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VOLUME 1
NUMBER 4
JUNE, 1977

A DIGEST OF CURRENT LITERATURE

A Quarterly Publication
Produced for
Office of Telecommunications Policy
and
United States Navy

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by
Biomedical Group, Science Information Services Department

(10) Bruce H. Kleinstein, Ph.D., J.D., Project Manager
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BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

June, 1977 Volume 1, Number 4

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PREFACE

Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Institute Research Laboratories, Science Information Services Department, under a contract with the U.S. Navy and administered by the Office of Telecommunications Policy.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed, and disseminated on a regular basis. *Biological Effects of Nonionizing Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Nonionizing Electromagnetic Radiation is published quarterly. The issues of Volume I, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.

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ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)
Å - angstrom(s)
BRH - Bureau of Radiological Health
C - centigrade
cm - centimeter(s)
cps - cycles per second
dB - decibel(s)
EPA - Environmental Protection Agency
FDA - Food and Drug Administration
g - gram(s)
G - Gauss
GHz - gigahertz
HEW - Health, Education, and Welfare
hr - hour
Hz - hertz
IEEE - Institute of Electronic and Electrical Engineers
IMPI - International Microwave Power Institute
IU - international unit(s)
J - joule(s)
k - kilo--
l - liter(s)
m - meter(s)
m - milli--
M - mega--
mho - unit of measurement of conductivity
min - minute(s)
mo - month(s)
n - nano--
NBS - National Bureau of Standards
NIH - National Institutes of Health
NSF - National Science Foundation
NIOSH - National Institute for Occupational Safety and Health
NTIS - National Technical Information Service
Oe - oersted(s)
OSHA - Occupational Safety and Health Administration
OTP - Office of Telecommunications Policy
PHS - Public Health Service
rad - radiation absorbed dose
R - roentgen(s)
rpm - revolutions per minute
sec - second(s)
USAFSAM - U.S. Air Force School of Aerospace Medicine
USDA - U.S. Department of Agriculture
UV - ultraviolet
V - volt(s)
VA - Veterans Administration
W - watt(s)
Wb - Weber(s)
WHO - World Health Organization
wk - week(s)
wt - weight
yr - year(s)

μ - micro--

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NEWS ITEMS

BRH DEVELOPS SAFETY STANDARDS FOR DIATHERMY EQUIPMENT

A study was conducted by the Bureau of Radiological Health's Division of Electronic Products to develop a radiation safety performance standard for microwave diathermy equipment. The study was designed to compare the performance of four commercially available applicators and several direct-contact applicators at 2.45 GHz. The direct-contact units included a square aperture horn, a circular waveguide, a teflon slab-loaded rectangular waveguide, and a circular aperture horn. Laboratory measurements were made on phantoms of simulated human fat and muscle tissue to determine the heating patterns induced by the different applicators. It was shown that direct-contact applicators provided more uniform heating than did spaced applicators. Measurements also were made of the scattered radiation from spaced applicators and the leakage radiation from the direct-contact types. Electric field measurements showed that leakage radiation from the loaded rectangular waveguide was less than 5 mW/cm^2/100 W of forward power, while scattered radiation from a commonly used loaded spaced applicator ranged as high as 30 mW/cm^2/100 W of forward power. Leakage radiation from the circular aperture horn was almost negligible, demonstrating that design techniques for minimizing unwanted radiation from direct-contact applicators are available.

BRH Bull. 11(3): 1977

BUREAU AND MICROWAVE DIATHERMY COMMUNITY AGREE ON DRAFT STANDARD

Attendees at the March 24, 1977, public meeting on the clinical implications of the Bureau of Radiological Health's draft performance standard for microwave diathermy products accepted the present draft, suggesting only one major change that would restate the requirement concerning the heating ability of the applicator. The modification, suggested by Drs. Justus F. Lehmann and Arthur W. Guy of the University of Washington, would change the requirement that diathermy equipment be capable of delivering a net forward power of at least 50 W to an applicator. They recommended that the draft include requirements for specific absorption rate (in units of watts per kilogram) in the simulated muscle tissue of a test phantom. The Bureau concurred, and the Electromagnetics Branch of the Division of Electronic Products presently is studying ways of incorporating such requirements into the draft and integrating them with the specified leakage limits. Once the standard has been redrafted to incorporate the change suggested at the meeting, it will be published in the FEDERAL REGISTER as a proposed rule. The Bureau-convened meeting was attended by representatives of the physical medicine and physical therapy professions, other government agencies interested in physical medicine and rehabilitation, and manufacturers of microwave diathermy equipment. The program included presentations by Bureau staff members and invited speakers on the biologic effects of microwave radiation, the medical uses of microwave diathermy, the performance of present diathermy equipment, prospects for improving that performance, and the requirements of the draft standard. In a presentation on applicator performance, Dr. Gideon Kantor of the Electromagnetics Branch indicated that a new applicator incorporating a flange choke has been developed under contract as part of the Bureau's effort to demonstrate the feasibility of the applicator requirements. The new applicator, he said, could meet the draft requirement of less than 5 mW/cm^2 leakage at 5 cm with a 1-cm air gap between the applicator and the phantom and a net forward power of 100 W. This allayed some prior concern regarding the feasibility of meeting the leakage requirement with an applicator that would be sufficiently simple and light in weight for satisfactory clinical use and that would not depend on physical contact with the patient to limit the leakage. Some clinicians have stated that contact between the applicator and patient may be undesirable because of surface heating problems.

BRH Bull. 11(7): 1977.

PRIMATE RESTRAINT DEVICE FOR MICROWAVE BIOLOGIC RESEARCH

Researchers at the Naval Aerospace Medical Research Laboratory, Pensacola, Florida, have developed a restraint chair for use with subhuman primates in microwave biologic studies. The Styrofoam chair is essentially non-reflective, causing minimal perturbation of the field incident on the animal. The basic design of the device is simple and adaptable to different experimental configurations.

IEEE Trans. Biomed. Eng. 24(2): 201-203; 1977.

MINIATURE ELECTROMAGNETIC PROBE DEVELOPED FOR BIOEFFECTS RESEARCH

A miniature electromagnetic probe system has been developed by Bureau of Radiological Health engineers to meet the needs of researchers investigating the biologic effects of electronic product emissions in the frequency range of 0.2 to 12 GHz. The probe's accuracy, small size, and fiber optic telemetry system makes it a valuable tool for laboratory measurements. Present probes are not appropriate because of their physical size or hard-wired readout. The system consists of a probe containing an array of three miniature orthogonal dipoles, 2.5 cm long, equipped with individual detector diodes. The probe is 30 cm long and has a cross-section of 3 x 5 mm. The detected voltage output of each dipole/diode is converted to digital form to drive light-emitting diodes whose output is transmitted via a fiber optic cable to a digital receiver. The fiber optically-linked telemetry system provides protection from radiofrequency interference and enhances accuracy by eliminating cable scatter. The Bureau has used the probe to study scattering and field distributions

near Plexiglas animal holders during microwave bioeffects experiments. Field distributions and scatter from animals and their restrainers also have been measured at different frequencies, and near fields with steep spatial gradients—a few centimeters away from microwave diathermy applicators—have been mapped. In many of these applications, the small size and maneuverability of the probe plus its nonmetallic optical data link allowed the use of simple setups and positioners while maintaining good system accuracy. The probe also has been implanted in biologic media to measure electromagnetic field distribution within simulated tissue irradiated with microwaves. Dr. A. Cheung of the University of Maryland assisted the Bureau in the implantation studies. The sensitivity of the present probe is sufficient to measure internal fields in finite biologic specimens irradiated under "nonthermal" plane-wave exposure conditions of a few milliwatts per square centimeter. In recent tests performed under a Bureau grant by the Brain Research Institute of the University of California at Los Angeles, similar probes have been used to measure the internal field strength in the brain of a living cat subjected to a plane-wave exposure of 1 mW/cm^2 at 450 MHz. The probe system was developed by the staff of the Electromagnetics Branch of the Division of Electronic Products with the contract assistance of Collins Commercial Telecommunications Division of Rockwell International, Dallas, Texas. The original fabrication of miniature electric field probes was performed under Bureau contract at the Johns Hopkins University Applied Physics Laboratory. The development effort was partially funded by the U.S. Naval Medical Research and Development Command.

BRH Bull. 11(7): 1977.

MINICOMPUTER SUPPORTS MW RESEARCH

The Bureau of Radiological Health is using minicomputers to expand its research capabilities and to allow more efficient use of time and resources in the administration of its radiation control programs. Each minicomputer is dedicated to a specific application, ranging from the study of radiation phenomena to the editing and formatting of text for publications. One minicomputer, interfaced with experimental equipment, is supporting research on the possible behavioral effects of microwave radiation. In these studies monkeys, which are being irradiated with microwaves, are required to perform repeated tasks and rewarded when they have performed correctly. The system controls the experimental setup and monitors the response of the monkeys.

BRH Bull. 11(2): 1977

TEMPERATURE MEASURING SYSTEM IS DEVELOPED

Ramal, Inc. of Sandy, Utah has developed and manufactured a temperature measuring system for use in microwave research. The LCT-1 Temperature Measuring System utilizes a liquid crystal sensor located at the tip of a fiberoptics bundle to measure temperatures in limited ranges. The probe has no metallic components and is essentially transparent to electromagnetic radiation. The complete system consists of an electronics unit housing a digital read-out and power supplies; an optics module to excite the probe; and the fiberoptic probe with liquid crystal sensor tip. The optics module, which excites the probe, is fabricated from aluminum to shield the unit from microwave radiation.

Ramal Inc. Announcement

BIOBEHAVIORAL EFFECTS OF MICROWAVES TO BE STUDIED

Drs. Om Gandhi, J. D'Andrea, and Cueller of the University of Utah, Salt Lake City, presented their proposed work on "2450 MHz Microwave Absorption in Large and Small Animals and Its Biobehavioral Effects in Birds and Reptiles" at the conference, *Ecological Impact of Microwaves from Proposed Space Power Satellites*. The conference was held at NASA-Ames Research Center, Moffett Field, California on February 23-25, 1977.

Utah Bioeng. Newsletter 4(4): 1977.

ITEMS FROM THE COMMERCE BUSINESS DAILY

☐ **ADDITIONAL RESEARCH ON THE NEUROPHYSIOLOGICAL AND BIOBEHAVIORAL EFFECTS OF CW AND PULSED MICROWAVES IN RODENTS AND OTHER LABORATORY ANIMALS.**

The Office of Naval Research, Arlinton, Virginia, has contracted with the Board of Regents of the University of Washington, Seattle, for the above study. (April 11, 1977)

☐ **A STUDY OF THE BIOLOGICAL & ECOLOGICAL EFFECTS OF ENERGY TRANSMISSION BY MICROWAVES.**

The National Aeronautics and Space Administration, Ames Research Center, Moffet Field, California, has contracted with Stanford Research Institute, Menlo Park, California, for the above study. (April 13, 1977)

MEETINGS AND CONFERENCES

INTERNATIONAL IEEE/AP SYMPOSIUM 7 USNC/URSI MEETING (RADIO SCIENCE/ANTENNAS AND PROPAGATION)

Date: June 20-24, 1977
Place: Palo Alto, California
Sponsor: Inst. of Electrical & Electronics Engineers (AP, Int.); Int. Union of Radio Science--US National Committee (USNC/URSI
Requests for Information: J. B. Damonte, 1716 Hillman Avenue, Belmont, CA 94002

URSI SYMPOSIUM ON ELECTROMAGNETIC WAVE THEORY

Date: June 20-24, 1977
Place: Palo Alto, CA: Stanford Univ.
Sponsor: URSI (US National Committee)--International Union of Radio Science
Requests for Information: Dr. F. M. Tesche, Science Applications, Inc., Box 277, Berkeley, CA 94701

1977 IEEE MTT INTERNATIONAL MICROWAVE SYMPOSIUM

Date: June 21-23, 1977
Place: San Diego, California
Sponsor: Inst. of Electrical & Electronics Engineers (MTT)
Requests for Information: D. Rubin, Code 2330, NELC, San Diego, CA 92152

Selected Bibliography of Papers Presented:

MICROWAVE THERMOGRAPHY AS A DIAGNOSTIC TOOL FOR THE DETECTION OF CANCER. (invited) A. Barrett, P. Myers

HYPERTHERMIA DOSE DEFINITION. E. R. Atkinson

SELECTIVE HEATING OF CUTANEOUS HUMAN TUMORS AT 27.12 MHz. P. Antich, N. Tokita, J. Kim, E. Hahn

HYPERTHERMIA: HEALING AND HAZARD IN TUMOR BEARING RATS. H. Moroson, S. Stowe, M. Schechter

CHANGES IN TUMOR BLOOD FLOW PRODUCED BY MICROWAVE-INDUCED HYPERTHERMIA. C. Sutton, F. Carroll

INCREASE IN X-RAY SENSITIVITY OF CANCER AFTER EXPOSURE TO 434 MHz ELECTROMAGNETIC RADIATION. J. Holt, P. Keckie, A. Nelson

PRELIMINARY IN-VIVO PROBE MEASUREMENTS OF THE ELECTRICAL PROPERTIES OF TUMORS IN MICE. E. Burdette, J. Seals, J. Toler, F. Gain

NON-PERTURBING MICROPROBES FOR MEASUREMENT IN ELECTROMAGNETIC FIELDS. A. Priou, A. Deficis

NEAR ZONE MICROWAVE EXPOSURE OF A BIOLOGICAL SPHERE. K. Al-Badwaihy, S. Hafiz

EFFECT OF SURFACE COOLING AND BLOOD FLOW ON THE ELECTROMAGNETIC HEATING OF TISSUE. H. Kritikos, K. Foster, H. Schwan

BOLUSING TECHNIQUE FOR BATCH MICROWAVE IRRADIATION OF TUMORS IN THE FAR FIELD. A. Cheung, D. McCulloch, J. Robinson, G. Samaras

A SYSTEM FOR DEVELOPING MICROWAVE INDUCED HYPERTHERMIA IN SMALL ANIMALS. R. Baker, V. Smith, L. Kobe, T. Phillips

THE DESIGN AND PERFORMANCE OF A CIRCULARLY POLARIZED DIRECT CONTACT APPLICATOR FOR MICROWAVE DIATHERMY. G. Kantor, D. Witters, J. Greiser

WORLD ELECTROTECHNICAL CONGRESS

Date: June 21-25, 1977
Place: Moscow, USSR
Sponsor: WELC (Org. Committee; Int)
Requests for Information: WELC: c/o Min for EE Industries, Kalinina prospect, 19, Moscow, G-19, USSR

SECOND ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM AND EXHIBIT

Date: June 28-30, 1977
Place: Montreux, Switzerland
Sponsor: Conv. of Natl. Electrical Engineering Assn. of W. Europe (EUREL); Int. Union of Radio Science (URSI); Inst. of Electrical and Electronics Engineers (EMC Gp) (Int.); Soc. of Auto Engineers (AE-4) (USA); et al.
Requests for Information: T. Dvorak, ETH Zentrum (HF), 8092 Zurich, Switzerland

Selected Bibliography of Papers Presented:

BIOLOGICAL EFFECTS OF HIGH INTENSITY, LOW FREQUENCY ELECTROSTATIC FIELDS. H. B. Graves

SOME SPECIAL APPLICATIONS OF MICROWAVE RADIOMETRY OF BIOLOGICAL SYSTEMS. J. Bigu del Blanco

PERCEPTION OF STATIC FIELDS BY LIVING ORGANISMS AND TERATOGENIC EFFECTS OF MICROWAVES. G. d'Ambrosio, V. La Manna

COMPATIBILITY OF WEAK MAGNETIC ELF FIELDS. H. W. Ludwig

EFFECT OF 60 Hz HIGH INTENSITY ELECTRIC FIELDS ON LIVING PLANTS. G. W. McKee, D. P. Knievel, D. T. Poznaniak, J. W. Bankoske

INFLUENCE ON IMPLANTED CARDIAC PACEMAKERS BY ELECTRONIC SENSOR SWITCHES AND ELECTROSTATIC DISCHARGES. H. J. Bisping, W. Irnich, S. Schroer

AN EMC STANDARD FOR MEDICAL ELECTRONIC DEVICES. R. J. Hoff

INTERNATIONAL SYMPOSIUM ON MICROWAVE DIAGNOSTICS OF SEMICONDUCTORS

Date: July 13-15, 1977
Place: Porvoo, Finland: Haikko Manor
Sponsor: Technical Research Ctr. of Finland--VTT (Semiconductor Lab.); Helsinki Univ. of Technology (Electron. Physics Lab.) Finlan
Requests for Information: R. Paananen, VT

ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM

Date: July 26-28, 1977
Place: Seattle, WA: Washington Plaza
Sponsor: Inst. of Electrical & Electronics Engineers (EMC)
Requests for Information: B. L. Carlson, Jr., Boeing Co., Box 3029, Seattle, WA

SEVENTH EUROPEAN MICROWAVE CONFERENCE

Date: September 5-8, 1977
Place: Copenhagen, Denmark: Bella Center
Sponsor: Dansk Ingeniorgorening
Requests for Information: Professor Preben Gudmandsen, Conf. Chairman, Electronics Inst., 348 Technical Univ. of Denmark, DK--2800 Lyngby, Denmark

INTERNATIONAL CONFERENCE ON RADAR (RADAR 77)

Date: October 25-28, 1977
Place: London, United Kingdom
Sponsor: Inst. of Electrical Engineers (Electronics Div.) [UK]; Inst. of Electrical & Electronics Engineers (Aerospace Electronics Society; [Int.]; Inst. of Electronics & Radio Engineers
Requests for Information: Conference Dept., IEE or K Milne, Plessey Radar, Southleigh Park House, Eastleigh Rd., Havant, Hants P09 2PE, UK

INTERNATIONAL SYMPOSIUM ON BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES

Date: October 30-November 4, 1977
Place: Airlie, Virginia
Sponsor: International Union of Radio Science Commissions A and B
Requests for Information: Professor Saul W. Rosenthal, Chairman, Symposium Steering Committee, Polytechnic Inst. of NY, Route 110, Farmingdale, NY 11735

ENGINEERING IN MEDICINE AND BIOLOGY CONFERENCE

Date: November 5-9, 1977
Place: Los Angeles, California
Sponsor: Alliance for Engineering in Medicine and Biology
Requests for Information: Mrs. P. I. Horner, Asst. Dir. & Conf. Coordinator, Alliance for Engineering in Medicine and Biology, Suite 1350, 5454 Wisconsin Ave., Chevy Chase, MD 20015

0120 MECHANISMS OF MICROWAVE INTERACTION WITH HUMAN AUDITORY SYSTEMS. Lin, J. C.; Yu, F. T. (Wayne State Univ., Graduate Sch., Cass & Antoinette Aves., Detroit, MI 48202).

The mechanism of interaction of pulsed microwaves with living tissues will be investigated theoretically and experimentally. The research will involve analytic studies of the stress and forces induced by the incident microwave energy and optical measurement of vibrations in models of human and animal heads exposed to pulsed microwaves. Theoretic and experimental investigations of the frequency behavior of the induced vibrations will be performed to isolate the precise mechanism involved in the auditory phenomenon. The results will elucidate the quantitative effects of microwave energy on living organisms and provide information needed to determine human tolerance to microwave radiation. (8/76-7/77)

Supporting Agency:NSF, Div. Engineering.

0121 HEART CONDUCTION DEFECTS. Beckett, S. D.; Branch, C. E.; Robertson, B. T.; Sims, M. H. (Auburn Univ., Sch. Veterinary Medicine, Auburn, AL 36830).

The etiology, heritability, diagnosis, and prevention of syncopal attacks and sudden death in a spontaneous animal model are being studied and compared with sudden death in humans. The animal model consists of a line of purebred dogs with a tendency towards syncopal attacks and sudden death. Repeated episodes of atrial asystole have been documented using continuous monotoring of the electrocardiogram. The frequency of atrioventricular heart block was higher for the purebred line than for mixed breed dogs and was associated with autonomic activity. The major objectives of the project are to: (1) document the syncopal attacks using multichannel radiotelemetry to define the etiology of the spontaneous attacks and the susceptibility of individual dogs, (2) compare the baroreflex activity of the purebred line to mixed breed dogs, (3) compare the effects of rapid pacing on overdrive suppression of the purebred line compared to mixed breed dogs, and (4) evaluate the effect of pharmacologic agents on the frequency of attacks. (5/76-10/76)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0122 MINIMALLY-INVASIVE STIMULATION WITH IMPLANTED DIODE. Schuder, J. C.; Stoeckle, H.; Almond, C. H.; Stephenson, H. E. (Univ. Missouri, Sch. Medicine, M228 Medical Sciences, Columbia, MO 65201).

