other nonionizing EMR. However, it is important to maintain a proper perspective.

Undertakinng a research program in itself can imply that a hazard is either known or suspected. The development of a research effort means more investigators, scientific publications and public presentations, involvement of professional groups, and, hence, greater visibility. This visibility has led to more publicity in the popular press. However, because of the complexity of the topic, information is sometimes limited, out of context, and, as a result, difficult to interpret.

Even with all of the available information, interpretation of research results and their significance for man is complicated. Consideration must be given to such things as: the number of observations of a phenomenon; whether a finding can be repeated in the same or another laboratory; how findings in various laboratory animals can be related to man; and, whether an observed change or effect, in fact, consitutes a hazard. One must also distinguish preliminary findings from results of completed research and avoid drawing conclusions based on work still in progress.

The apparent differences in Eastern and Western research and safety standards also contribute to confusion. While we do not know the precise reasons, these differences may, to some extent, be due to different approaches to the development of standards and the definition of a "hazard." We hope that our recently increased contacts and cooperative research with Soviet scientists will help to resolve some of these apparent differences.

Finally, the use of the term "low-level" has created misunderstandings. It has often been indiscriminately applied to levels from fractions of a microwatt/cm^2 to 10 mW/cm^2 and above (a range of more than 10,000). Levels of a few microwatt/cm^2 are very high levels in communications or interference terms.

In summary, research to date has not demonstrated that any hazard to the general population exists. However, many questions remain unanswered, including some raised by the research we have conducted to date. Resolutions to these questions and experience gained make it possible to identify outstanding research needs and priorities. These are:

- experiments to investigate effects of long-term relatively low-level exposure;

- studies of people exposed in specific occupations or special environmental circumstances;

- increased investment in basic research, including investigations of mechnisms of biological interaction;

- additional development and refinement of techniques and field measurement capabilities for determining radiation dose, for measuring internal energy fields and energy distribution, and for interpreting laboratory findings to man.

Our goal should be a productive effort which continues to make effective use of the capabilities already developed by the agencies and makes it possible for them to meet the research objectives of this program.

In conclusion, I believe that a continued vigorous program of research based on long-term stable funding is necessary to develop a sound scientific basis for evaluating any possible biological effects from nonionizing radiation, particularly at a time when use of the radio frequency spectrum is growing so rapidly. Further, I feel it is important that we assure that any regulatory or control measures be based on both demonstrated need and sound scientific judgment so that we can be sure that we have best served the total public interest.

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This report summarizes activities associated with the Federal Program to assess the biological effects of nonionizing electromagnetic (radio frequency) radiation (0-300 GHz) being coordinated by the National Telecommunications and Information Administration. It covers Calendar Years 1976, 1977, and early 1978 and includes information on research in progress during Fiscal Years 1977 and 1978. An overview of Program progress and funding is presented. Publications and presentations representative of Program activity are cited. Relevant legislation, standards (on a worldwide basis) and various non-federal activities are also included.

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