Electrical stimulation of biologic tissue is currently used or under active consideration for use in the treatment of a variety of clinical problems. While the possibility of selective electrical stimulation of a localized region within the body by completely non-invasive means has been postulated theoretically, such stimulation has yet to be demonstrated experimentally. However, the selective stimulation of a localized region within the body can be achieved by implanting a very small diode at the desired site and then applying a pulsed radiofrequency field by means of electrodes or a coil on or near the surface of the body. This project has derived reasonably complete theoretic descriptions of the two systems on the basis of an idealized model in which circular electrodes or the coil are placed on the surface of a semi-infinite homogeneous medium. The direct current component of diode current is related to the power input to the electrode pair or to the coil and to the geometry of the system. The two systems are being evaluated for the cardiac pacing of dogs. The study will be extended to cover other stimulation applications. In addition, input power-diode current relationships for more complex models will be developed. (6/76-5/77)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0123 WESTERN CANCER STUDY GROUP. Block, J. B. (Los Angeles County Harbor General Hosp., 1000 W. Carson St., Torrance CA 90509).

The influence of heat on tumor uptake of anticancer drugs will be investigated. For *in vitro* studies, clinical (surgical) material will be used; for *in vivo* work, microwave heating of transplanted animal tumors will be used. (9/75-7/77)

Supporting Agency:HEW, PHS, NIH, NCI.

0124 REMOTE STIMULATION BY RADIO-FREQUENCY TRANSMISSION. Glenn, W. W.; Holcomb, W. G.; Bouhuys, A.; Gee, J. B.; Cohen, L. S. (Yale Univ., Sch. Medicine, 333 Cedar St., New Haven, CT 06510).

Clinical studies will continue on the selection of patients with chronic ventilatory insufficiency for diaphragm pacing. The evaluation of diaphragm pacing in patients with central alveolar hypoventilation and quadriplegia will be emphasized. A study will be made of the causes of upper airway obstruction in patients selected for diaphragm pacing and a study of the loss of hypoxic drive in patients with ventilatory insufficiency requiring diaphragm pacing will be continued. The influence of diaphragm pacing on pulmonary hypertension during sleep will be studied. A registry of all patients with diaphragm pacemakers will be maintained. Experimental and clinical evaluation of phrenic nerve stimulation on diaphragm function will also be evaluated both experimentally and clinically. Clinical application of a demand-type diaphragm pacemaker will be expanded. In the animal laboratory *in vivo* testing of a hermetically sealed capsule for implant of radiofrequency components will be started. The experimental application of a totally implantable diaphragm pacemaker in the study of several stimulating waveforms will be done. The prototype of a total implantable pace-

maker programmable from the exterior for human application will be constructed. A quantitative study of tissue perfusion by heat loss calorimetry will be expanded. (1/77-12/77)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0125 MOLECULAR MOTION AND ENERGY TRANSPORT IN MOLECULAR AGGREGATES. Prasad, P. N. (State Univ. New York, Graduate Sch., 1300 Elmwood Ave., Buffalo, NY 14222).

The process of energy transport through organic molecular aggregates which proceeds by the molecular motions and electronic excitation in various ordered and disordered crystalline aggregates will be studied. The nature of electron-phonon interaction, and the application of these studies in establishing the detailed nature of the energy transport will be examined. The investigations have both biologic and technologic applications. In a number of photophysical or photochemical processes in biopolymers, the primary step is the transport of the excitation. Additionally, a study of electron-phonon coupling and molecular motional instability is important for the technology of efficient energy transport and superconductors. The research is divided into four categories on the basis of the technique (Raman, electronic, excited state microwave resonance, and thermal modulation). (10/76-9/77)

Supporting Agency:NSF, Div. Materials Res.

0126 THE EFFECTS OF NON-IONIZING ELECTROMAGNETIC RADIATION ON SUBCELLULAR PREPARATIONS. Straub, K. D. (U.S. Veterans Admin. Hosp., 300 E. Roosevelt Rd., Little Rock, AK 72206).

The effects of low frequency electric fields from 10-20,000 Hz on both the sodium-potassium adenosine triphosphatase (ATPase) from guinea pig brain and mitochondria isolated from rat liver and pig heart were studied. The mitochondria derived from pig heart were subjected to current densities up to the point of marked heating of the solution at 20-2,000 Hz. During this time, calcium uptake was measured and oxidative phosphorylation was monitored; there were no changes in the ability of heart mitochondria to take up calcium, nor were there any decrements in oxidative phosphorylation until heating occurred, which was at current densities well above 1 mA/cm^2. Low frequency magnetic field effects on the active transport of frog skin were examined at 10-2,000 Hz and field strengths up to 100 G peak to peak. The isolated frog skin had a variable but persistent increase in short circuit current and potential immediately after the application of these fields with the maximum effect being observed below 100 Hz. No explanation can be given for the lack of field effects at 7 Hz at 28 kG. Further studies are underway to delineate the magnetic field effect on frog skin and to extend these measurements to sodium potassium ATPase *in vitro*. It can be concluded, however, that low frequency electrical fields from 10-2,000 Hz up to the point of current densities which heat the solution do not affect the sodium potassium ATPase from brain, the function of mitochondria in oxidative phosphorylation, or the calcium uptake from rat liver or from pig heart. (12/75-11/76)

Supporting Agency:U.S. Veterans Admin., Dep. Medicine & Surgery.

0127 ELECTROMAGNETIC RADIATION EFFECTS ON BRAIN TISSUE PERMEABILITY. Oscar, K.; Stokes, N. (U.S. Army, Mobility Equipment & Development Command, Fort Belvoir, VA 22060).

The functional relationship of microwave parameters to changes in the permeability of small inert polar molecules in the blood-brain barrier of rats will be determined. Rats will be exposed to pulsed and continuous wave microwave energy to assess the uptake of nondiffusible neutral polar substances in certain areas of the brain. A quantitative, radioactive isotope method, which uses a highly diffusible substance as an internal standard, will be employed to measure the loss of a labeled test substance to the brain tissue as a function of different microwave exposure parameters. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Army.

0128 BIOELECTRIC PHENOMENA CONTROLLING BONE GROWTH. Bassett, C. A.; Chokshi, H. R.; Pawluk, R. J. (Columbia Univ., Sch. Medicine, 630 W. 168th St., New York, NY 10032).

Methods and mechanisms will be defined for controlling osteogenesis using inductively-coupled-pulsing electromagnetic fields, established external to the organism. Both *in vivo* studies of fracture healing in a rat femoral osteotomy model and *in vitro* studies of collagen synthesis and ^{45}Ca release by osteogenic cells will be used. Primary emphasis will be on elaborating those pulse characteristics, e.g., shape, width, amplitude and repetition rates, that have biologic significance during bone formation and repair. Attempts will be made to correlate the rate and amount of ^{45}Ca release by prelabeled cells with increases in collagen synthesis by osteogenic cells and with increases in fracture healing, as measured radiographically, histologically, and by mechanical testing. (2/76-1/77)

Supporting Agency:HEW, PHS, NIH, NIAMDD.

0129 NAVY ENVIRONMENT: EFFECT OF RF AND MICROWAVE RADIATION ON NERVOUS SYSTEMS. Takashima, S.; Kritikos, H. N. (Univ. Pennsylvania, Sch. Electrical Engineering, 203 Logan Hall, Philadelphia, PA 19104).

Controversy surrounds the likelihood of significant disturbances to humans resulting from the interaction of low-level electromagnetic (EM) fields with the

nervous system. Although it appears that EM fields do not alter the activity of single axons, it is worthwhile to determine which segment, or process, of the nervous system is susceptible to EM field interactions. The object of this research is to study the activities of relatively simple nervous systems in the presence and absence of EM fields. The first, and most critical, aspect of this work will be the characterization and quantification of the power absorbed by nerve tissue in the exposure chamber. Using the stellate ganglion of the squid, electrical transmission of alternating current and direct current fields across neuromuscular junctions will be studied. The effect of chronic exposure with weak fields on neuromuscular activities will also be studied. A very simple system or response will be studied first followed by more complex systems until the segment of the nervous system that is particularly susceptible to EM fields is found. The synaptic and neuromuscular junctions will be studied primarily. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0130 RENAL CRYOPRESERVATION. Lillehei, R. C.; Kubota, S.; Graham, E. F.; Crabo, B. G.; Shatney, C. H. (Univ. Minnesota, Sch. Medicine, 1305 Mayo, Minneapolis, MN 55455).

A significant problem in freezing organs is the need for a substitute for cryo-precipitated plasma, which is used pre- and post-freezing. Various colloid solutions will be substituted for the plasma, and weight gain of the kidney compared with that using the plasma. Lactate dehydrogenase (LDH) and glutamic oxaloacetic transaminase (GOT) levels in the venous effluent are already used to assay *in vitro* renal damage following freeze-thawing. A similar study will correlate electrolyte changes as a measure of renal damage. While microwave thawing is the only way to achieve quick thawing, microwaves may intrinsically damage the kidney. Electronmicroscopy will be used to assess such damage at various power outputs and frequencies when kidneys are thawed from 75°C. Observations on using increasing concentrations of cryoprotective agents during freezing and decreasing concentrations during thawing will continue. (1/76-12/76)

Supporting Agency:HEW, PHS, NIH, NIAMDD.

0131 A STUDY OF DENDRITIC SPINE MORPHOLOGY IN RAT BRAIN FOLLOWING CHRONIC EXPOSURE TO LOW INTENSITY MICROWAVE RADIATION. Manthei, R. C.; Glaser, Z. R. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

Eastern European studies suggest that reversible changes occur in the proliferation and/or the number of synaptic spines associated with the apical dendrites of rat cortical pyramidal cells following chronic electromagnetic radiation (EMR) exposure to between 1 and 10 mW/cm^2 of pulsed and continuous 10 cm waves. As such a phenomenon has broad implication for central nervous system plasticity, the credibility of Soviet data will be tested and a reliable histologic technique developed to complement future neurologic study. Eighty adult male rats (40 experimental, 40 control) will undergo 2-hr daily exposures to 10 cm pulsed microwaves at a power density of 10 mW/cm^2 for a period of 3 mo. Attempts will be made to assess morphologic effects described as having an early onset as well as the progressive, yet reversible effects described by the Soviets. Basalar and apical dendritic processes of pyramidal cells located in discrete areas of sensory-motor cortex will be examined at various depths utilizing accepted rapid Golgi procedures. Quantitative spine counting on 48 (24 experimental, 24 control) animals utilizing light microscopic technique will enable the classification of type of dendritic process and area of tissue involved. Histologic procedure and spine density counting will be performed by the Dept. of Anatomy, U.C.L.A.; Naval Medical Research Institute, Detachment Laboratory (Dahlgren, Va.) will be responsible for research design, irradiation (including field mapping, dosimetry, etc.), tissue preparation for shipment, as well as interpretation, analysis, and reporting of data. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0132 NAVY ENVIRONMENT: THE NATURE OF ELECTROMAGNETIC FIELD INTERACTION WITH BIOLOGICAL SYSTEM FUNCTION. Frey, A. H. (Randomline Incorporated, Huntingdon Valley, PA 19006).

The effects of exposure to low power, modulated, and continuous wave microwave energy on nerve cells is being studied utilizing a preparation of the ventral nerve cord of the crayfish. Exposure will be in an anechoic chamber, and the dye chosen will allow for detection of active and passive parameters. Relevant information is expected on critical aspects of electromagnetic energy in inducing neural effects and the thresholds for such direct neural effects. Additionally, holography will be used to determine if the radiofrequency hearing phenomenon is caused by vibration of the skull or other head and ear structures. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0133 LABORATORY AND FIELD EVALUATIONS OF HEAT ENERGY TO CONTROL STORED-PRODUCT INSECTS. Kirkpatrick, R. L. (U.S. Dept. Agriculture, Stored Products Insects Res. & Development Lab., 3401 Edwin Ave., Savannah, GA 31405).

The objective of this project is to develop rapid simple and practical techniques in the laboratory and to adapt these methods for field evaluations using temperature, including infrared and microwave radiation, to control stored-product insects infesting grain or other stored commodities. Research data obtained from these laboratory and field tests will be used to develop a practical and inexpensive commercial unit to control stored-product insects.

The laboratory tests will determine the repellancy, attractancy, effect on life history, behavioral responses, and dosage-mortality relationship of stored-product insects exposed to infrared, microwave radiation and other types of heat energy. Thus far, larvae of the pecan weevil, *Curculio caryae* (Horn), have survived temperatures of 5C but could not survive warm air temperatures of 43C for 24 hr. No changes in quality, taste, or lipid content of pecans occurred after treatment or during a 5-mo storage at 2C. Adult mortalities of 99% or more were obtained by treating bulk quantities of wheat with an infrared heater to obtain grain at a temperature of 48C. The immature insects were controlled at this temperature if the wheat retained at least 38C for 24 hr after treatment. (10/76-9/77)

Supporting Agency:U.S. Dep. Agriculture, Agricultural Res. Service, Georgia-South Carolina Area.

0134 TO DESIGN AND STUDY THE EFFECTS OF BIOMEDICAL SYSTEMS ON ANIMALS. Dracy, A. E.; Sander, D. E.; Bush, L. F. (South Dakota State Univ., Agricultural Experiment Station, Brookings, SD 57006).

The threefold objectives of this study are: (1) to design and test the validity of a volume conduction system for measuring body temperature continuously, (2) to study the effects of microwaves for partial and complete sterilization of farm animals, and (3) to design and test a unit that will have an exciting effect on rats and mice. The latter will also be used for rodent control. The stated approach is to use the circuitry built during the school year and improve on the water stability problems as they affect the operation of the circuit, to implant and monitor temperatures of the internal organs of the animal, to build a microwave cavity and obtain equipment to irradiate safely the testicles of a sheep, and to irradiate the subjects and test the amount of sterility as a function of radiation power and time of exposure. In addition, investigators will design and build a power supply from existing sources and test the effectiveness of the sound source on the eradication of rats and mice. In January of 1975, the Federal Communications Commission (FCC) designated the research telemetry bands to be 40.66-40.70 MHz and 216-220 MHz. In anticipation of this change and in order to upgrade the existing implantable electrocardiogram (ECG) telemetry systems previously developed at South Dakota State University, a new telemetry system was designed. This system utilizes an amplitude modulated carrier at 40.67 MHz. The carrier is pulse frequency modulated by a pulse generator whose frequency is dependent on the magnitude of a voltage impressed upon its input. This voltage is, at the present time, an amplified ECG voltage, which is picked up by Ag-AgCl electrodes. However, voltages proportional to pressure, temperature, or other physiologic variables can be used if desired. The system utilizes amplitude modulation with a pulse frequency modulated subcarrier and is reliable because: (1) the radiofrequency carrier is crystal controlled to reduce drift due to metal proximity effects; (2) a magnetically operated switch is used to turn the unit on only when data are to be collected; and (3) the unit is encapsulated in a silicone resin for mechanical strength. (10/76-9/77)

Supporting Agency:South Dakota State Government

0135 ABSORPTION OF RADIO FREQUENCY POWER BY BIOLOGICAL PHANTOMS. Lagrone, A. H.; Hurt, W. D. (Univ. Texas, Sch. Engineering, 200 W. 21st St., Austin, TX 78712).

Analytic solutions for power absorbed by spheroidal and ellipsoidal models of man and animals in the frequency range where the wavelength is long compared to the length of the phantom (up to approximately 30 MHz for man-sized models) were determined using perturbation techniques. The extended boundary condition method is a numeric technique that extends these calculations of absorbed power up to approximately 80 MHz for man-sized spheroidal models in the E-orientation and beyond for other orientations. Comparisons of calculated values of power absorbed by saline-filled spheroidal phantoms at frequencies from 10 to 50 MHz were made with measured values. (7/75-6/76)

Supporting Agency:Univ. Texas.

0136 ELECTROMAGNETIC RADIATION AND BIOLOGICAL SYSTEMS. Bawin, S. M.; Adey, W. R.; Medici, R. G.; Sagan, P. M.; Sheppard, A. (Univ. California, Sch. Medicine, 405 Hilgard Ave., Los Angeles, CA 90024).

The study of interaction between weak electric fields (extremely low frequency and radiofrequency) and calcium ion binding in the central nervous system will be continued and will serve as reference (frequency and amplitude thresholds, size and direction of field effect) for experiments involving amino acids and putative neurotransmitters. Chick and cat isolated cerebral tissues will be compared in their response to field stimulation. *In vivo* experiments on cat cortex will attempt to determine if live tissue responds to a field stimulus that affects isolated samples. Tissue dosimetry studies will be done in collaboration with the BRH. Preliminary measurements of field intensity in cat cortex, made with a miniature E field probe, will be repeated. An attempt to correlate tissue gradient and neurochemical response will be made. Detailed field mapping awaits development of an implantable probe. Recent developments in theoretic physics will be applied in modeling nonlinear responses of the central nervous system to weak perturbations of the extracellular environment. Schedule-controlled behavior in monkeys will be tested during exposure to 450 MHz fields. Performance of neonate chicks and ducklings exposed to the same field conditions will be compared in a series of behavioral measurements ranging from free behavior to sophisticated behavioral tasks, including variation of an interresponse time schedule. (12/76-11/77)

Supporting Agency:HEW, PHS, FDA, BRH

0137 EFFECT OF LONG-TERM MICROWAVES ON THE IMMUNE RESPONSE OF EXPERIMENTAL RABBITS. Wieslaw, J.; Sell, K. W. (U.S. Navy, Medical Res. Inst., Bethesda, MD 20014).

The effects of long-term, low dose microwave exposure on the immune response of laboratory animals will be studied. The bone marrow and peripheral blood profiles, the number of neutrophils present in the bone marrow, the unsaturated vitamin B12 binding capacity, and the lysozyme activity in blood serum of normal and microwave exposed rabbits will be determined. Skin windows will be set up to determine the differences in the inflammatory process. About 12 rabbits will be exposed to a 3000 MHz microwave source at a power density of 1-2 mW/cm^2 for 4 hr/day for 2 or more mo. Experimental animals will be exposed for several hours a day. The subsequent immune response of these animals will be studied using established assays of cellular immunity. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0138 EFFECT OF LONG-TERM MICROWAVES ON THE IMMUNE RESPONSE OF EXPERIMENTAL RABBITS. Jedrezejczak, W.; Sell, K. W. (U.S. Navy, Medical Res. Inst., Bethesda, MD 20014).

See Current Research 0137. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0139 BEHAVIORAL CHARACTERISTICS OF MONKEYS AND RATS IRRADIATED WITH MICROWAVES. Delorge, J. O.; Beischer, D. E. (U.S. Navy, Biomedical Div., Pensacola, FL 32512).

See Current Research 0007. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0140 BIOCHEMICAL EFFECTS OF MULTIFREQUENCY MICROWAVE RADIATION. Reno, V. R.; Beischer, D. E. (U.S. Navy, Biomedical Div., Pensacola, FL 32512).

See Current Research 0055. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0141 CARDIOVASCULAR EFFECTS OF MULTIFREQUENCY MICROWAVE RADIATION. Reno, V. R.; Beischer, D. E. (U.S. Navy, Biomedical Div., Pensacola, FL 32512).

See Current Research 0003. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0142 REFLECTION AND DIFFRACTION ASPECTS OF BIOLOGICAL MICROWAVE DOSIMETRY. Reno, V. R.; Beischer, D. E. (U.S. Navy, Biochemical Div., Pensacola, FL 32512).

See Current Research 0057. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0143 BIOLOGICAL EFFECTS OF LOCALIZED E- AND H-FIELDS IN THE STANDING MICROWAVE FIELD. Beischer, D. E.; Reno, V. R. (U.S. Navy, Biomedical Div., Pensacola, FL 32512).

See Current Research 0006. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0144 NONIONIZING ELECTROMAGNETIC RADIATION INTERACTION WITH CENTRAL NERVOUS SYSTEM FUNCTION AS EVIDENCED BY MEASUREMENT OF FINGER TREMOR IN HUMANS. Diachenko, J. A.; Glaser, Z. R. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0002. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0145 EFFECTS OF HIGH POWER PULSED AND LOW LEVEL MICROWAVE RADIATION ON OPERANT BEHAVIOR IN RATS. Diachenko, J. A.; Glaser, Z. R. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0032. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0146 EFFECTS OF CHRONIC EXPOSURE TO HIGH PEAK POWER PULSED ELECTROMAGNETIC RADIATION ON ANIMALS. Ogrady, T. C.; Hosszu, J. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0027. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0147 ALTERED CSF CONSTITUENTS AS A FUNCTION OF CHRONIC LOW INTENSITY ELECTROMAGNETIC RADIATION EXPOSURE IN RABBITS. Manthei, R. C.; Glaser, Z. R. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0038. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0148 MEDICAL SURVEILLANCE OF PERSONNEL OCCUPATIONALLY EXPOSED TO ELECTROMAGNETIC RADIATION. Benedum, J. L.; Glaser, Z. R. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0040. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0149 EFFECTS OF HIGH PEAK POWER PULSED ELECTROMAGNETIC RADIATION ON CELLULAR KINETICS. Ogrady, T. C.; Glaser, Z. R. (U.S. Navy Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0035. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0150 INVESTIGATION OF BIOMOLECULAR FUNCTIONS BY MICROWAVE RADIATION. Eisenbud, M.; Rabinowitz, J. R. (New York Univ., Sch. Medicine, 550 1st Ave., New York, NY 10016).

See Current Research 0030. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0151 ULTRASTRUCTURAL STUDIES OF MICROWAVE CATARACTOGENESIS. Simon, D. R.; McKee, A. E. (U.S. Navy, Experimental Pathology Dept., Bethesda, MD 20014).

See Current Research 0025. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0152 OCULAR EFFECTS OF MICROWAVE RADIATION. Carpenter, R. L. (U.S. Dept. Health, Education, and Welfare, Public Health Service, Food and Drug Admin., Winchester, MA 01890).

See Current Research 0060. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0153 THE EFFECTS OF MICROWAVE RADIATION ON THE CENTRAL NERVOUS SYSTEM. Albert, E. N. (George Washington Univ., Sch. Medicine, 1331 H St. N.W., Washington, DC 20037).

See Current Research 0029. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0154 MAGNETICALLY COUPLED DRIVE OF THE EAR. Moushegian, G.; Rupert, A. L.; Gerken, G.; Glorig, A.; Owens, F. (Univ. Texas, Graduate Sch., Richardson, TX 75080).

See Current Research 0067. (6/76-5/77)

Supporting Agency:HEW, PHS, NIH, Natl. Neurological & Communicative Diseases.

0155 ALTERATIONS IN THE SLEEP PROCESS OF THE RABBIT AS A FUNCTION OF CHRONIC LOW INTENSITY ELECTROMAGNETIC RADIATION EXPOSURE. Manthei, R. C.; Glaser, Z. R. (U.S. Navy, Surface Weapons Center, Dahlgren, VA 22448).

See Current Research 0033. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

0156 IONIZING AND NON-IONIZING RADIATION BIOLOGY. Appleby, A. (Rutgers State Univ., Agricultural Experiment Station, Old Queens Building, New Brunswick, NJ 08903).

See Current Research 0009. (10/76-9/77)

Supporting Agency:New Jersey State Government.

0157 ELECTRICAL & ACOUSTIC PROPERTIES OF BIOLOGIC MATERIAL. Schwan, H. P. (Univ. Pennsylvania, Sch. Engineering & Applied Science, 4001 Spruce St., Philadelphia, PA 19104).

See Current Research 0043. (12/76-11/77)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0158 THERMOGRAPHY AT MICROWAVE AND MILLIMETER WAVELENGTHS. Hendee, W. R. (Univ. Colorado, Sch. Medicine, 4200 E. 9th Ave., Denver, CO 80220).

No descriptive information is available. (2/77-1/78)

Supporting Agency:HEW, PHS, NIH, NCI.

0159 SURGICAL IMPLANT COUPLING OF MICROWAVES TO BRAIN. Sutton, C. H.; Carroll, F. B. (U.S. Veterans Admin. Hosp., 1200 Anastasia Ave., Miami, FL 33134).

The resistance of the rat blood-brain barrier to microwave heating has been studied in an initial investigation. The director of a microwave diathermy generator at 2,450 MHz was placed at a fixed distance from the intact scalp of each rat, while the remainder of its body was shielded with microwave-absorbing Eccosorb. Brain temperatures were

monitored with a needle-mounted thermocouple inserted into the right frontal lobe. The integrity of the blood-brain barrier was studied with horseradish peroxidase, a basic protein, which has been employed as a tracer substance; it can be studied enzymatically, both morphologically and quantitatively, in tissue. It does not penetrate the intact blood-brain barrier but can indicate sites of barrier impairment. Rats were injected intravenously with 1.8 mg of horseradish peroxidase per 10 gm of body weight. Body-core temperatures were maintained at normothermic levels, while the brains of experimental groups were heated to 40°, 42°, 45° or 47°C. In quantitative studies, the anesthetized animals were sacrificed by perfusion through the aorta with a solution of 5% PVP in ice-cold normal saline. Homogenates of perfused brains were analyzed for residual peroxidase activity with a fluorometric method. Lack of extravascular peroxidase activity indicated an intact blood-brain barrier. There was no activity after 10 min at any temperature up to 45°C. After 30 min, there was residual activity at 42°C, although there was still greater activity at 45°C. In animals whose brains were heated to 47°C, it was difficult to maintain viability for as long as 10 min. Morphologic studies were then begun by demonstrating peroxidase activity in animals sacrificed by perfusion through the aorta with cold 3% glutaraldehyde. The primary changes noted were those in white matter. In the brains of animals heated to 42°C, the smallest capillaries were usually intact, while some of the slightly larger vessels showed escape of peroxidase from the vessel lumen with diffusion into surrounding white matter. The earliest site of vascular leakage appeared to be the white matter immediately adjacent to the granular cell layer of the cerebellum. There was a greater loss of blood vessel integrity at 45°C than at 42°C. (9/76-8/77)

Supporting Agency:U.S. Veterans Admin., Dept. Medicine & Surgery.

0160 EXTERNAL CARDIAC STIMULATION WITH MICROWAVE RADIATION. Zoll, P. M.; Frank, H. A.; Belgrad, A. H.; Weintraub, M. J.; Nowogrodzki, M. (Beth Israel Hosp., 330 Brookline Ave., Boston, MA 02215).

Researchers will develop the apparatus and techniques by which microwave thermal energy, applied externally over the precordium, may be transmitted through the chest wall to warm atrial or ventricular pacemaker cells in selected areas of the heart to arouse, accelerate, and maintain intrinsic rhythms at clinically useful rates and time intervals. A microwave generator and matched applicator will be developed using solid-state microwave technique, computer simulations, optimization procedures, and modern fabrication technologies to allow control of the depth of penetration, volume of tissue irradiated, and temperature change. The distribution, degree, and temporal course of heating of the target areas of the heart and of intervening tissues will be determined in normal anesthetized dogs by appropriate placement of thermistor probes. In dogs with surgically induced atrioventricular block the changes in atrial and ventricular rhythmicity will be studied. In particular, acceleration of the normal sino-atrial node and of the dominant idioventricular pacemaker, and the arousal, acceleration, and maintenance of ectopic atrial and ventricular pacemaker will be examined. Thermal effects on cardiac metabolism and hemodynamics will also be observed. Techniques of temporary control of cardiac rhythm to be developed will be quick, effective, entirely safe and painless, and completely noninvasive. Such techniques may supplement and possibly supplant present-day methods involving external cardiac pacemakers and intravenous drugs. (12/76-11/77)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0161 TUMOR RADIOCHEMOTHERAPY--EFFECTS OF ULTRASOUND AND HEAT. Hahn, G. M.; Marmor, J.; Li, G.; Fajardo, L.; Donaldson, S. S. (Stanford Univ., Sch. Medicine, Palo Alto, CA 94305).

The interaction of X-irradiation and chemotherapy with hyperthermia generated by ultrasound and microwaves in effecting tumor cures in laboratory animals will be investigated. Specifically, the effects of ultrasound and microwaves in cells will be examined *in vitro* and *in vivo* at temperatures above 37°C. Combined treatments of X-irradiation (or chemotherapy) and hyperthermia will be quantitated in tissue culture systems and in experimental tumors. Both cell survival studies of EMT-6 tumors as well as tumor cure experiments with EMT-6 and other tumors will be performed. Combinations that prove promising will be examined for possible clinical applications. Equipment will be developed to carry out laboratory and eventually clinical studies. (12/76-11/77)

Supporting Agency:HEW, PHS, NIH, NCI.

0162 BIOELECTRIC PHENOMENA CONTROLLING BONE GROWTH. Bassett, C. A.; Pilla, A. A.; Chokshi, H.; Pawluk, R. J. (Columbia Univ., Sch. Medicine, 630 W. 168th St., New York, NY 10032).

Methods and mechanisms for the bioelectric control of cell function will be defined. The investigators will analyze potential dependent phenomena at cell surfaces involving interactions of charged species, such as, divalent cations and hormones. Inductively-coupled electromagnetic fields will be utilized to provide a variety of bioelectric perturbations. This approach will be assessed through *in vitro* studies of protein synthesis and ^{45}Ca release by osteogenic and chondrogenic cells and of dynamic Na ion transport in the toad bladder membrane, as well as by *in vivo* studies of fracture healing in a rat radial osteotomy model. Primary emphasis will be focused upon the elaboration of induced current pulse characteristics, which have biologic significance during bone formation and repair, e.g., shape, frequency content, amplitude spectrum, and repeti-

tion rate. Quantitative evaluations will be obtained via impedance, radioactive labelling, radiographic, histologic and mechanical testing techniques. (2/77-1/78)

Supporting Agency:HEW, PHS, NIH, NIAMDD.

0163 INTERACTION OF ELECTROMAGNETIC FIELD WITH BIOLOGICAL SYSTEMS. Chen, K. (Michigan State Univ., Sch. Engineering, Engineering Building, East Lansing, MI 48824).

This research effort will develop theoretic methods for determining the internal electromagnetic field inside a biologic body of arbitrary shape. In addition, an experimental measurement program will be conducted using simulated biologic models. A digital computer program will be used to quantify the induced electric field inside the biologic bodies to provide theoretic predictions. The theoretic methods will also be applied to study possible therapeutic and diagnostic applications, such as, local heating in hyperthermia and noninvasive diagnostics. (2/77-1/78)

Supporting Agency:NSF, Div. Engineering.

0164 PERSONNEL TECHNOLOGY--DETERMINATION & IDENTIFICATION OF EVOKED MAGNETIC RESPONSE OF THE HUMAN BRAIN ASSOCIATED WITH SENSORY STIMULATION. Kaufman, L.; Williamson, S. J. (New York Univ., Sch. Arts & Sciences, 421 1st Ave., New York, NY 10012).

The investigators will attempt to relate the temporal and spatial features of the magnetic field external to the scalp to sensory stimulation and the internal state of the subject. Such information should provide a better understanding of neurologic relationships and lead to improved stimulus presentation for Naval equipment displays. Such data should also allow more precise identification of brain neurologic problem areas in Naval personnel. Planned experiments will use a superconducting quantum interference device (SQUID) with a second order gradiometer to detect changes in the evoked magnetic field near the human scalp, while the subject is stimulated visually, auditorily, or both simultaneously. With respect to visual stimulation, the effects of average grating luminance, contrast, bar orientation, spatial frequency, temporal frequency, and binocular versus monocular viewing will be examined. Auditory stimuli will include clicks and tones presented to one or both ears at various pressure levels. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Navy.

4877 MICROWAVES AND HUMAN SAFETY, PART 1. (Eng.) Minin, B. A. (No affiliation given). 139 pp.; 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. JPRS 65506-1].

A comprehensive review of the physical and biologic effects of superhigh frequency microwave radiation is presented. General topics covered include the nature and ecology of the earth's electromagnetic biosphere, the biologic effects of microwaves and methods for studying these effects, the establishment of norms for electromagnetic fields, and methods for predicting irradiance. Specifically, microwaves are discussed both in terms of their pathologic effects (thermal and nonthermal) and their physiologic effects (irritating properties). Pathologic changes in biologic organisms arise during continuous prolonged irradiation by microwave fields with an intensity of 1-10 mW/cm^2 or more. However, body sensitivity to field exposure has been noted at densities of fractions of a $\mu W/cm^2$. Body organs, which are most vulnerable to irradiation (eyes and tissues of the testes), are those with poor heat transfer. For example, the irradiation of the eyes of a rabbit by an energy with a density of 0.12-0.6 W/cm^2 over periods of from 5-270 min results in cataract formation as a result of temperature build-up in the eye. The most common effect exerted on the human body by low-level radiation is loss of adaptation to changes in environmental conditions (heat, cold, noise, psychological trauma); hence, the superhigh frequency field is a typical stressor. Irritating effects can be produced at radiation levels lower than those that are necessary for the appearance of energy interaction. A vascular conditioned reflex in man is associated with radiations of 10^{-4} V/m. Changes in salivation in dogs occur at 3×10^2 V/m, and changes in the encephalogram of rabbits occur at 20 $\mu W/cm^2$. Changes in the epithelial and interstitial cells of animals occur even at power densities of 0.3 $\mu W/cm^2$. Difficulties in establishing norms for microwave radiation revolve around the fact that human reaction to exposure may be characterized by purely qualitative concepts, such as deterioration of state of well-being. (No refs.)

4878 MICROWAVE INDUCED ACOUSTIC EFFECTS IN MAMMALIAN AUDITORY SYSTEMS. (Eng.) Guy, A. W.; Chou, C. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22151, Document No. AD A015200].

The threshold for microwave (2450 MHz) pulse evoked auditory sensations or responses in both humans and cats was shown to be related to the incident energy per pulse, with values of approximately 20 $\mu J/cm^2$ for cats and 40 $\mu J/cm^2$ for humans at pulse widths < 30 μsec. This corresponded to an estimated peak absorbed power density of 10-16 mJ/kg in the cat head and about 16 mJ/kg for the human head. This energy density increased the tissue temperature by only 5×10^{-6}C. As background noise increased, the threshold for evoked responses in the medial geniculate nucleus of the cat remained stable for pulsed microwave stimuli but increased for acoustic stimuli. Cochlea microphonics were recorded in guinea pigs exposed to microwave pulses when sufficient incident power (average absorbed power density of 1.33 J/kg in the head) was used. The frequency of the microphonics (50 kHz) in guinea pigs supported the hypothesis that a vibration is set up in the head corresponding to its acoustical resonant frequency. Since cochlear destruction resulted in total loss of all evoked potentials due to microwave and acoustic stimuli, it appeared that the microwave auditory effect was exerted on the animal in the same manner as the conventional acoustic stimuli. The most likely mechanism for microwave induced acoustic effects in mammalian auditory systems involves the induction of high frequency vibrations in the head by a transient thermal expansion of tissue due to the rapid absorption of pulsed microwave energy. This hypothesis is reinforced by the fact that the behavior of the measured threshold characteristics with pulse width agree with those predicted by the thermal expansion theory. (19 refs.)

4879 BIOLOGICAL EFFECTS OF NON-IONIZING RADIATION. (Eng.) Varma, M. M.; Traboulay, E. A. (Bio-Environmental Engineering and Sciences Res. Lab., Dept. of Civil Engineering, Howard Univ., Washington, DC 20059). 57 pp.; 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A013315].

Mutagenic injury resulting from the exposure of male Swiss mice to nonionizing radiation (microwaves) was investigated. Gross postmortem findings indicated that exposure to 1.7 GHz and 200 mW/cm^2 resulted in diffuse hemorrhages in the subcutaneous tissue, with subsequent damage to major organs. At a power density of 10 mW, exposure for 100 min resulted in the sloughing of degenerating germinal cells into the lumen of the seminiferous tubules. When the power density was increased to 50 mW/cm^2 for an exposure duration of 30-40 min, there was disintegration of spermatids, sertoli cells, and connective tissue. Dominant lethal tests revealed increases in infertility and pre-implantation losses after a 30-min exposure to 1.7 GHz microwaves at a power density of 50 mW/cm^2. Out of 10 animals exposed to this power level, three died between the second and sixth wk after exposure. The overall pregnancy rate for female mates of the irradiated males was 63.83% as compared with 86% for controls. The mutagenicity index of treated animals was 3.30 in contrast to 1.17 for controls; this high mutagenicity index indicated damage in the post-meiotic and meiotic stages in spermatogenesis. Studies of deoxyribonucleic acid (DNA) isolated from the testes of animals exposed to 1.7 GHz radiation at a power density of 50 mW/cm^2 for 30 min revealed a change of 2°C in the melting temperature of DNA and a change of about 2% in the base composition of the irradiated DNA. Optical density measurements of DNA showed a small difference between irradiated DNA samples and those from controls; this supports the possibility that irradiation causes DNA strand separation since the change

in optical density reflects a decrease in hydrogen bonding in the DNA molecule. If strand separation does occur, the possibility exists that a point mutation could occur, if there is imprecise base pair matching. (34 refs.)

4880 MICROWAVE EXPOSURE FACILITY: MULTIPLE ANIMAL EXPOSURE AT EQUAL POWER DENSITY. (Eng.) Oliva, S. A.; Catravas, G. N. (Armed Forces Radiobiology Res. Inst., Defense Nuclear Agency, Bethesda, MD 20014). 27 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A024939].

A microwave irradiation facility for multiple animal experimental exposures is described. A feature of the facility is that the natural radiation characteristics of the microwave field were utilized to ensure that each animal in the array received an equal exposure. Cages of sufficient microwave transparency to minimize microwave reflections were arranged in a parabolic pattern and were sufficiently separated from each other to ensure minimum interactions between animals due to microwave reflections. Power density measurements in each cage indicated that the variation in received power density in the array of cages when empty was ± 4.8% of the median cage. After the introduction of rats into the cages, the energy density in the "worst case" cage (furthest from the antenna and located to the rear of all other cages) fluctuated between -2.2% and +24.4% of the empty cage value for a short period and then stabilized to a value of between +2.2% and +8.8% after a few min. The overall facility ensured equal power to all locations to within ± 15% after a short period at the beginning of the exposure. (5 refs.)

4881 MEASUREMENT OF RADIOFREQUENCY POWER ABSORPTION IN MONKEYS, MONKEY PHANTOMS, AND HUMAN PHANTOMS EXPOSED TO 10-50 MHz FIELDS. (Eng.) Allen, S. J.; Hurt, W. D.; Krupp, J. H.; Ratliff, J. A.; Durney, C. H.; Johnson, C. C. (USAF Sch. Aerospace Medicine, Aerospace Medical Div., Brooks Air Force Base, TX 78235). 17 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A024373].

Differential power measurement techniques were used to determine radiofrequency (10-50 MHz) power absorption in a 70-kg prolate spheroid human phantom and in 20 prolate spheroid monkey phantoms (3.5 g). Twenty rhesus monkeys averaging 3.5 kg were also used to compare power absorption of primates with the equivalent primate phantoms. Prolate spheroid theory and measurement predicted low levels of power absorption for man exposed to 10-30-MHz radiofrequency fields. For 50 mW/cm^2 exposures with cross-polarization, only 12 W of total absorption is predicted at 30 MHz; at 10 MHz, slightly over 1 W total power would be absorbed. Compared to man's basal metabolic rate ranging from 80 W at rest to 600 W for heavy labor, 50 mW/cm^2 at frequencies below 30 MHz represent an almost insignificant thermal insult. The absorbed power decreases approximately as the square of the frequency for all phantom and monkey exposures, indicating the need for frequency-dependent radiofrequency radiation hazard standards. A comparison of the results using phantoms with those obtained from power absorption measurements on live monkeys indicated that an ellipsoid model is more appropriate geometrically for describing power absorption in primates. When perturbation analysis was applied to an ellipsoid model for 40 MHz, the ellipsoid model provided excellent results when compared with the animal data. (7 refs.)

4882 ENGINEERING CONSIDERATIONS AND MEASUREMENTS. (Eng.) Guy, A. W. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22151, Document No. AD A015200].

Engineering considerations involved in the quantitation of biologic effects in subjects exposed to electromagnetic fields are discussed. Topics covered include: measurement instrumentation; thermographic measurements of the absorbed power in regular shaped phantom tissue models; waveguide exposure systems; the absorbed power distribution in animals and man exposed to various electromagnetic sources; and the problem of localized power absorption due to attached instrumentation and implants. Quantitation of the biologic effects of electromagnetic fields in subjects requires that both the fields in the environment and within the exposed tissues be measured. Fields in the environment can be measured by means of standard field survey meter sensors consisting of small dipoles with diode or thermocouple-type transducers for converting microwaves or radiofrequency energy to proportional electrical signals. Fields and associated absorbed power density in the tissues can be measured by means of thermocouples, thermistors, fiber optic liquid crystal sensors, and thermography. The quantitation of fields associated with exposure of test subjects can be significantly simplified by a careful choice of exposure techniques. (29 refs.)

4883 THE BIOLOGICAL SIGNIFICANCE OF RADIOFREQUENCY RADIATION EMISSION ON CARDIAC PACEMAKER PERFORMANCE. (Eng.) Mitchell, J. C.; Hurt, W. D. (USAF Sch. Aerospace Medicine, Aerospace Medical Div., Brooks Air Force Base, TX 78235). 19 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A022886].

Laboratory and field tests to determine the effect of various radiofrequency emission sources on cardiac pacemaker performance were performed. Tests with 80 pacemakers (23 different models) were conducted in implant simulation chambers using three different frequencies (450, 1600, and 3200 MHz), a constant pulse rate of 10 pulses/sec, pulse widths of 0.01, 0.02, 0.5, 1, 2, 5, 10, and 20 msec, and electric field strength levels of up to 1200 V/m. Of the three frequencies used, the 450 MHz sources resulted

in the lowest electromagnetic radiation interference (EMI) thresholds (defined as the electric field strength at which the pacemaker rate falls below 50 beats/min or exceeds 120 beats/min); the EMI thresholds at this frequency ranged from as low as 4 to more than 260 V/m. Shorter pulse widths resulted in higher EMI thresholds; for example, at 450 MHz a pulse width of 20 msec resulted in an EMI of 4 V/m in comparison to an EMI of 65 V/m at a pulse width of 10 μsec. Field tests were conducted in close proximity to a variety of radiofrequency radiation sources; the emitter characteristics ranged in operating frequencies from 35 kHz to 9 GHz, pulse widths from 1-2000 μsec, pulse rates from 20-400 pulses/sec, and peak output powers from 0.02-32 MW. Many of the tested pacemakers demonstrated some form of periodic interference resulting in reductions in pacemaker rate by 5-6 beats/min; from a clinical viewpoint, this type of interference is generally judged insignificant. Extrapolation of these field test data to the vast majority of operational radiofrequency emitters or emitter complexes reveals that few produce electric field strength levels greater than 100 V/m for sufficient time periods to significantly disrupt normal pacemaker functions. Therefore, if pacemakers were designed and tested to be compatible with the minimum electric field strength level of 200 V/m, which is associated with the unrestricted personnel exposure level of 10 mW/cm^2, potential EMI situations would be substantially reduced or effectively eliminated. (18 refs.)

4884 RECEPTION OF MICROWAVES BY THE BRAIN. (Eng.) Joines, W. T. (Electrical Engineering Dept., Duke Univ., Durham, NC). *Med. Res. Eng.* 12(3): 8-12; 1976.

Studies to determine how microwave energy is absorbed by the skull and how nerve cells might interact with this energy are reported. Theoretic studies of microwave interaction with homogeneous and inhomogeneous sphere models of the human skull indicated that at a microwave frequency of 2.1 GHz the layers on an inhomogeneous sphere formed an effective quarter wave transformer, which matched the intrinsic impedance of the brain (about 48.5 ohms at 2.1 GHz) to the impedance of the surrounding air (377 ohms) over most of the irradiated surface of the sphere. These studies also demonstrated that calculations using a homogeneous sphere model of the skull would be in error at frequencies between about 1 and 3 GHz and should not be used in determining potential hazards from equipment operating in this range (e.g., microwave ovens at 2.45 GHz). Studies of microwave interaction with a nerve membrane model, which assumed a power density near the mid-brain of 20 mW/cm^3 (10 mW/cm^2 incident power at 2.1 GHz), indicated that a combined penetration-rectification efficiency of 0.01% would yield 2 mV across the nerve membrane. Membrane rectification, therefore, is a plausible mechanism that could account for responses to microwave irradiation elicited from humans. Studies involving the placement of live nerve cells from the marine gastropod *Aplysia* within a strip transmission line showed changes in regular firing patterns of *Aplysia* neurons at absorbed power levels much less than 20 mW/cm^3, and some of these changes were not reproduced by equivalent heating. For example, in one case microwave irradiation caused a decrease in the time between bursts of a bursting pacemaker neuron (from 12 to 7 sec), while an equivalent amount of convective heating caused an increase in the time between bursts (from 12 to 14 sec). In another case, a beating neuron stopped firing when microwaves were applied, but the firing rate approximately doubled when an equivalent amount of heat was applied. Studies using conventional microelectrodes and nerve cells of *Aplysia* to determine whether or not the nerve membrane rectifies or is nonlinear at microwave frequencies have failed, since microwave signals large enough to produce a detectable output are also large enough to melt the tip of the electrode. (23 refs.)

4885 BIOLOGICAL EFFECTS OF MICROWAVES (A BIBLIOGRAPHY WITH ABSTRACTS). (Eng.) Harrison, E. A., ed. (Natl. Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161). 153 pp.; 1976. [available through National Technical Information Services, PS-76/0387].

A bibliography containing 153 abstracts of literature (1964-1976) covering the biologic effects of microwaves on man and animals is presented. Examples of specific subjects covered include: the effect of radiofrequency radiation on pacemaker operation; cerebral and peripheral circulation in persons handling sources of ultrahigh radiofrequencies; measurements of power density from marine radar; the genetic effects of microwave radiation; effects of electromagnetic radiation on the central nervous system; techniques for protection against electromagnetic superhigh frequency fields; the effects of microwave radiation on the lens of the eye; the effects of low-level microwave radiation on animal behavior; methods for calibrating microwave hazard probes; measurements of absorbed power patterns in animals exposed to microwaves; the effect of microwave fields on peripheral nerves; the biologic effects of locally applied microwaves on the thyroid gland; local heating by microwaves; the action of pulsed versus continuous microwave fields; microwave reflection, diffraction, and transmission studies in man; regulations, standards, and guidelines for microwave radiation; hemodynamic changes in individuals working under microwave irradiation; and hazards associated with the operation of microwave ovens. (153 refs.)

4886 THE DETECTION OF RF DAMAGE TO HIGH MOLECULAR WEIGHT BIOPOLYMERS BY RAMAN SPECTROSCOPY. (Eng.) Cody, C. A.; Modestino, A. J.; Miller, P. J.; Klainer, S. M. (Block Engineering, Inc., 19 Blackstone St., Cambridge, MA 02139); 34 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A 027049].

Raman and infrared spectrometric techniques were investigated as methods of detecting, quantifying, and

diagnosing molecular damage in biologic compounds due to radiofrequency (RF) exposure. Spectrometric studies were made with DNA, DNase, RNase, RNA, and a mixture of DNA and DNase. In all examined solutions, fluorescence from impurities obscured the Raman signal. Because of the limited solubility of all high molecular compounds, the Raman signals remained weak even for highly purified samples, and particulate scattering from suspensions attenuated the laser beam to a sufficiently high degree to significantly reduce the Raman signals. Preliminary studies of the infrared method indicate that useful results can be obtained on RF effects to biologic molecules. Four advantages of the infrared method, which justified the selection of this approach, were: 1) Small levels of fluorescing impurities did not cause a problem in infrared detection. 2) The spectral features of impurities could be ratioed out. 3) The spectral quality of samples prepared by placing thin dry films on wedged AgCl windows was sufficient to monitor RF damage that caused a major disruption in the vibrational spectrum of the biologic samples. 4) The infrared technique allowed study of the RF damage levels as a function of molecular weight because low solubility problems were eliminated due to the high sensitivity of the method. (3 refs.)

4887 MAGNETIC FIELD EFFECTS ON BIRADICAL INTERMEDIATES IN BACTERIAL PHOTOSYNTHESIS (MEETING ABSTRACT). (Eng.) Blankenship, R. E. (Dept. of Biochemistry, Univ. of Washington, Seattle, WA 98195); Schaafsma, T. J.; Parson, W. W. *Biophys. J.* 17(2): 148a; 1977.

Magnetic field effects on biradical intermediates involved in bacterial photosynthesis were studied. The room-temperature quantum yield of flash-induced bacteriochlorophyll triplet formation in chemically reduced reaction centers of the bacterium *Rps. spheroides* (strain R-26) was decreased by 40% upon the application of a 2,000-G magnetic field. A 50% decrease in carotenoid triplet quantum yield was observed in the reaction centers of strain 2.4.1. The field dependence of the effect showed a monotonic decrease, saturating at about 1,000 G. No magnetic field effect was observed on bacteriochlorophyll triplet yield *in vitro* or on P870+ formation in reaction centers at moderate potential. The effect of the magnetic field became less at lower temperatures (15% at 80 Kelvin) where the triplet yield was higher; this agrees with predictions based on a simple kinetic theory. The existence of the magnetic field effect provides strong evidence in favor of a biradical model of bacterial photosynthesis. The sign of the magnetic field effect indicates that the biradical is born in a singlet state. Local magnetic field differences evidently induce singlet-triplet mixing in the biradical, and the triplet states observed in reduced reaction centers arise from biradicals with triplet character rather than via the traditional route of intramolecular intersystem crossing. The magnetic field is interpreted as affecting triplet yields by decreasing the number of biradical triplet states in equilibrium with the singlet state from three at zero-field to one at high field. Equilibration between singlet and triplet levels of the biradical is concluded to be rapid at both zero and high fields. (No refs.)

4888 MICROWAVES, MAGNETIC IRON PARTICLES AND LASERS AS A COMBINED TEST MODEL FOR INVESTIGATION OF HYPERTHERMIA TREATMENT OF CANCER. (Eng.) Goldman, L. (Laser Lab., Dept. Dermatology Medical Center, Cincinnati, OH); Dreffer, R. *Arch. Derm. Res.* 257(2): 227-232; 1976.

Microwave radiation and laser radiation were used to induce tissue hyperthermia in rabbits injected with various iron compounds in skin pockets. The iron compounds were deposited into skin pockets to increase the tissue hyperthermia induced by microwaves. A Rozzel liquid crystal probe was used to measure tissue temperature induced by microwaves and during exposure to microwaves. The average tissue temperature measured after 30 min of microwave (2,450 MHz) exposure ranged from 43.5-54.5°C, depending on the type of iron compound used as compared with 39.0°C when no iron compound was injected into the skin pocket. Tissue temperatures before microwave exposure ranged from 34.2-35.0°C. No direct temperature measurements were done during or after laser impacts. Biopsies taken from the iron depot areas and adjacent normal skin showed diffuse spread of iron particles with globular masses and intracellular iron particles. There was some lymphocytic infiltration and an intense histiocytic response. No thermal coagulation necrosis was observed, except after laser impacts. It appears that with exposure to microwaves a superficial depot of various types of iron particles produced local tissue hyperthermia of significant intensity. (17 refs.)

4889 CENTRAL NERVOUS SYSTEM RESPONSES TO MICROWAVE-INDUCED HEATING. (Eng.) Michaelson, S. M. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 98-100; 1977.

The effect of microwave-induced heating on the central nervous system is discussed. An important consideration in microwave exposure studies is the resonant absorption of microwaves in the skull of many mammals at field wavelengths in the cm range. This may result in the focusing of energy and the production of hot spots in the brain so that the observed effects may relate to higher absorption in such regions as the hypothalamus than in other tissues. This possibility has been considered for mammalian exposures to 3,000-MHz and 10,000-MHz microwaves and to infrared fields. Similar changes in peripheral nerve conduction were seen with all three types of fields, and it was concluded that these effects might be attributable to a thermally induced neurophysiologic response at certain body sites. The irradiation of dogs' heads with 80 mW/cm^2 microwaves 1 hr after the onset of pentobarbital anesthesia caused a slow rise of 1-2°C in skin, tympanic, and rectal temperatures. This increase in temperature was sustained throughout the field exposure period of 1 hr; with focal irradiation of the head,

the tympanic temperature tended to rise above the rectal temperature. A slower rise in rectal temperature suggested a conservation of mean body temperature which persisted after the cessation of microwave exposure. During the exposure, there was an initial increase in average heart rate which resulted in an exaggerated sinus arrhythmia with increased depth of respiration, leading in turn to bradycardia. The ventricular conduction time increased with the respiration rate. Pulmonary arterial pressure remained unchanged during microwave exposure up to 100 mW/cm^2 for 1 hr. There was a tendency for increased pulmonary arterial flow, but this did not correlate with body temperature rise. Mean renal blood flow was slightly depressed at the beginning of the irradiation and then increased. This cardio-respiratory response was interpreted as an early increase in sympathetic activity followed by a parasympathetic response. These findings indicate that when the circulatory system responds inadequately to handle the increasing body temperature, the respiratory system participates to minimize further core temperature increases. (No refs.)

4890 USE OF ARTIFICIAL ELECTROMAGNETIC FIELDS IN MEDICINE. (Eng.) Demetskiy, A. M.; (Dept. of Operative Surgery and Topographic Anatomy, Vietbsk Medical Inst. Ploymya). 13 pp.; 1975. Sobolevskaya, N. P. [available through National Technical Information Services, Springfield, VA 22161, Document No. JPRS-66339].

A survey of literature on the use of artificial electromagnetic fields in medicine is presented. Magnetotherapy (intensities ranging from 50-680 Oe) has been used for the treatment of skin diseases, circulatory disorders, musculo-skeletal pathologies, malignant neoplasms, the adverse effects of gamma irradiation, inflammatory gynecologic sicknesses, and gastrointestinal disorders. Magnetic fields have been used for tissue regeneration and for increasing the anti-infection properties of blood. Magnetic fields are also capable of inducing unique hemodynamic effects, and it has been found that such fields cause a constriction of the vascular lumen. (49 refs.)

4891 PATHOPHYSIOLOGIC ASPECTS OF EXPOSURE TO MICROWAVES. (Eng.) Michaelson, S. M. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

Pathologic effects of microwave exposure are reviewed. If the amount of absorbed energy exceeds the optimal amount of heat energy that can be handled by the mechanisms of temperature regulation in an organism, the excess energy will cause continuous temperature rise with time. Hyperthermia and, under some circumstances, local tissue destruction can result. Cataracts have been produced in some experimental animals, primarily rabbits, when the eyes were directly exposed to high power density microwave fields over periods ranging from several minutes to hours. Isolated reports of microwave-induced cataracts in man have been disputed. In terms of gonad damage, exposure of the scrotal area to high power densities (>250 mW/cm^2) has resulted in varying degrees of testicular damage such as edema, enlargement of the testis, atrophy, fibrosis, and coagulation necrosis of seminiferous tubules in rats, rabbits, or dogs exposed to 2450, 3000, 10,000, or 24,000 MHz. Reports of sterility or infertility in humans from exposure to microwaves are questionable. There is no direct or confirmed evidence for genetic effects due to exposure to radiofrequency or microwave fields. Microwave effects on hematopoiesis have been reported for both experimental animals and humans. Early and sustained leukocytosis in animals exposed to thermogenic levels of microwaves may be related to stimulation of the hematopoietic system, leukocytic mobilization, or recirculation of sequestered cells. Eosinopenia and transient lymphocytopenia with rebound or overcompensation when accompanied by neutrophilia may indicate increased adrenal function. A study of a large group of people occupationally exposed to microwaves revealed that a small drop in the number of erythrocytes occurs in all people exposed to microwaves. A tendency toward lymphocytosis with accompanying eosinophilia is apparent in persons working more than 5 yr under conditions of low and medium microwave exposure. About 50% of persons exposed to microwaves show a moderate drop in platelet number. Functional damage to the cardiovascular system has been observed in workers exposed to radiofrequency or microwave fields; such damage is indicated by hypotonus, bradycardia, delayed auricular and ventricular conductivity, decreased blood pressure, and decreased height of electrocardiogram waves. (79 refs.)

4892 ENDOCRINE AND CENTRAL NERVOUS SYSTEM EFFECTS OF MICROWAVE EXPOSURE. (Eng.) Michaelson, S. M. *In: Agard Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

Studies dealing with the effects of microwave exposure on the central nervous system and endocrine glands are reviewed. Biochemical and physiologic changes, as a result of microwave exposure, have been reported that suggest an adrenal effect. Three and 24 hr after dogs were irradiated with 3000 MHz microwaves (10 mW/cm^2), the corticosteroid content of their blood increased by 100 and 150% of the original level. Reductions in pituitary gland activity were observed in female mice exposed to 3000 MHz (10 mW/cm^2) twice daily for 5 mo. A stimulatory influence of 5 mW/cm^2 of microwave radiation on the trapping and secretory functions of the thyroid gland of rabbits has been reported. Increased radioactive iodine uptake has been observed in dogs exposed to 1,280 or 2,880 MHz pulsed microwaves (100-165 mW/cm^2); this was postulated to be the result of increased thyroid-stimulating hormone due to thermal stimulation of hypothalamic-hypophysial activity. Transient functional changes of the central nervous system have been reported following low level (<10

mW/cm^2) microwave irradiation. Exposure of monkeys to 225-400 MHz has resulted in agitation, drowsiness, akinesia, and eye signs of nervous system disruption as well as autonomic, sensory, and motor abnormalities. Microwave exposure also has been reported to produce alteration in the electroencephalogram (EEG). Stimulation is often followed by increased amplitude and decreased frequency of EEG components or by decreased amplitude and increased frequency. The general character of the observed EEG alterations is constant throughout a wide range of intensities (0.02 to about 100 mW/cm^2). Rats exposed in a closed space situation to 2,450 MHz microwaves (15 mW/cm^2) demonstrated a behavioral state suggesting flaccid paralysis. Humans working in microwave fields of various intensities have complained of a heavy feeling in their heads, headaches, fatigue, drowsiness in the daytime, irritability, poor memory, and heart pain. Individuals subjected to microwave fields of a few mW/cm^2 have exhibited neurasthenic syndrome, autonomic vagotonic dystonia, and diencephalic syndrome. (68 refs.)

4893 METABOLIC RATES IN FIVE ANIMAL POPULATIONS AFTER LONG-TERM EXPOSURE TO SANGUINE/SEAFARER ELF ELECTROMAGNETIC FIELDS IN NATURE. (Eng.) Greenberg, B. (Dept. of Biological Sciences, Univ. of Illinois at Chicago Circle, Chicago, IL 60680). 35 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A024955].

Five species of animals dwelling in or on the soil under the United States Navy's extremely low frequency antennas at a Wisconsin test facility were collected and tested for oxygen consumption and respiratory quotients. The animals belonged to four phyla and comprised: the redbacked salamander, *Plethodon cinereus cinereus* (Green); the woodlouse, *Oniscus asellus* L.; the slug, *Arion* sp.; the earthworm, *Lumbricus terrestris* L.; and the redworm *Lumbricus rubellus* Hoffmeister. Controls were collected 7-13 miles from the antenna site on the same or next day and were tested simultaneously with the exposed group of animals. The antenna current at the test site was 300 A, and the frequencies of operation were 42, 45, and 76 Hz. The magnetic field at the test site ranged as high as 0.053 G; whereas, the magnetic field strength at control sites was below the 1 mG level. The low impedance electric field strength at the test site ranged from 0.005-0.121 V/m and was anywhere from 53-61,200 times that at the control sites. The high impedance electric field strength at the test site ranged from 0.0099-1.9700 V/m and ranged from 180-2,099 times that at the control sites. There were no significant differences in oxygen consumption or respiratory quotients among test animals or controls in any of the five species. Comparisons of metabolic rates between exposed and control groups showed no seasonally linked change in sensitivity to the electromagnetic fields. No abnormalities in behavior, habitat selection, or external features and pigmentation were observed in any of the exposed animals during 4 yr of collection and observation. (13 refs.)

4894 EVALUATION OF POSSIBLE MICROWAVE-INDUCED LENS CHANGES IN THE UNITED STATES AIR FORCE. (Eng.) Shacklett, D. E. (USAF Sch. Aerospace Medicine, Aerospace Medical Div. (AFSC), Brooks Air Force Base, TX 78235); Tredici, T. J.; Epstein, D. L. *Aviation Space Environmental Med.* 46(11): 1403-1406; 1975.

Clinical ophthalmologic examination of 817 subjects revealed no significant differences in the presence or absence of opacities, vacuoles, and posterior subcapsular iridescence between 477 workers in a microwave field and 340 control subjects with no known occupational exposure to microwave irradiation. Among the 340 control subjects, 60% had lenticular opacities visible in the red reflex of the slitlamp at 6 or 10 power, while 56% of the 477 study subjects had this finding. The percentage of totals found positive for vacuoles was identical at 41% for each group. The percentage of individuals found positive for posterior subcapsular irldescence was 62% for controls and 60% for the study subjects. Additional in-depth history was taken from eight study subjects felt to have clinically significant lens changes; however, all but one case had a history of known cataractogenic familial diseases, ocular conditions, or therapeutic treatment (beta irradiation to the eye for recurrent pyerygium). It is concluded that any connection between their lens changes and occupational exposure to microwave radiation is doubtful. (18 refs.)

4895 PROTECTION GUIDES AND STANDARDS FOR MICROWAVE EXPOSURE. (Eng.) Michaelson, S. M. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975 [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

American and foreign standards for personal exposure to microwaves are reviewed along with the basis for such standards. The United States standard of 10 mW/cm^2 for radiofrequency exposure is at least a factor of 10 below thresholds of damage by thermal effects, assuming a long duration of exposure, i.e., 0.25 hr or more. For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm^2, and the equivalent free-space electric and magnetic field strengths are about 200 V/m (root mean square) and 0.5 A/m (root mean square), respectively. For modulated fields, power density and the squares of the field strengths are averaged over any 0.1-hr period; i.e., none of the following levels should be exceeded as averaged over any 0.1-hr period: electric field strength squared--40,000 V^2/m^2 and 0.25 A^2/m^2; power density--10 mW/cm^2; and energy density--1 mW/hr/cm^2. This guide applies whether the radiation is continuous or intermittent and applies to the general public as well as to workers. Personal exposure standards in the USSR specify maximum safe exposure for an unlimited period of time at 0.01 mW/cm^2; 0.1 mW/cm^2 exposure is permitted for a period of 2 hr in a 24-hr period; and up to 1 mW/cm^2 is permitted for 20 min in a 24-hr period.

While the personal exposure standard in the United States is based on the amount of exogenous heat that the body can tolerate and dissipate without any resulting rise in body temperature, the USSR maximum permissible exposures are based on asthenia syndromes reported by workers in the microwave field. There is no documented evidence of injury to military industrial personnel or to the general public from the operation and maintenance of microwave emitting sources within the 10 mW/cm^2 limit of exposure. There is some concern about the safety of personnel in intense radiofrequency fields close to transmitting antennas operating in the frequency bands below 30 MHz. Such environments are in general of a near-field type, which precludes the measurement of power flux. Since hazard evaluation in this frequency range is a function of measurement in the near-field, attention should be paid to the problems inherent in such measurement. (24 refs.)

4896 PROPOSED REVISIONS TO ANSI STANDARD C95.1 FOR EXPOSURE TO RADIO FREQUENCY AND MICROWAVE RADIATIONS. (Eng.) Wellsand, J. A. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A020681].

Proposed revisions to the American National Standards Institute standard C95.1 (Safety Level of Electromagnetic Radiation with Respect to Personnel) are presented. A review of the thermal and possible nonthermal effects resulting from radiofrequency and microwave rediation indicates that the guide number of 10 mW/cm^2 is acceptable as the maximun recommended exposure level for the prevention of human biologic damage. However, it is proposed that the current standard, which covers the frequency range of 10 MHz-100 GHz, be extended to cover the lower frequencies (down to at least 10 kHz). Another change necessary to improve the effectiveness of the standard is to expand the scope of the explanation presented with the exposure levels. A minimum summary of health effects should include the possibility of cataract formation at intensities as low as 10 times the guide number as well as the possibility of temporary and reversible sterility in male subjects. Irreversible damage to cells and tissues as a result of thermal abuse should also be warned against. Finally, a precautionary summary of the possible occurrences of nonthermal biologic effects at power density levels well within the present maximum exposure limit should be included in the explanation portion of the standard. (34 refs.)

4897 EFFECTS OF UNIFORM MAGNETIC FIELDS ON THE BIOELECTRIC RESPONSE OF THE ALGA *NITELLA CLAVATA*. (Eng.) Lin, L.-C. (Ph.D. dissertation, Dept. Physics, Clarkson Coll. Technology, 1976); 134 pp. [available through Xerox University Microfilms, Ann Arbor, MI 48106, Document No. 76-22, 489].

The bioelectric signals from single internodal cells of the alga *Nitella clavata* were studied in uniform magnetic fields ranging in intensity from 40 Oe up to 17,000 Oe. The magnetic field reduced the spike amplitude, the propagation speed, and the excitation threshold, whether the field lines were parallel or perpendicular to the streaming protoplasm of the cell. A magnetic field of just 40 Oe produced the above mentioned effects. In general, the effects were larger for parallel than for perpendicular fields. A statistically significant recovery in the bioelectric behavior of the alga was observed when the cells were exposed to weak fields for short periods of time; however, higher fields affected the cells irreversibly. A dipole flip-flop model of nervous excitation was used to account for many of the phenomena associated with action potentials. (95 refs.)

4898 ELECTROPHORESIS OF CONCANAVALIN A RECEPTORS ALONG EMBRYONIC MUSCLE CELL MEMBRANE. (Eng.) Poor, M. (Dept. Physiology, California Coll. Medicine, Univ. California, Irvine, CA 92717): Robinson, K. R. *Nature* 265(5595): 602-605; 1977.

Fluorescent concanavalin A (con A) labeling showed that an electric field of 4 V/cm grossly redistributed con A receptors along the plasma membranes of cultured embryonic amphibian (*Xenopus laevis*) muscle cells. The redistribution occurred within 4.5 hr, and the receptors (presumably glycoproteins) accumulated on the side of the cells nearer to the negative pole in a way consistent with a passive electrophoretic mechanism. The potential difference produced by the field across a perpendicularly aligned muscle cell (average width of 30 micron) was about 12 mV. Time-course experiments revealed that the con A receptor moved halfway across the surface of the muscle cell in 1-2 hr. After a field as small as 0.2 V/cm (corresponding to a potential difference of 0.6 mV across a 30-µl cell) was applied to a culture for 24 hr, a detectable asymmetry in con A receptors was observed; fields smaller than 0.2 mV/cm did not cause detectable redistribution. Experiments with a field of 4 V/cm were performed in the absence of poly-L-lysine (used to coat the surface of the glass on which the cells were grown) and resulted in the same accumulation of con A receptors on the negative side of the cell after about 4 hr, indicating that the apparent positive charge of the con A receptors was not due to the polycation poly-L-lysine. During two separate experiments in which fluorescent-labeled wheat germ agglutinin was added to cells in a 4 V/cm field for 4.5 hr, less asymmetry occurred than that observed for the con A receptors after 1 hr in the same field; thus the wheat germ agglutinin receptor was either much less charged or much less mobile than the con A receptor. Experiments were also performed in the presence of metabolic inhibitors (10^{-2} molar sodium azide plus 10^{-3} molar dinitrophenol or 10^{-2} molar sodium arsenate plus 10^{-3} molar sodium fluoride plus 10^{-3} molar dinitrophenol). Neither treatment had any effect; similarly, the presence of 5×10^{-6} molar colchicine throughout the experiment had no effect on the redistribution. Moreover, when calcium cation was omitted from the medium during the application of the field, the redistribution proceeded as in the normal calcium medium. It is concluded that the observed redistribution of the con A

receptors appears to be a passive response of these molecules to the electric field. (19 refs.)

4899 CATION BINDING MODELS FOR THE INTERACTION OF MEMBRANES WITH EM FIELDS. (Eng.) Kaczmarek, L. K. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 54-60; 1977.

Cation binding models derived from experiments investigating the interaction of biologic membranes with electromagnetic fields are discussed. The effects of weak (0.8 mW/cm^2) very high frequency (VHF) fields on calcium exchange in the neonate chick cerebral hemisphere were studied *in vitro*. There was a progressive increase in calcium efflux from the brain exposed to fields modulated at 6 Hz (10.1%), 9 Hz (14.3%), 11 Hz (16%), and 16 Hz (18.5%). These effects gradually declined at higher frequencies, with fields modulated by 20 Hz leading to an increase in calcium efflux amounting to 9.5%. There was no significant change in comparison with untreated control brains for unmodulated signals and for modulation frequencies higher than 25 Hz or lower than 6 Hz. Identical results were obtained after incubation of specimens with sodium cyanide (10^{-4} molar), suggesting that the increased calcium efflux seen after exposure to a specific range of modulation frequencies could be initiated in the polyanionic macromolecular material of the cell surface where fixed charge distribution is relatively unaffected by metabolic inhibitors. The potential of the above extra low frequency (ELF) field components to modify calcium exchange was subsequently tested in a series of *in vitro* experiments involving chick and cat cerebral tissues exposed to ELF fields. Exposure to ELF fields at 1, 6, 16, 32, and 75 Hz at peak gradients of 5, 10, 56, and 100 V/m resulted in a general trend toward reduction in the release of calcium cation. Both frequency and amplitude sensitivities were observed, with maximum decreases occurring at 6 and 16 Hz. Thresholds were around 10 V/m and 56 V/m in chick and cat tissues, respectively. For both ELF and radiofrequency fields, the evidence indicates maximal sensitivity at biologic frequencies. The opposite effects of the two types of irradiation (increase versus decrease of calcium ion for VHF versus ELF fields) may be due to differing strengths of the incident fields. It is suggested that calcium binding in neural membranes exhibits limit-cycle behavior due to the reaction steps being maintained far from chemical equilibrium; weak external perturbations could therefore easily disrupt the electrochemical balance. The narrow frequency range evidenced in weak field interactions does not support a molecular or dipole moment interaction at, or close to, equilibrium. (No refs.)

4900 NAVY SPONSORED ELF BIOLOGICAL AND ECOLOGICAL RESEARCH SUMMARY (UPDATE). (Eng.) Anonymous. (PME 117 Special Communications Project Office, Naval Electronic Command, Dept. of the Navy, Washington, DC). 72 pp; 1976. [Available through National Technical Information Services, Document No. AD A027061].

Navy sponsored biologic/ecologic research studies initiated to determine the effects of electromagnetic fields in the extremely low frequency (ELF) range are summarized. General research areas covered include: physiology, biochemistry, animal behavior, growth and development, biorhythm research, human performance, genetics, ecologic research, and research relating to cardiac pacemakers and ELF coupling to biospheres. Most of the studies summarized were conducted at electric and/or magnetic field levels in excess of the ELF system levels of 0.07 V/m and 0.2 G associated with the Navy's ELF submarine communications system. To date, the results of these studies show no significant adverse effects on humans, animals, plants, or microorganisms at electromagnetic field levels to be used for an operational ELF system. (57 refs.)

4901 ATOMIC AND MOLECULAR MECHANISMS UNDERLYING BIOLOGICAL INTERACTION WITH EM RADIATION. (Eng.) Illinger, K. H. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 64-66; 1977.

Mechanistic considerations underlying the interaction of biopolymer systems with electromagnetic radiation are discussed. A variety of molecular interactions are reviewed for typical biologic molecular systems, and it is shown that secondary and tertiary structures of biologically important molecules, particularly biopolymers, are strongly determined by intermolecular forces. A multitude of configurations of the isolated molecule can occur by internal rotation about carbon-carbon, carbon-nitrogen, and carbon-oxygen bonds. Consequently, there exists a large set of conformations having slightly different energies for a biopolymer. Each component has a slightly different stability that depends on its intermolecular environment. Since the energies of molecular interaction and the energies attributable to interaction of the molecule with the electromagnetic field are not accurately known, it is necessary to consider the case where both molecular interactions and field interactions with the molecules are small compared with their intrinsic energy levels. The system energy is then treated within the framework of perturbation theory, and solutions to the time-dependent Schroedinger equation are derived. For complex molecules, this equation can be solved with fair accuracy, although the computational effort increases rapidly with the total number of electrons in the molecule. (No refs.)

4902 EFFECT OF HIGH-FREQUENCY ELECTROMAGNETIC OSCILLATIONS ASSOCIATED WITH TASHKENT MINERAL WATER ON THE PANCREATIC FUNCTION IN PATIENTS WITH CHRONIC COLITIS. (Rus.) Nikoriukina, I. P. (N. A. Semashko Uzbek Scientific Res. Inst. Balneology Physiotherapy, Tashkent, USSR). *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (2): 14-17; 1976.

The effect of inductothermia and microwave irradiation in association with Tashkent mineral water on the pancreatic function was studied in 152 patients with chronic colitis with disturbances in the pancre-

atic function. The patients received 8-10 treatments of 10 min each (microwave irradiation) or 15 min each (inductothermia) every other day. "Luch-58" apparatus was used for microwave irradiation at 40 W, with a gap of 6-7 cm. DKV-2 apparatus with an anode current of 180-200 mA was used for inductothermia; the gap between the inductor disc and the mesogastrium was 1-2 cm. Microwave irradiation and inductothermia normalized the pancreatic function and the biochemical parameters, such as the synthesis and secretion of lipase, diastase, and trypsin, the blood diastase, and sugar levels in 32.6% and 41% of the microwave and inductothermy patients, respectively. (6 refs.)

4903 ORIENTATION OF ACTIN AND MYOSIN FILAMENTS IN INTERMEDIATE STRENGTH MAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Houk, T. W. (Dept. Physics, Miami Univ., Oxford, OH 45056); Smith, T. A. *Biophys. J.* 17(2): 296; 1977.

The orientation of actin and myosin filaments in intermediate strength magnetic fields was studied to investigate the possibility that, due to their structure, thin and thick filaments may individually possess sufficient susceptibility to be aligned by magnetic fields in solution. Changes in filament orientation were monitored by observing changes in form birefringence. (4 refs.)

4904 HEAT IN TUMOR THERAPY (LETTER TO EDITOR). (Eng.) Hahn, G. M. (Stanford Univ. Medical Center, Stanford, CA); Boone, M. L. *JAMA* 236 (20): 2286; 1976.

A report describing the treatment of 21 cancer patients with radiofrequency-induced hyperthermia is critically analyzed. The clinical results reported, although anecdotal, are cited as being consistent with the conclusion that if the temperature of tumors is elevated above the thermal death point for tissue, necrosis will result. This is the basis of electrocautery, and these results should not be confused with hyperthermic cancer therapy in the range of 42-45°C in which the destruction of tumor cells can be achieved without necrosis. The report asserts that the tumor temperature was 8-10°C higher than that of the normal adjacent tissue; however, any reasonable assumption regarding tissue conductivity and blood flow indicates that such high temperature gradients would violate basic laws of thermodynamics. In more than 100 measurements of tumor temperatures during ultrasound, microwave, or radiofrequency heating, the authors of the present paper have never seen temperature gradients over periods of minutes of greater than 1-2°C. One possible explanation of the reported findings might be that the tumor temperature was measured in tumors containing large necrotic volumes. Presumably because of almost total lack of blood flow, such necrotic volumes could rise substantially in temperature above their more distant surroundings. However, such readings would be meaningless because the ultimate survival of the tumor is determined not by the temperature of the necrotic tissue but by the lowest tumor temperature. The report fails to describe the technique used to measure tumor temperature, and it is well known that accurate measurement of temperature in the presence of a radiofrequency field is full of technical pitfalls. The validity of low tumor blood flow measurements recorded after radiofrequency therapy is also questioned. (5 refs.)

4905 HEAT IN TUMOR THERAPY: AUTHOR'S REPLY (LETTER TO EDITOR). (Eng.) LeVeen, H. H. (Veterans Admin. Hosp., Brooklyn, NY); *JAMA* 236(20): 2286-2287; 1976.

The use of radiofrequency-induced hyperthermia for the treatment of 21 cancer patients is discussed. The technique involved both dielectric and inductive heating of tissue and was clearly different from electrocoagulation and electrocautery. Temperatures in the tumor reached 44-48°C during therapy, with the temperature in the center of the tumor sometimes exceeding these values. Temperature measurements were made by the method of Lehmann *et al.* and by the use of thermocouples. Problems with radiofrequency filtration during temperature measurements were overcome by the use of commercial filters and shielded lead wires. Excellent results were achieved with lung tumors, and these results could not have been predicted by any animal models or theoretic considerations. There are no laboratory animals that have the same chest configuration and the same electrical impedance as the human chest. With regard to diminished blood flow after radiation, it is emphasized that although acute reactions in highly radiosensitive tissues are initiated before radiation-induced vascular changes become apparent, late reactions are almost entirely secondary to radiation-induced vascular changes. (5 refs.)

4906 ELECTROMAGNETIC INTERFERENCE OF CARDIAC PACEMAKERS. (Eng.) Mitchell, J. C. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

The effect of electromagnetic radiation (EMR) on cardiac pacemakers is discussed. Reported threshold values for pacemaker electromagnetic interference (EMI) range from 10 V/m for the more sensitive devices to greater than 300 V/m for the less susceptible devices. Maximum interference coupling appears to occur at frequencies between 100 and 500 MHz, and the EMI threshold is inversely proportional to pulse width over the range from 1 μsec to several msec. The ultimate biologic effect is dependent on the characteristics of the radiation source, the proximity of the pacemaker user to the source, the attenuation afforded by body shielding and orientation, and the state of health of the pacemaker user. Many pacemakers in common use several years ago exhibited serious disruption by second modulation (0.5-10 Hz) signals emitted by microwave ovens. The EMR emission from various electrical appliances (drills, saws,

food mixers, hair dryers, razors, vacuum cleaners) can cause pacemakers to exhibit reversion to fixed rates, inhibition (cutoff), and tachycardia. However, in almost all such cases the pacemakers must be within about 0.5 m of the source to be adversely affected. Many different types of high power EMR emitters ranging from television transmitters to radar can produce pacemaker interference. Typical of such emitters are the air route surveillance radars that produce sufficiently intense EMR signals at ground level to disrupt some pacemakers at distances of 300 m or more from the antenna. Pacemakers do not appear to be seriously disrupted by electromagnetic pulse facilities. Adverse effect thresholds are tabulated for 23 commercial pacemakers. (19 refs.)

4907 BIOPHYSICAL CHARACTERISTICS OF ELECTROMAGNETIC FIELDS. PROBLEMS OF DOSIMETRY AND DOSIMETRIC TECHNIQUES. (Eng.) Guy, A. W. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 81-88; 1977.

Problems of microwave dosimetry in biological preparations are reviewed. A prime problem is the distortion of the microwave field by the introduction of metallic measuring devices, either on the surface of the test subject or in its interior. Another problem in microwave tissue dosimetry concerns the size and shape of the bodies of small laboratory animals with respect to the wavelength and orientation of the incident microwave energy. For small objects measuring approximately 3 cm in diameter, exposure at a frequency of 2,450 MHz leads to a specific absorption rate (SAR) of energy as high as 4.8 W/kg. This contrasts with a typical metabolic energy production in tissue of 1-2 W/kg. In experiments simulating the human head as a body 15 cm in diameter, a 2,450-MHz microwave beam has been shown to be rapidly absorbed at the surface of the head with a maximum SAR of 2.0 W/kg for an incident power density of 1 mW/cm^2. Because of these measuring problems, the evaluation of the thermal effects of a microwave field requires that increased tissue temperature be measured independently of any effects of the field on the temperature measuring device. One such approach involves the use of an implanted hollow glass probe into which a thermocouple may be inserted transiently before and after radiation. A further development in miniature implantable temperature measuring devices involves a small fluid crystal sensor connected by a fiber optic system to external photoelectric measuring equipment. To overcome problems in accurately evaluating energy absorption in whole bodies of large test subjects, such as, man, as well as in very small animals, such as, insects, a miniature scale model of the human body or a large-scale model of an insect can be substituted for the actual object, providing that they have appropriate electrical characteristics to simulate body structure. For example, when man is represented by a model reduced by a scaling factor of 4.6 and exposed to fields at a frequency of 144 MHz, the thermographically measured absorbed energy patterns will be identical to those for a full scale man exposed to 31-MHz fields. (No refs.)

4908 INTERACTIONS BETWEEN INTRINSIC MEMBRANE PROTEIN AND ELECTRIC FIELD (MEETING ABSTRACT). (Eng.) Stevens, C. F. (Dept. Physiology, Yale Univ. Sch. Medicine, New Haven, CT 06510). *Biophys. J.* 17(2): 264a; 1977.

The interaction of imposed electric fields and membrane proteins was analyzed using the techniques of nonequilibrium statistical mechanics. The analysis revealed that the rate at which a membrane protein makes the transition from one of its conformational states to another depends exponentially on $m(V)\cdot V$, where V is the membrane potential and $m(V)$ is the normal component of a quantity called the equivalent dipole moment change of the protein. The quantity $m(V)$ contains all complications arising from protein-membrane interactions and non-constancy of the membrane field. The $m(V)$ may depend on V; i.e., the equivalent dipole in general shows polarization. The precise voltage dependence of $m(V)$ must be determined experimentally, but it is shown that in at least two instances $m(V)$ can be described by the Debye low field approximation. The study of electric field-induced changes in membrane protein conformation is relevant to understanding the physical mechanisms underlying the nerve impulse because the gating behavior described by the Hodgkin-Huxley equations presumably reflects such field driven conformational changes. (No refs.)

4909 THE EFFECT OF THE ELECTRICAL ULTRAHIGH-FREQUENCY FIELD ON THE COAGULATION OF ANIMAL BLOOD. (Rus.) Rusyayev, V. F. (Chair of Physics, Medical Inst., Chita, USSR); Mulundina, G. I. *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (4):76-79, 1976.

Blood-clotting changes in 10 experimental and 8 control rats exposed to an electrical ultra-high frequency field were studied. The experimental group received 80 V/min over 10 days at 5 min/day. Blood was withdrawn from the animals' hearts by puncture, and erythrocyte sedimentation rate, hemoglobin, erythrocyte and leukocyte counts, and viscosity were determined. The blood was then centrifuged to obtain plasma, which was used to establish recalcification and thrombin times, prothrombin factor, fibrinolysis in the blood of both animal groups, and the effect on the clotting indicators of tissue extract homogenates (left ventricle and aorta). While hemoglobin content, viscosity, and erythrocyte count were lowered, leukocyte count and erythrocyte sedimentation rate increased compared with controls. Changes in the clotting process appeared as a significant rise in thromboplastic activity indicating increased antiheparin activity. Both tissue extracts showed a significant decrease of coagulating activity with higher recalcification times, lowered prothrombin factor, and slower fibrinolysis. These observations suggested that the mechanism responsible for the changes was the ultra-high frequency field, which altered the structure of the cell membrane through the dissociation of a thromboplastic phospholipid-protein link and the phospholipids subsequently entering the bloodstream. (8 refs.)

4910 MICROWAVE IRRADIATION, BEHAVIORAL AND OCULAR EFFECTS ON RHESUS MONKEYS (MEETING ABSTRACT). (Eng.) McAfee, R. (Res. Dept., Veterans Admin. Hosp., New Orleans, LA 70146); Cazenavette, L.; Shubert, H.; May, J.; Elder, S. T.; Gordon, R. *Biophys. J.* 17(2): 145a; 1977.

The behavioral and ocular effects of 9.3 GHz pulsed microwave radiation on four adult rhesus monkeys were investigated. The monkeys were trained to lever press for fruit juice from a plastic tube delivered on a 20% variable schedule. During a 20-min session, the monkeys were allowed to respond for 5 min without being irradiated and were then irradiated over the face and eyes when drinking from the plastic tube. Each irradiation session lasted 15 min. The animals were allowed to cease lever pressing and withdraw from the radiation if they so desired. Infrared irradiation sessions were interspersed with microwave sessions for comparison. Although the lever press rate was suppressed as the dose of infrared radiation increased, microwave irradiation up to an intensity of 495 mW/cm^2 for 15 min had no effect on the animal's behavioral response. Ocular effects, such as, lenticular opacity formation, were not seen after 2 yr of observation. (No refs.)

4911 LONG-WAVELENGTH ANALYSIS OF ELECTROMAGNETIC POWER ABSORPTION BY PROLATE SPHEROIDAL AND ELLIPSOIDAL MODELS OF MAN. (Eng.) Massoudi, H. (Ph.D. dissertation, Univ. Utah, 1976) 218 pp.; 1976. [available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 76-15,57?].

An electromagnetic (EM) field perturbation technique is used to obtain the induced fields and associated power deposition in both prolate spheroidal and ellipsoidal models of man and experimental animals irradiated by an EM plane wave (the wavelength is long compared with the major axis of the spheroid or ellipsoid). Calculations of the power absorbed by both spheroidal and ellipsoidal models of man and animals are given for different frequencies and orientations of the models with respect to the incident field vectors. The results show that the induced fields and the absorbed power in the two models are strong functions of frequency, size, and orientation with respect to the incident EM field vectors. In the ellipsoidal model, for a given plane wave, the strongest absorption was found when the incident electric field vector was parallel to the longest axis and when the incident magnetic field vector was parallel to the shortest axis of the ellipsoid. The validity of the perturbation theory was checked by comparison of the data obtained by it with data obtained from the extended boundary condition method (EBCM) and with data obtained from Mie solutions for spheres. Within the long wavelength range, the data obtained from the perturbation technique were in excellent agreement with those from both the EBCM and the Mie solutions. Comparisons of the calculated data with preliminary experimental data on monkeys also showed good agreement. An investigation of the effects of tissue anisotropy on power absorption in planar and spherical models revealed that marked differences in tissue absorbed power can occur due to tissue anisotropy at frequencies below 10 MHz. The quantitative data from this study are useful for estimating tissue EM power absorption in experimental animals and man and for extrapolating EM induced effects measured in animals to those expected in man. (93 refs.)

4912 BIOLOGICAL RISKS IN THE ELECTROMAGNETIC ENVIRONMENT OF AEROSPACE ACTIVITIES. (Fre.) Martin, A. V. J. (Dept. Development and Technology, European Space Res. Technology Center, Noordwijk, Netherlands). *L'Aeronautique et l' Astronautique* (61): 53-72; 1976.

In the aerospace research environment, personnel are exposed to sources of electromagnetic radiation ranging from 30 kHz to 30 GHz. Equations and graphs are presented that establish the hazard limits for exposure to various types of antennae, telecommunication and radiodiffusion emitters, televisions, and radar present in the aerospace research environment. Damaging effects to humans can be either thermal, consisting of overheating of body tissue; or biological, consisting of biochemical, morphological, genetical, and psychological alterations. Thermal effects only are studied here. The electric macroscopic properties of biologic tissue, such as, muscle, fat, bone, and blood are described. The propagation and absorption of electromagnetic waves in biologic tissue and the transmission and reflection of the waves at the interface, which separates two media of different electromagnetic characteristics, are discussed, and the amount of absorbed energy presented graphically. Values for all parameters involved in tissue-radiation interactions are presented graphically for the frequency range of 25 MHz to 8,500 MHz and for various angles of incidence. (8 refs.)

4913 TWO MICROWAVE BIOLOGICAL EFFECTS EXPERIMENTS: HEART RATE AND MYOTATIC REFLEX OF FROGS. (Eng.) Piontek, G. E. (Ph.D. dissertation, Univ. Michigan, 1976); 109 pp. [available through Xerox University Microfilms, Ann Arbor, MI 48106, Document No. 76-19,217].

To study the effects and mechanisms of action of microwaves and the nervous and cardiovascular system the heart rates of six pithed or anesthetized leopard frogs (*Rana pipiens*) were exposed to 2.45 GHz microwave energy. The heart rate data were reduced to time interval histograms, and separate histograms were obtained for the microwave on and off data. These histograms revealed no consistent changes in heart rate during radiation. The myotatic reflex of frog's gastrocnemius muscle was also studied in 20 frogs irradiated with 1.2 GHz. Alternate 5-min off and on irradiation periods were administered over a total experimental time span of 55 min. In each 5-min period ten reflexes were elicited. The power density was calculated to be about 13 mW/cm^2. The reflex parameters analyzed were the peak reflex tension and the latency to one-half peak reflex tension. The results from the paired t-test indi-

cated that both peak and latency decreased significantly (0.05 level) during microwave exposure. The effects observed are consistent with those expected from heating. Two sham experiments were also performed. These data, when contrasted with the irradiated data, enforce the view that the effects observed were due to the radiation. (52 refs.)

4914 BIOLOGICAL EFFECTS OF HIGH VOLTAGE ELECTRIC FIELDS: BIBLIOGRAPHY AND SURVEY OF ONGOING WORK, 1975. (Eng.) Bridges, J. E. (IIT Res. Inst., Chicago, IL). 320 pp.; 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. PB 247 455].

A bibliography and survey of ongoing research concerning the biologic effects of electric fields from overhead high-voltage power transmission lines is presented. Approximately 800 citations are noted, some with abstracts, and about 80 ongoing research efforts are identified. The following subject areas are emphasized: the biologic effects of alternating current (AC) power line fields between frequencies of 45-75 Hz, the biologic effects of direct current electrostatic fields, and the influence of AC power line fields and radiofrequency wave fields on patients with implanted cardiac pacemakers. (800 refs.)

4915 PERTURBATION EFFECT OF ANIMAL RESTRAINING MATERIALS ON MICROWAVE EXPOSURE. (Eng.) Lin, J. C. (Dept. Electrical Engineering, Wayne State Univ., Detroit, MI 48202); Bassen, H. I.; Wu, C.-L. *IEEE Trans. Biomed. Engineering* BME-24(1): 80-83; 1977.

Theoretic and experimental studies of the scattered fields produced by rectangular Plexiglas slabs of the thickness and width found in animal restrainers, which are used in research on microwave biologic effects, are reported. In the theoretic studies, the incident microwave radiation was assumed to be a uniform plane wave, and the slabs were taken to be infinitely long. The theoretic solution involved obtaining a set of linear equations for the induced fields inside the slab; the equations were solved using a large digital computer to give the field outside the Plexiglas slab. During the experimental part of the study, a good approximation of a plane wave field was generated in a high-performance anechoic chamber containing a 2,450 MHz source driving a 200-W amplifier, which was fed into a truncated pyramidal horn antenna. A Plexiglas sheet of 6 mm x 0.13 m x 1.21 m was used to simulate the basic components of an animal holder; the 1.21-m length was chosen to approximate an infinitely long slab. It was experimentally demonstrated that the perturbation produced by a slab paralled to the direction of propagation is at least as great as that for the normal alignment case. Moreover, the maxima for the parallel case always occur alongside the slab's widest surface rather than in front of the slab, as is the case with the normal orientation. Good agreement was obtained between the theoretic model and the experimental results. It appears that for minimal perturbation by an animal holder, constructed with Plexiglas or equivalent materials, the longest and broadest face of the holder should be oriented normal to the direction of propagation. (5 refs.)

4916 ON EMP SAFETY HAZARDS. (Eng.) Guy, A. W. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

Possible criteria for setting electromagnetic pulse (EMP) safety standards are theoretically evaluated. The only two quantitative criteria presently available for setting EMP safety standards are the ANSI C95.1 safety standard based on limiting thermal insult at microwave frequencies and the thresholds for the stimulation of excitable membranes by electric current, i.e., guidelines pertaining to electrical shock. The first criterion is not realistic for application to EMP, since the induced currents and energy deposition in exposed tissue is not based on an applied field amplitude and duration relationship but is related only to the rise and fall time of the applied field pulse. The induced currents in the tissues of man exposed to impulsive electromagnetic fields do not appear to be sufficient for stimulating action potentials. For impulsive fields such as EMP, it is recommended that more attention be given to the rate of change of the field rather than to the width or peak amplitude of the field in establishing safety standards. (9 refs.)

4917 LONG-WAVELENGTH ANALYSIS OF PLANE WAVE IRRADIATION OF AN ELLIPSOIDAL MODEL OF MAN. (Eng.) Massoudi, H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H.; Johnson, C. C. *IEEE Trans. Microwave Theory Techniques* MTT-25(1): 41-46; 1977.

A long-wavelength analysis of electromagnetic (EM) plane wave (perturbation technique) is applied to analyze the internal fields in an ellipsoid for each of the six major orientations of the incident fields with respect to the ellipsoid. Expressions for average absorbed power and power distributions inside the ellipsoid are given. Expressions for the internal fields and specific absorbed power as well as the curves of specific absorbed power versus frequency showed that the internal electric fields and the specific absorbed power depended on the body's dielectric properties and geometry as well as on the frequency and polarization of the incident wave. A comparison of the theoretic specific absorbed power in prolate spheroidal and ellipsoidal models with corresponding experimental data on live monkeys indicated that the prolate spheroidal models were not adequate for primates; however, they might be adequate for rodents, since the cross sections taken normal to the long axis for these primates appeared to be approximately circular. For primates with approximately elliptical cross sections, the ellipsoidal model offered a superior representation. The results of this analysis showed marked differences

in electromagnetic absorption characteristics between man and animals at the same frequency and same incident field level; therefore it will be necessary to relate the biologic effects to the internal fields or power absorption and then relate the internal fields or power absorption to the incident fields in extrapolating animal effects to man. (9 refs.)

4918 ELECTROMAGNETIC FIELDS INDUCED INSIDE ARBITRARY CYLINDERS OF BIOLOGICAL TISSUE. (Eng.) Wu, T.-K. (Dept. Electrical Engineering, Univ. Mississippi, University, MS 38677); Tsai, L. L. *IEEE Trans. Microwave Theory Techniques* MTT-25(1): 61-65; 1977.

The electromagnetic field induced inside arbitrarily shaped cross-sectioned cylinders of biologic tissue is analyzed by surface integral equations and moment method techniques. A TM or TE plane wave was the illumination source, and the cylinders consisted of bone or muscle, which might be multilayered. The integral equations were of the surface type and were derived via Maxwell's equations, Green's theorem, and boundary conditions. Surface and interior fields for both a one-layer and two-layer circular cylinder were found to have excellent agreement with the exact eigenfunction expansion results, thus validating the numeric method. Results are presented for arbitrary cross-sectioned cylinders, including an arm model composed of an elliptical outer muscle layer and a circular bone at the center. The field plots throughout the cylinder interior are useful in microwave hazard diagnostics. (20 refs.)

4919 MIGRATING BIRDS RESPOND TO PROJECT SEAFARER'S ELECTROMAGNETIC FIELD. (Eng.) Larkin, R. P. (Rockefeller Univ., New York, NY 10021); Sutherland, P. J. *Science* 195(4280): 777-779; 1977.

Radar tracking of individual migrating birds flying at night over a large alternating current antenna system showed that the birds turned or changed altitude more frequently when the antenna system was operating than when it was not. The alternating current source was a sinusoidal oscillator (72-80 Hz) connected to two orthogonal dipole antennas oriented approximately north-south and east-west. At distances of 100-400 m from the antenna system, the calculated electric field generated by the antenna was about 0.07 V/m in air. The calculated magnetic field at these distances ranged from about 0.1-0.5 μtesla. The birds were tracked at low altitudes ranging from 80-300 m above the ground. When the antenna system was not operating, a total of 157 linear flights and six nonlinear flights were recorded. In contrast, when the antenna system was turned on, there were 204 linear and 28 nonlinear flights recorded. When the antenna system was operating in a condition involving current changes (from 0-75 A or 75-0 A), the percentage of nonlinear flights (28%) increased still further, with 21 nonlinear and 53 linear flights being recorded. Neither wind condition nor cloud cover appeared to account for the occurrence of responses on at least some of the nights when the birds were tracked. The results imply that some birds can sense low-intensity, alternating-current electromagnetic fields during nocturnal migratory flight. (14 refs.)

4920 COCHLEAR MICROPHONICS GENERATED BY MICROWAVE PULSES. (Eng.) Chou, C.-K. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine RJ-30, Univ. Washington, Sch. Medicine, Seattle, WA 98195); Galambos, R.; Guy, A. W.; Lovely, R. H. *J. Microwave Power* 10(4): 361-367; 1975.

Oscillations at a frequency of 50 kHz were recorded from the round window of guinea pigs exposed to irradiation by 918-MHz pulsed microwaves (1-10 μsec pulse duration, 100-Hz pulse repetition rate). Five anesthetized guinea pigs were placed into cylindrical circular waveguides (standing wave ratio of 1.04) and were irradiated intermittently for durations of 1.5 min at various peak power levels below 10 kW. The average absorbed energy per pulse was 1.33 J/kg. After a 3-5 hr experiment, the animals were killed, and the response recording was continued until the physiologic potentials disappeared completely. The 50-kHz oscillations promptly followed the stimulus, outlasted it by about 200 μsec, and measured 50 μV in amplitude. The threshold energy for producing the microwave auditory effect was 20 mJ/kg, which is of the same order of magnitude as the threshold energy of 16 mJ/kg for the human head. The induced oscillations preceded the auditory nerve's response and disappeared with death; they were interpreted to be a cochlear microphonic. Since the cochlear microphonic elicited by microwave irradiation was followed by auditory nerve activity after an interval of time that closely resembled that seen in the acoustically stimulated ear, it is reasonable to assign this event to activation of the cochlear hair cells. (11 refs.)

4921 METAL ION CONTENT OF SPECIFIC AREAS OF THE RAT BRAIN AFTER 1600 MHZ RADIOFREQUENCY IRRADIATION. (Eng.) Chamness, A. F. (Radiobiology Div., USAFSAM, Brooks Air Force Base, TX 78235); Scholes, H. R.; Sexauer, S. W.; Frazer, J. W. *J. Microwave Power* 11(4): 333-338; 1976.

Changes in brain metal ion content were studied in male Sprague Dawley rats who were exposed to either a hyperthermal environment (80°C for 10 min) or 1,600 MHz radiation (80 mW/cm^2 for 10 min) to achieve an equivalent rectal temperature of 4°C. Increased iron levels were found in several brain areas of both experimental groups of animals. The levels (in μmoles/g dry tissue) in the hypothalamus, corpus striatum, midbrain, hippocampus, cerebellum, medulla, and cortex of irradiated animals were 3.55 ± 1.33, 1.75 ± 0.22, 2.51 ± 0.62, 1.78 ± 0.21, 1.84 ± 0.20, 1.58 ± 0.18, and 1.98 ± 0.56, respectively; the corresponding values for rats in the hyperthermal environment were 2.41 ± 0.48, 1.74 ± 0.26, 2.12 ± 0.25, 1.63 ± 0.15, 1.91 ± 0.26, 1.66 ± 0.19, and 1.97 ± 0.41, respectively. Control levels were 1.87 ± 0.38,

1.41 ± 0.24, 1.67 ± 0.21, 1.41 ± 0.22, 1.60 ± 0.19, 1.35 ± 0.18, and 1.63 ± 0.27, respectively. Copper was increased in the cortex of both groups: 0.207 ± 0.024 for irradiated rats and 0.210 ± 0.029 for hyperthermal rats as compared with a control value of 0.195 ± 0.024. Zinc was decreased in the hypothalamus of the hyperthermal group, being 0.716 ± 0.174 as compared with 0.918 ± 0.080 for controls and 0.806 ± 0.137 for irradiated rats. Sodium was decreased in the cortex of the hyperthermal rats, being 227.5 ± 18.0 as compared with a control value of 242.6 ± 29.5 and a value of 248.2 ± 9.59 for irradiated rats. Magnesium was increased in the cortex (33.0 ± 1.2) and medulla (26.7 ± 1.3) of irradiated rats; the corresponding control values were 31.8 ± 2.1 and 25.4 ± 1.2, respectively, while those for hyperthermal rats were 31.6 ± 2.6 and 26.0 ± 1.3, respectively. The increases in metal ions observed, especially in the case of iron, suggest vascular changes that occur in response to physiologic adjustments to an imposed heat load. The decrease in zinc seen in the hypothalamus of the hyperthermal group may signal an increase in protein synthesis. Overall, the changes in metal ion distribution observed after exposure to 1,600 MHz radiation are probably the result of concomitant hyperthermia, since most of the alterations observed in irradiated rats were also observed in rats exposed to the hyperthermal environment. (9 refs.)

4922 RF FIELD INTENSITY MEASUREMENTS IN SELECTED BROADCAST FACILITIES. (Eng.) Wang, J. C.; Linthicum, J. M. (Technical Memorandum, Federal Communications Commission, 1976) 7 pp. [available through Research and Standards Div., Federal Communications Commission, Washington, DC 20554].

Power density and field strength measurements were made in or near four typical transmitting stations licensed by the Federal Communications Commission to obtain information concerning the highest levels of electromagnetic radiation that exist in such areas, particularly near human activity. Power density measurements made near a television translater, operating at a frequency of 704-710 MHz and radiating 1,000 W through a parabolic dish, ranged from 0.3 mW/cm^2 near the front of the transmitter to more than 10 mW/cm^2 at 1 foot below the front of the dish. At the site of a television transmitter (Empire State Building) operating on channel 31 with a visual power of 890 kW, power density readings ranged from negligible inside the transmitter room to more than 10 mW/cm^2 near the antenna. Readings as high as 0.5 mW/cm^2 were obtained on an observation deck (102nd floor) used by the general public. Field strength readings taken at a radio station broadcasting on 1,500 kHz (power not specified) ranged from 8.64 V/m at a distance of 50 feet from one of the antenna towers to 945.0 V/m at the base of two towers and at a distance of about 2 feet from the output transmission line. Field strength measurements at a 50-kW radio station broadcasting on 1,090 kHz ranged from 4.4 V/m near the front panel of the transmitter cabinet to 5,440 V/m about 2 feet from the antenna loading coil. (5 refs.)

4923 POWER DENSITY IN NEAR FIELD OF SMALL LINEAR ANTENNAS. (Eng.) Wang, J. C. (Technical Memorandum, Federal Communications Commission, 1976) 13 pp. [available through Applied Propagation Branch, Federal Communications Commission, Washington, DC 20554].

A theoretic analysis of the power density in the vicinity of a small linear antenna emitting nonionizing radiation is presented, with emphasis on the near field. Equations are derived for the time-average power density in the near and far fields and for the maximum possible power density in the near field. The theoretic results are compared with measurements made on a walkie-talkie operating on a frequency of 415 MHz, which radiates 1.26 W of power from an antenna 4.57 cm in height. The calculated and measured results agreed quite well in the far field (less than 1 dB apart) and reasonably well in the outer part of the near field (about 3 dB apart). However, agreement became progressively worse as the field radius decreased. This increasing inaccuracy resulted from the fact that the latest commercially available power density meter was better when used in the far field and also to the fact that as the radius approaches 0, the antenna could no longer be considered small. (10 refs.)

4924 INDUCED EM FIELD AND ABSORBED POWER DENSITY INSIDE HUMAN TORSOS BY 1 TO 500 MHZ EM WAVES. (Eng.) Chen, K.-M. (Div. Engineering Res., Michigan State Univ., East Lansing, MI 48824) 184 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. PB-254 247].

Numeric results on the internal electromagnetic field and absorbed power density inside a human torso induced by electromagnetic waves of frequencies ranging from 1-500 MHz are presented. The numeric results were based on a recently developed tensor integral equation and on the assumption that a heterogeneous body could be partitioned into a number of electrically small and parametrically similar subvolumes or cells. If the size of the cells was kept smaller than 1/4 of the free-space wavelength, sufficiently accurate results were obtained in terms of quantifying the induced electromagnetic field inside an arbitrarily shaped biologic body, such as the human torso. After the validity and accuracy of the tensor integral equation method were confirmed experimentally by measuring the induced electric field inside boxes containing saline solution, the numeric method was applied to quantify the induced electric field and absorbed power density inside human torsos. The following specific cases were considered: induced electromagnetic field and absorbed power density in an adult torso by both vertically and horizontally polarized electromagnetic waves, induced electromagnetic field and absorbed power in a child's torso by vertically polarized waves, and electromagnetic field and absorbed power density induced by vertically and horizontally polarized electromagnetic waves in human torsos as functions of the frequency of radiation and torso geometry. (14 refs.)

4925 X-RAY DIFFRACTION FROM CHLOROPLAST MEMBRANES ORIENTED IN A MAGNETIC FIELD. (Eng.) Sadler, D. M. (H. H. Wills Physics Lab., Univ. Bristol, Royal Fort, Tyndall Ave., Bristol BS8 1TL, UK). *FEBS Lett.* 67(3): 289-293; 1976.

X-ray diffraction signals were obtained from chloroplast membranes oriented in a magnetic field of approximately 10 kG. A chloroplast suspension from spinach leaves, which corresponded to about 5 mg chlorophyll/ml, was placed in a glass capillary, which was mounted between the poles of an electromagnet on a low angle x-ray camera. A photographic recording of low angle scattering from the suspension revealed arcs in the direction of the magnetic field that were attributable to the enhanced scatter when the diffraction vector was parallel to the lamellar normals. This confirmed that the lamellar normals were aligned along the magnetic field. A degree of magnetic orientation of a ± 15° arc was estimated; the information gained from the orientation indicated that there was a nonmeridional component to the scatter that was comparable in intensity to the meridional component. This was interpreted on the basis of proteins associated with the chloroplast membranes. Differences in ionic conditions (presence or absence of magnesium chloride in the medium) demonstrated the effect of membrane pairing in the partition region. A distance between the centers of the membranes across the partition of 77 angstroms was estimated. The results lend support for a mosaic model structure for the chloroplast membrane. (10 refs.)

4926 RADAR AND MIGRATING BIRDS. (Eng.) Krupp, J. H. (USAFSAM, Aerospace Medical Div., Brooks Air Force Base, TX 78235) 11 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A030346].

Studies on the effect of radar on migrating birds are reviewed. Generally, reports of radar influence on bird flight are based on subjective observation without statistical validity in most cases. Cranes have been reported to alter their flight route near an airport after the installation of a new and more powerful radar; however, a detailed analysis of weather influences was not made. A microwave effect on birds has been implicated by experiments in which chickens exposed in the far-field exhibited immediate spontaneous reactions (wing drooping and leg paralysis). Although the field intensity was relatively high (10-46 mW/cm^2), heating was dismissed as a cause despite the fact that temperature measurements were not made. Visual and photographic tracking analysis of birds being tracked by radar pencil beams aimed directly at them have failed to reveal any significant deviation from straight-line flight. In a controlled experiment where radars with wavelengths of 3, 10, 23, 25, and 50 cm were used as perturbing sources and/or trackers in a statistically meaningful way to assess the effect on bird flight, no radar effect was observed. Experiments evaluating the effect on pigeons being fed in a microwave field of 3 mW/cm^2 failed to reveal any disturbance in eating habits, even when the birds were near the radar horn where the field strength was estimated to be 52 mW/cm^2. Therefore, the preponderance of evidence supports the conclusion that radar is not a perturbing influence on birds. (27 refs.)

4927 MICROWAVES AND HUMAN SAFETY. PART II. (Eng.) Minin, B. A. (Joint Publications Res. Service, 1000 North Glebe Rd., Arlington, VA 22201) 195 pp.; 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. JPRS 65506-2].

Fundamental principles pertaining to the protection of humans from super high frequency radiation (microwave) exposure are outlined. Protection measures on both large- and small-scale levels are discussed and include the use of natural screens (existing nonresidential structures, strips of forest, hills); the proper design and placement of microwave antennae; the use of adequate shielding on microwave transmitters; the protection of rooms from external radiation by the application of radioprotective coverings to the walls; and the use of individual protective measures, such as, protective suits, masks, glasses, and helmets. Detailed data are supplied on the characteristics of various radioprotective materials and on methods for theoretically predicting the effectiveness of radioprotective measures. Techniques for measuring the intensity of microwave fields, including those at biologically dangerous levels, are also described. (165 refs.)

4928 BIOPHYSICS - ENERGY ABSORPTION AND DISTRIBUTION. (Eng.) Guy, A. W. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

Biologic and physical considerations involved in the interpretation of effects of electromagnetic fields on biologic tissues are discussed. Topics covered include dielectric properties and electromagnetic wave propagation through biologic tissues, thermal effects on biologic tissue exposed to electromagnetic fields, relations between plane wave fields and absorbed power density in exposed biologic objects, quasi-static field coupling to spheres and ellipsoids, and field coupling from finite sources. In general, the total amount and distribution of the absorbed electromagnetic power in biologic tissue exposed to electromagnetic fields is a function of the magnitude of the electric and magnetic fields, the relative stored energy in the magnetic and electric fields, the source and tissue configurations, the tissue composition, the radiation frequency, and environmental factors. The average and maximum absorbed power density may vary over many orders of magnitude for the same applied field intensities, and, depending on conditions, power absorption may be predominantly at the surface of the subject or may affect interior tissues. A tabulation of the dielectric properties, the depth of

penetration, and the reflection characteristics of various tissues (muscle, skin, fat, bone, and tissues of high and low water content) exposed to electromagnetic waves as a function of frequency (1 MHz-10 GHz) is provided. (23 refs.)

4929 INVESTIGATION OF THE EFFECT OF LOW-INTENSITY UHF ELECTROMAGNETIC WAVES ON *BACILLUS MESENTERICUS* AND *PSEUDOMONAS FLUORESCENS*. (Rus.) Ostapenkov, A. M. (No affiliation given); Matison, V. A.; Kaptereva, I. V.; Belovolov, A. V.; Lavrova, V. L. *Biol. Nauki* (6): 47-50; 1976.

The effect of ultra-high frequencies on the survival and growth of *Bacillus mesentericus* and *Pseudomonas fluorescens* was studied after irradiation of cell cultures at 200 μW. The cell survival-frequency curves obtained had a resonance character and were different for each species. The survival of *B. mesentericus* was sharply reduced by radiation at 10,450 MHz, while growth stimulation was observed at 10,300 MHz. The growth of *P. fluorescens* was stimulated by irradiation at the frequencies of 1,400-1,500 MHz, 39,450 MHz, and 39,600 MHz. The radiation had considerable bactericidal effect on both species at 39.555 MHz. (9 refs.)

4930 EFFECTS OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS ON GROWTH AND DIFFERENTIATION OF *PHYSARUM POLYCEPHALUM*. (Eng.) Goodman, E. M.; Greenebaum, B.; Marron, M. T. (Div. Science, Univ. Wisconson-Parkside, Kenosha, WI 53140) 65 pp.; 1976. [Office of Naval Research, Contract No. N-00014-76-C-0180].

The effects of extremely low frequency electromagnetic fields on the growth and differentiation of the myxomycete *Physarum polycephalum* were studied over a 4-yr period. Weak, continuous sine wave (CW), alternating electromagnetic fields (45, 60, or 75 Hz; 2.0 G; 0.7 V/m) affected the cell cycle of the myxomycete by increasing the interval between consecutive nuclear divisions. The mitotic delay was reproducible, and the time required to induce the effect was frequency dependent. About 14 days were required to observe a statistically significant mitotic delay at 45 Hz CW, about 90 days at 60 Hz CW, and about 120 days at 75 Hz CW. Cultures exposed to a modulated 76 Hz signal (0.4 G, 0.14 V/m) also exhibited a mitotic delay; in contrast, plasmodia exposed to CW fields of similar intensity (0.4 G, 0.15 V/m) for 180 days failed to display a mitotic delay. The introduction of cultures already displaying a mitotic delay into either a control environment or into a field about five times weaker than that used for inducing the delay resulted in the disappearance of the delay within about 40 days, indicating that the effect on the mitotic cycle was reversible. Continuous exposure to 45, 60, and 75 Hz CW at 2.0 G and 0.7 V/m resulted in a 7-15% retardation in the rate of shuttle streaming in *P. polycephalum*. At 75 Hz CW, alterations in the streaming period occurred several weeks before significant deviations in the mitotic cycle were noted, and it appears that shuttle streaming may be a more sensitive indicator of extremely low frequency effects than mitosis. Similar decreases in the rate of streaming were observed when plasmodia were exposed to modulated 76 Hz signal (2.0 G, 07 V/m). When the field intensity was reduced five-fold, a decrease in the rate of streaming was still observed; in contrast, similar field intensities at 75 Hz CW failed to affect the rate of shuttle streaming. Plasmodia exposed to 75 Hz CW (2.0 G, 0.7 V/m) displayed an approximate 13% depression in oxygen consumption; exposure to the same field intensity in the modulation mode resulted in an 8% lowering of the respiration rate. When exposed cultures were fused with unexposed cultures, the entire mass was observed to assume average properties, indicating the existence of some transferable substance(s) in the exposed cultures to which the control cultures responded. (17 refs.)

4931 CARDIAC PACEMAKERS AND EMI FROM THERAPEUTIC RADIATION GENERATING MACHINES (MEETING ABSTRACT). (Eng.) Baker, R. J. (Univ. California, San Francisco, CA 94143); Vreeland, W.; Smith, V. *Health Phys.* 31(6): 530; 1976.

When using radiation therapy to treat cancer patients with implanted cardiac pacemakers, there may be concern about the possible electromagnetic interference (EMI) from the radiation generating machine with the normal functioning of the patient's pacemaker. For this reason, a set of measurements were performed on a 4 MV linear accelerator. The first consisted of a survey of the low frequency components and entire microwave generating and transport components with a Narda meter. The second consisted of measurements employing a Tektronix 7L12 frequency spectrum analyzer with one of two calibrated antennae on the treatment couch simulating the patient. A biconical antenna with calibration data from 20 to 200 MHz was available and also log spiral antenna calibrated from 0.2 to 1.0 GHz. For frequencies below 20 MHz, an uncalibrated linear wire antenna was used. The quantitative results of these measurements are given, as well as a brief review of relevant literature. (No refs.)

4932 TUMOR HYPERTHERMY BY MEANS OF RADIOFREQUENCY IN ORDER TO ENHANCE ONCOLYSIS BY CLOSTRIDIUM BUTYRICUM (STRAIN M 55). (Ger.) Dietzel, F. (Abteilung Nuklearmedizin, Zentrum fur Radiologie des Klinikums der Justus-Liebig-Universitat, 63 Giessen, Friedrichstrasse 25, W. Germany); Gericke, D.; Konig, W. *Strahlentherapie* 152(6): 537-541; 1976.

The effect of short-term local hyperthermia induced by high-frequency eddy current fields (461 MHz, 150 W) on the oncolytic activity of *Clostridium butyricum* (strain M 55) was studied in female NMRI mice with tumors of the neck (transplanted solid Ehrlich carcinoma, Harding-Passey melanoma, and methylcholanthrene-induced fibrosarcoma). The tumor temperature was increased to 42-44°C by the

local irradiation, which was followed by intravenous application of *C. butyricum* spores 12 hr later. The animals were sacrificed 5 days after the injection of spores. The rates of oncolysis achieved in animals with Ehrlich carcinoma, Harding-Passey melanoma, and fibrosarcoma were 61.31%, 84.09% and 22.4%, respectively, vs 27.65%, 14.77% and 1.16% in the control treated with spores only. The corresponding tumor weights were 1.27 g, 0.14 g and 1.85 g, respectively, vs 2.36 g, 2.49 g and 2.29 g in the control. The findings indicate that short-term hyperthermia, producing anoxic necrobiotic conditions, significantly enhances the oncolytic activity of *C. butyricum* M 55. (10 refs.)

4933 PROTECTION OF WORKERS OPERATING HIGH-FREQUENCY INDUCTION HEATING EQUIPMENT. (Rus.) Kulikovskaia, E. L. (M. I. Kalinin Polytechnical Inst., Leningrad, USSR). *Gig. Tr. Prof. Zabol.* (11): 47-48; 1976.

Various screen designs for industrial inductive heating units were studied to estimate their irradiation protection efficiency for workers. Cylindrical inductors should be screened by means of two concentric semicylinders, and the screen material should be aluminum alloy sheet with a minimal thickness of 1 mm. The electrical resistance of the alloy should be close to that of aluminum. Sight glasses should be metallized to protect workers from the electrical component of the radiation. (No refs.)

4934 MICROWAVE RADIOMETRY AND ITS POTENTIAL APPLICATIONS IN BIOLOGY AND MEDICINE: EXPERIMENTAL STUDIES. (Eng.) Bigu-Del-Blanco, J. (Anatomy Dept., Queen's Univ., Kingston, Ontario, Canada); Romero-Sierra, C.; Watts, D. G. *Biotelemetry* 2: 298-316; 1975.

Microwave radiometric experiments were performed with humans, rabbits, cats, mice, rats, guinea pigs, and plant tissue. The experiments consisted of measuring the brightness temperature under normal conditions, under the influence of some drugs, and under the influence of microwave radiation. In the latter case, brightness temperature measurements were initiated 3 sec after removal of the microwave field to avoid interference from electronic transients. Radiometric signatures obtained for the above specimens indicated the feasibility of using microwave radiometry to detect radiation emitted by biologic systems at microwave frequencies. In one experiment, when an anesthetized rabbit received 2.5 min of microwave radiation (30 mW/cm^2 as measured in free space), an increase in brightness temperature of about 1.8 Kelvin was observed. This increase diminished rapidly in an exponential fashion, reaching an almost steady value in about 60 sec after the microwave field was switched off. During three sets of experiments involving the irradiation of an unanesthetized rabbit with 30 mW/cm^2 of microwave radiation for 3 min, the steady-state brightness temperatures obtained after removal of the field were practically the same for each experiment. However, the increase in brightness temperature exhibited by the irradiated specimen, at the time of field removal, was largest in the first two experiments and minimal in the third experiment. This result, although difficult to explain in terms of a tissue dielectric heating effect alone, appears to be a condition or an adaptation of the animal to the external stimulus. The radiometers used in the above experiments included a correlation type and a Dicke type, operating in the X-band at about 9 GHz with a sensitivity of about 0.1 Kelvin. (48 refs.)

4935 PUBLIC HEALTH HAZARDS FROM ELECTRICITY-PRODUCING PLANTS. (Eng.) Neyman, J. (Statistical Lab., Univ. California, Berkeley, CA 94720). *Science* 195(4280): 754-758; 1977.

Problems involved with determining safe levels of human exposure to radiation are discussed in connection with potential hazards from electrical power plants. Currently available estimates of radiation effects on humans are based on extrapolations from studies of two kinds; those exemplified by studies of Japanese atomic bomb casualties and laboratory experiments with lower animals. The unreliability of both kinds of extrapolations is connected with the following circumstances: the phenomenon of competing risks in the environment, the dependence of health effects of a given noxious agent on the preexisting local pollution, the dependence of health effects not only on the dose of an agent but also on the rate at which the agent is administered, and difficulties in making extrapolations from one mammal to another. The need for epidemiologic studies of radiation effects is stressed, in particular in such areas as Rocky Flats, Colorado, where increased malformation frequency in domestic animals may be due to the presence of selenium in the food chain or to other sources of contamination, such as a nuclear facility in the area. (20 refs.)

4936 EFFECTS OF NON-IONIZING ELECTROMAGNETIC RADIATION. (Eng.) Mints, S. M. (Joint Publications Res. Service, 1000 North Glebe Road, Arlington, VA 22201) 100 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. JPRS-66512].

A compilation of various articles on the effects of non-ionizing radiation on humans and animals is presented. Topics covered include: the effect of microwave emission on the content of iron, copper, cobalt, and metallic proteins bonded with them in organs and tissues of test animals; cerebral and peripheral circulation in persons handling sources of ultrahigh radio frequencies (UHF) based on the results of rheographic examinations; changes in the membrane potential of nerve cells of isolated ganglia in the mollusk *Planorbis corneus* under the influence of a UHF electromagnetic field; the effects of ionizing radiation in combination with microwaves on the permeability of histo-hematic barriers; the influence of super high frequency (SHF) electromagnetic fields on the capillary bed, parenchyma, and bio-

chemistry of the rat testes; the effects of experimental toxic hepatitis and microwaves on the function of hepatic and renal mitochondria in the rat; the action of SHF electromagnetic fields on human erythrocytes preserved at low temperature; the effects of SHF fields of different intensity on the balance and metabolism of copper, manganese, molybdenum, and nickel in experimental animals; the effect of UHF fields on pathogenic microorganisms; the effect of UHF fields on the course of hypertension in humans; the effect of a low frequency pulsed electromagnetic field on rat testes; hygienic evaluations of the effects of medium wave electromagnetic fields in populated areas; the effect of microwaves on blood serum butyryl cholinesterase activity in rats; the effect of microwaves on the function and structure of hepatic and renal mitochondria of rats; experimental, clinical, and epidemiologic studies of the health hazards and biologic effects associated with microwave exposure; the effects of SHF fields on enzymatic activities and pyridoxine levels in the organs of white rats; metabolic disorders and liver function in rats exposed to low frequency pulsed electromagnetic fields; studies of the digestive system in workers exposed to the effects of UHF electromagnetic fields; hygienic investigations of working conditions during the high frequency heating of metals and semiconductors; the effect of microwaves on the metabolism of trace elements, metalloproteins, and indicators of oxidation-reduction processes in rabbits; and the use of microwave therapy for treating inflammation of the female human genitals. (103 refs.)

4937 LONG-WAVELENGTH ELECTROMAGNETIC POWER ABSORPTION IN ELLIPSOIDAL MODELS OF MAN AND ANIMALS. (Eng.) Massoudi, H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H.; Johnson, C. C. *IEEE Trans. Microwave Theory Techniques* MTT-25(1): 47-52; 1977.

A previously developed long-wavelength analysis of electromagnetic (EM) plane wave irradiation of ellipsoidal models of humans and experimental animals was used to obtain quantitative theoretic estimates of the average specific absorbed EM power and EM power distributions within the model. The EM specific power absorption varied significantly with the orientation of the ellipsoid axis in the incident field vectors and also with frequency, size, and dielectric properties of the ellipsoid. Theoretic data were obtained for the average specific absorbed power for six different orientations of the ellipsoid with respect to the incident plane wave field vectors; the strongest absorption was found when the electric field vector of the incident plane wave was along the longest dimension of the ellipsoid. Curves showing the distribution of absorbed power inside the model and the average absorbed power versus frequency were presented for humans, dogs, rabbits, rats, mice, and monkeys. Theoretic results for average specific absorbed power in rhesus monkeys were compared with experimental data on live rhesus monkeys and found to be in agreement. The quantitative data presented can be used to estimate tissue power absorption in experimental animals and man. Extrapolation of EM effects in animals can then be applied to those expected in humans, since the biologic effects due to irradiation are expected to be a function of specific absorbed power. (20 refs.)

4938 STUDY OF BIOLOGICAL MEMBRANES ORIENTED IN A HOMOGENEOUS MAGNETIC FIELD. (Eng.) Becker, J. F. (Ph.D. dissertation, Dept. Physics, New York Univ., 1976): 158 pp. [available through Xerox University Microfilms, Ann Arbor, MI 48106, Document No. 76-19, 483].

Living cells in aqueous suspensions under normal physiologic conditions were oriented in a homogeneous magnetic field of 10,000 G or more. Photosynthetic algae (*Chlorella pyrenoidosa, Scenedesmus obliquus,* and *Euglena gracilis*), photosynthetic bacteria (*Rhodopseudomonas palustris* and *R. viridis*), spinach chloroplasts, and bovine visual rod outer segments were oriented. The orientation was caused by the interaction between the magnetic field and the induced diamagnetic moment of ordered cell components having an anisotropic diamagnetic susceptibility. The aromatic amino acid residues of membrane proteins or the chlorophyll molecules were the most probable source of this anisotropy, depending on the type of cell. Cell orientation was monitored by observing the polarization of fluorescence and the linear dichroism of order cell components. It was shown that the whole cell orients in the magnetic field and that there was no detectable re-arrangement of internal cellular components at the magnetic field strength employed. A rhodamine-B staining technique was used to show that the membrane planes were oriented perpendicular to the external magnetic field. Studies of energy transfer in photosynthetic membranes and studies of the photo-induced charge separation occurring in photosynthetically active spinach chloroplast membranes were also performed. Preliminary measurements of the electromotive force in suspensions of oriented chloroplasts demonstrated the anisotropic absorption properties of the membranes. (111 refs.)

4939 EFFECTS OF WEAK ELECTRIC FIELDS ON BEHAVIOR AND EEG OF LABORATORY ANIMALS. (Eng.) Gavalas-Medici, R. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 27-36; 1977.

Experiments dealing with the effects of extremely low frequency (ELF) electromagnetic fields on reaction time and task performance are reviewed. During experiments where high and low frequencies (2-12 Hz, 4 V/m [root mean square]) were presented in a double-blind test to each of 29 human subjects, the higher frequency of each pair resulted in a longer reaction time. Tests of four monkeys on an inter-response time (IRT) task revealed shifts towards faster IRT's during exposure to 45-Hz magnetic fields in some of the animals during some tests. Experiments in which three monkeys were trained to press a lever for fruit juice reinforcement and then tested in 7-Hz (7 V/m (peak-to-peak) fields revealed a significantly shorter average IRT in the presence

of the field for at least two of the monkeys. Sets of electroencephalogram data selected from the beginning and end of the testing periods and corresponding to correct (i.e., properly timed) and incorrect responses revealed statistically significant differences in data selected from the hippocampus near the end of the run, with the appearance of a spectral peak at the field frequency of 7 Hz. Similar experiments involving the exposure of five monkeys to frequencies ranging from 7-75 Hz and voltage gradients ranging from 1-100 V/m showed that at 10 V/m the 7-Hz field was associated with a reduced average IRT; the mean IRT across all five animals was about 0.12 sec shorter than the control value. Neither 45-Hz nor 75-Hz fields produced a significant change at this voltage level. At 56 V/m, (significant differences (almost three times as large as those seen at 10 V/m (7 Hz)) were observed for both 7-Hz and 75-Hz fields. Data at 100 V/m indicated that field exposure was affecting control tests that occurred 24 hr later. Overall, the results suggest that there may be a frequency-specific threshold for weak ELF fields; sensitivity to 7-Hz fields may reflect the fact that this frequency is within the range of hippocampal theta for monkeys. A dose-dependency relationship also appears to exist since IRT shifts were much larger at 56 V/m than at 10 V/m. (No refs.)

4940 AMPLITUDE-MODULATED, VERY HIGH FREQUENCY (VHF) ELECTRIC FIELDS. (Eng.) Bawin, S. M. (No affiliation given); Adey, W. R. *Neurosci. Res. Prog. Bull.* 15(1): 36-38; 1977.

The effect of amplitude-modulated, very high frequency (VHF) electric fields on conditioned electroencephalogram (EEG) rhythms of cats was investigated. In the first experiment, five cats were initially trained to produce a particular EEG rhythm as a response to a light flash. Prior to VHF exposure, the five cats were retrained. Two cats (with conditioned rhythms in the hippocampus and nucleus centrum medianum, respectively) served as controls and were overtrained and extinguished in the absence of field. The other three cats (two of them with hippocampal rhythms and one with a centrum medianum pattern) were irradiated with a 147-MHz VHF carrier (0.8 mW/cm^2), which was amplitude-modulated at 3 and 4.5 Hz (hippocampal frequencies) and at 14 Hz (centrum medianum frequency) during overtraining and extinction. The control cats maintained regular levels of performance during the training sessions but never exceeded their previous achievement. The extinction of the response in the absence of field was very rapid as in the first conditioning. Performance dropped to 40% during the first session in both animals. The performance of the irradiated animals reached levels equal or superior to the highest scores seen in the first conditioning, and these high performance levels persisted for 25-40 days into the extinction schedule. No change was ever elicited in the EEG of other brain sites not subjected to the conditioning procedure. A second series of experiments involved the selection of two different rhythms in two different brain structures for each of two animals. In one cat, two mutually exclusive patterns were selected: 14 Hz in the nucleus centrum medianum and 10 Hz in the presylvian gyrus. In the other animal, two concurrent patterns were selected: 13 Hz in the caudate nucleus and 4 Hz in the centrum medianum. The spontaneous occurrence of one selected rhythm was used to trigger the VHF fields, which were amplitude modulated at the same frequency for 20 sec. The results clearly indicated that the fields were acting as reinforcers, increasing the rate of occurrence of the initially spontaneous rhythms but only when modulated at frequencies close to the biologically dominant frequency of the selected intrinsic EEG patterns. The results support evidence that the modulation was responsible for the specific EEG enhancements seen in both experiments. (No refs.)

4941 BIOLOGICAL SIGNIFICANCE OF ZERO MAGNETIC FIELD CONDITIONS AND PERTURBATIONS OF MICROWAVE FIELDS BY LIVING ORGANISMS. (Eng.) Beischer, D. E. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 100-103; 1977.

The interaction of weak non-ionizing electromagnetic fields with nervous tissue is discussed. The coupling of the field to the tissue is extremely weak at extremely low frequencies of radiation. It increases progressively at higher radio frequencies, with the possibility of resonant interactions with molecular components at specific frequencies above about 100 GHz including dielectric interactions for frequencies as high as about 10 GHz. As distinct from the carrier wave itself, there is evidence for the detection of low frequency modulation of the carrier, apparently based on detector properties of tissue phase partitions and associated asymmetries in the distribution of fixed charges on macromolecular sheets at membrane surfaces. Very weak extremely low frequency fields, with tissue gradients of the order of 10^{-5} V/m, have been shown to alter circadian rhythms and subjective timing estimates and to be capable of altering the binding of calcium ions in brain tissue by 15%. In pilot studies of the effects of an alternating magnetic field of 45 Hz and 10^{-4} weber/m^2 strength in man, a possible time-delayed increase in serum triglycerides has been reported. Bee orientation experiments in chambers shielded from the earth's magnetic field have revealed a sharp increase in erroneous orienting responses. Natural magnetic fields may involve transients of as much as 500 gamma, or about 1.0% of the steady level, and bees have been found to be sensitive to as little as 10 gamma. Man appears to suffer no ill physiologic or central nervous system effects from exposure to zero magnetic fields during a period of 2 wk. Calculations of the field pattern for the interaction of a plane wave and a conductive cylinder with its axis parallel to the electric field and a cylinder diameter equal to the wavelength have yielded a reasonable fit to the observed contours for man. In experiments with a conductive mannequin (life-size with a metallic surface), standing wave patterns closely resembling those found for man have been obtained. It has been observed that when the electric field is parallel to the long axis of the body, the structure of the parabolic standing wave field extends a considerable distance to the

sides of the body; whereas, in horizontal polarization the side structure is low in amplitude. This point may be significant when men are exposed standing side by side. (No refs.)

4942 THE EFFECTS OF LOCALIZED MICROWAVE EXPOSURE ON THE DOG THYROID. (Eng.) Magin, R. L. (Ph.D. dissertation, Dept. Radiation Biology and Biophysics, Univ. Rochester, Rochester, NY, 1976); 165 pp. [available through Xerox University Microfilms, Ann Arbor, MI 48106, Document No. 76-26, 914].

The effects of localized continuous wave microwave (2.45 GHz) exposure on the dog thyroid gland were studied. Preliminary experiments demonstrated that the thyroid gland temperature could not be elevated by more than 1°C without thermally damaging the skin and intervening tissues when a dielectrically loaded wave-guide applicator was located on the ventral surface of the neck. Experiments designed to assess the effects of microwave exposure following stimulation of the release of total plasma thyroxine (T4) with thyroid-stimulating hormone (TSH) could not be conducted, since a good control gland response was not established. Therefore, the response of the thyroid gland without the administration of TSH was studied. Cannulated glands were allowed a 1-hr equilibration period followed by a 2-hr exposure period. Sham exposure experiments showed that both of the glands comprising the dog thyroid released T4 at a relatively constant rate for the 3-hr experimental period. During the exposure period, the heated glands were maintained at about 39, 41, or 45°C by the absorption of 58, 131, or 190 W/kg of microwave power. The thyroxine release rate was determined from the difference between the T4 concentration in the thyroid veins and femoral artery, the thyroid vein blood flow, and the hematocrit. The thyroxine release rate was increased during the exposure period to 150, 350, and 1000% of the equilibration period averages for the three temperature groups studied. The blood flow was increased to 140 and 170% of the equilibration period averages in glands heated to 41 and 45°C, respectively. Contralateral control glands maintained a constant thyroxine release rate. These results demonstrate that local heating of the thyroid gland can stimulate both thyroid gland blood flow and the release of thyroxine. (57 refs.)

4943 DIRECT CURRENT STIMULATION OF THE GROWING DEER ANTLER. (Eng.) Lake, F. T. (Ph.D. dissertation, Colorado State Univ., 1976). 207 pp. [available through Xerox University Microfilms, Ann Arbor, MI 48106, Order No. 77-1175].

The effects of direct current (DC) stimulation on the regeneration and bone growth of mature Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) antler were investigated. Direct currents of 0.066, 0.05, 2.0, and 3.0 μamp were used, with the cathode attached to the growing tip of the antler and the anode attached near the antler base. The longterm application of low levels of cathodal DC to growing antlers produced abnormal branching patterns and antlers that grew in atypical directions. The stimulated antler tines showed statistically significant reductions in length and diameter. Moreover, the stimulated antler tines showed a significant reduction in the rate of longitudinal growth during the antler growth cycle. Measurements of the electric potentials on the antler showed that the most negative potential was associated with the most metabolically active portion of the antler, namely, the growing tip. In reference to the antler base, electrical potentials recorded from the antler indicated an electronegative potential at the growing tip during most of the growth cycle. However, as the antler matured, the tip became less negative and approached zero potential when the growth process ceased. This decrease in the electronegative potential of the growing antler tip paralleled the decreased longitudinal growth rate. Bone labeling and subsequent bone dynamic studies of the cortical osteons indicated the following: osteon wall thickness in experimental and control antlers was not significantly different; bone formation rates in the stimulated tines appeared to be decreased; and osteon formation time in the stimulated antlers appeared to be increased. Chemical and gravimetric analyses revealed that bone formed in stimulated tines was similar to bone formed in nonstimulated tines. No consistent histological or histochemical differences were found between experimental and control antlers. (190 refs.)

4944 EFFECTS OF MICROWAVE RADIATION ON APLYSIAN GANGLION CELLS. (Eng.) Seaman, R. L. (No affiliation given). *Neurosci. Res. Prog. Bull.* 15(1): 45-48; 1977.

Comparative studies of microwave and thermal effects on *Aplysia* ganglion cells were performed. Ganglionic warming was produced convectively by flushing warm water through an enclosed space surrounding the chamber housing the ganglion. Microwave frequencies of either 1.5 or 2.45 GHz were used either as a continuous wave (CW) signal or as trains of pulses. Typically, both CW and pulsed microwave irradiations, as well as circulation of warm water, caused a decrease in cell firing rate. Less frequently the microwave field and subsequent heating produced opposite effects. A total of 55 different cells were tested with microwaves; no difference was noted in the effects induced by 1.5 GHz or 2.45 GHz nor between the effects of CW and pulsed radiation for the majority of observations. Convectively, temperature changes of 0.1-2.7°C were found to affect the firing rates of white cells. Effective rates of temperature change ranged from 0.004-0.180°C/sec. Irradiation temperature increases were duplicated by convective heating in 29 white cells, and some cells that showed a consistent firing-rate decrease with increasing temperature exhibited increased firing rate during microwave irradiation. A rapid change in firing rate was often observed at the cessation of irradiation, and these changes were generally similar to those occurring with decreased temperature. However, decreased interspike interval, as seen in some white cells at the onset

of irradiation, was never produced by a simple rise in environmental temperature. Likewise, a decreased interburst interval in burster cells at the termination of irradiation was never produced by an environmental temperature decrease. Both white cells and bursters were tested for their sensitivity as expressed in the lowest effective absorbed power (LEAP). About 50% of the white cells exhibited a LEAP less than 15 mW/cm^3, and 30% were sensitive to absorbed powers of 10 mW/cm^3. Combined data for white cells and bursting cells produced a regression that would predict 0.1% of the cells to be affected by an absorbed power of 1 mW/cm^3. The effects of extracellular currents introduced into the test chambers were also tested to establish the sensitivity of the white cell to these stimuli. For direct current, the largest critical value observed in 12 white cells was 20 μA, which yielded a current density of 110 $\mu A/cm^2$. For alternating currents of 10 Hz, 100 kHz, and 1 MHz, the critical values for one white cell were 118, 3,730, and 8,250 $\mu A/cm^2$ (root mean square), respectively. (No refs.)

4945 EFFECTS OF ALTERNATING MAGNETIC FIELD (12 GAUSS) ON TRANSPLANTED NEUROBLASTOMA. (Eng.) Batkin, S. (John A. Burns Sch. Medicine, Univ. Hawaii, Honolulu, HI 96822); Tabrah, F. L. *Res. Commun. Chem. Pathol. Pharmacol.* 16(2): 351-362; 1977.

A total of 10 A/J female mice bearing transplanted neuroblastoma (C1300) were exposed to a 12-G, 60-Hz magnetic field for 16 days, starting 3 days after tumor transplantation. At 19 days post-transplant, macroscopic and microscopic evaluations of the tumors were performed. The visible growth rate of the tumors was slower in the 15 mice exposed to the magnetic field than it was in another 10 tumor-bearing control mice not exposed to the magnetic field. For the exposed group, there were four evident tumors at day 6 and 6-7 and visible tumors at day 8-9; visible tumors occurred in all 10 exposed animals by post-transplant day 10-11. This contrasted with the appearance of visible growths in all 10 control mice receiving tumor transplants by the 5th-6th post-transplant day. Tumor weights in both groups of mice were not significantly different at the 19th post-transplant day. Microscopically, two distinct histologic differences were observed between exposed tumor-bearing mice and control tumor-bearing mice. Exposed mice had more free red blood cells in the tumor areas and showed a tendency toward focal tumor cell destruction. Two common features were exhibited by the 10 tumor-bearing mice exposed to the magnetic field and by another 10 non-tumor-bearing mice also exposed to the magnetic field; both of these groups were more active than tumor-bearing mice not exposed to the magnetic field, and no odor was perceptible from their cages as compared with an ammonia odor from the cage cleanings of mice not exposed to the magnetic field. The possibility of differential bacterial growth is being considered in connection with these observations. Overall, the results suggest that a small alternating magnetic field may affect transplanted tumor growth. (12 refs.)

4946 THERAPEUTIC USE OF ALTERNATING MAGNETIC FIELD IN THE TREATMENT OF PATIENTS WITH CHRONIC DISEASES OF THE VEINS OF THE LOWER LIMBS. (Rus.) Pasynkov, E. I. (Dept. Surgery, N. I. Pirogov Second Moscow Medical Inst., Moscow, USSR); Konstantinova, G. D.; Vlasova, E. I. *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (5): 16-19; 1976.

A total of 271 patients with chronic venous insufficiency, varicose veins, and trophic ulcer of the shin were treated with alternating magnetic field (15-20 min/day, courses of 20-20 sessions). Good therapeutic results were achieved in 236 cases, satisfactory results in 34, and no effect was observed in one case. When the interval between acute phlebothrombosis and treatment was short, the therapeutic result was better. In some cases, good results were achieved only after a second therapy course given 6 mo after the first one. Magnetic field therapy is indicated for the treatment of cellulitis, in association with other therapeutic methods, and in the prophylaxis of postoperative complications in patients with varicose veins and postthrombotic conditions. (3 refs.)

4947 NON-THERMAL HAZARDS OF EXPOSURE TO RADIO FREQUENCY FIELDS. MICROWAVE STUDIES. (Eng.) Mickey, G. H.; Heller, J. H.; Snyder, E. (The New England Inst., P.O. Box 308, Ridgefield, CT 06877). 51 pp.; 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A019359].

Cytogenetic and genetic tests of nonthermal hazards associated with *in vitro* and *in vivo* exposures (10-500 mW/cm^2 average field power densities) to radiofrequencies in the 15-40 MHz range and microwaves in the X-band (9,345-9,405 MHz) and K-band (23,800-24,270 MHz) range were performed. Radiofrequencies in the 15-40 MHz range were effective in inhibiting mitosis and in producing chromosome abnormalities in human lymphocytes and in Chinese hamster lung cells in culture. Significant increases in chromosome abnormalities occurred following irradiation at 21, 25, and 40 MHz. *In vivo* treatment of Chinese hamster bone marrow and testicular cells at 20, 25, 30, and 35 MHz for 1-9 days induced significant increases in aneuploid and polyploid cells but very few chromosome breaks. In bone marrow cells, the percent of abnormal cells reached as high as 1.65% as compared with a maximum of 0.6% for control cells. A stronger effect was observed in germ cells where 25% of the cells irradiated at 35 MHz for 57 hr were abnormal as compared with 1.7% for control cells. Corneal epithelium and hair follicle cells were negative to such exposures. Brain cells of *Drosophila melanogaster* larvae also showed no evidence of nondisjunction at these radiofrequencies. K-band microwaves produced chromosome abnormalities in tissue cultures of Chinese hamster lung cells, with the rate of abnormalities increasing 4-12 hr after treatment. In contrast, no significant increases in chromosome abnormalities occurred after irradiation with X-band microwaves. *In vivo* microwave tests showed that K-band microwaves were effective in producing chromosome aberrations in Chinese hamster bone marrow and

testicular cells, with the effect increasing with the period of microwave exposure. Chromosome breakage in bone marrow cells showed statistically significant increases after exposure periods of 12, 18, 19, 28, and 35 hr. Abnormal cells in the testis of irradiated animals showed significant increases after 28 hr of exposure or more. X-band microwaves were ineffective against bone marrow, male germ cells, lung cells, and corneal epithelium cells. Genetic tests with *D. melanogaster* following irradiation of marker females at 20, 25, 30, and 35 MHz showed no significant increase in nondisjunction in successive broods of offspring. (24 refs.)

4948 COMPARATIVE ASSESSMENT OF ULTRASOUND AND MICROWAVE THERAPY OF CHRONIC TONSILLITIS IN EPILEPTIC PATIENTS. (Rus.) Khodan, I. V. (Volyn Oblast Psychiatric Hosp., USSR). *Zh. Ushn. Nos. Gorl. Bolezn.* (4): 96-97; 1976.

Results of ultrasonic and microwave treatment of epileptic patients with chronic tonsillitis are presented. Thirty patients with compensated and 20 patients with subcompensated chronic tonsillitis underwent ultrasonic therapy (0.4 W/cm^2, 5 min/day, 10 days). In patients with compensated tonsillitis, good results were achieved in 86.6% and satisfactory results, in 10%. In patients with subcompensated tonsillitis good results were obtained in 20% and satisfactory results, in 25%. Twenty-eight patients with compensated, and 20 patients with subcompensated tonsillitis underwent microwave irradiation (2,375 ± 50 MHz, 0.4-0.5 W/cm^2, 5 min/day, 12 days). Good results were obtained in 78.6%, satisfactory results in 14.4% of the cases of compensated tonsillitis, versus 50% and 20% in subcompensated tonsillitis. The efficiency of antiepileptic therapy was improved, i.e., the frequency of epileptic seizures was decreased, in patients in whom the ultrasonic and microwave treatment for tonsillitis was successful. (7 refs.)

4949 SOME POSSIBLE EFFECTS OF STATIC MAGNETIC FIELDS ON CANCER. (Eng.) Kim, Y. S. (Dept. Physics, Ohio State Univ., Columbus, OH 43210). *TIT J. Life Sci.* 6: 11-28; 1976.

Some possible effects of static magnetic fields on cancer cells are discussed. Topics covered include: the electric and magnetic properties of tumor cells and tissues; biomagnetic effects on membranes, genes and replication, metabolic rates, and growth; and the biomechanical actions of magnetism. Evidence exists that at least some cancer cells are more susceptible to magnetic fields than normal cells, that cancer cells are less organized and less cohesive than normal cells, that the surface of cancer cells are more negatively charged than normal cell surfaces, that they have larger dielectric constants, and that they fail to form membrane junctions for intercellular communication. Cancer cells appear to be more paramagnetic than normal cells when they are allowed to proliferate, but due to the presence of anoxic cells in solid tumors, the magnetic susceptibility of tumor tissues (solid) can be more diamagnetic than normal tissues. Magnetic fields can affect cellular functions by distorting membranes and the orientation of various cellular components. These actions may be translated into such biologic effects as growth retardation, cell membrane depolarization, localization and rejection of tumors, temporary and semipermanent genetic and replication anomalies, cell degeneration, and, perhaps, reversion of some cancer cells to normalcy. Biomagnetic effects on tumor growth rates at field strengths ranging from 0-77,000 Oe are tabulated for various types of tumors. Reduced growth rates are reported for Ehrlich adenocarcinoma exposed to 1,500-1,700 Oe, and tumor regression is reported for crown gall tumor exposed to 100-2,200 Oe over a 3-mo period. Tumor rejection in some animals is reported for mice tumors (H2712, C3HBA, and T2146) exposed to 3,000-4,500 Oe. Tumor cell degeneration has been observed with Ehrlich S-37 ascites tumor exposed to 7,300 Oe for a few hr. (101 refs.)

4950 BIOSYNTHESIS OF ACETYLCHOLINE IN DIFFERENT BRAIN REGIONS *IN VIVO* FOLLOWING ALTERNATIVE METHODS OF SACRIFICE BY MICROWAVE IRRADIATION. (Eng.) Nordberg, A. (Dept. Pharmacology, Faculty Pharmacy, Biomedical Center, Univ. Uppsala, Uppsala, Sweden); Sundwell, A. *Acta Physiol. Scand.* 98(3): 307-317; 1976.

The amounts of endogenous acetylcholine (ACh) and choline (Ch) and the rate of biotransformation of tritium-labelled choline (^{3}H-CH) were studied in the brain regions of female NMRI mice (18-24 g) following three different methods of sacrifice. The animals were sacrificed by whole body irradiation (1.3 kW, 7 sec), by head irradiation (5 kW, 0.25 sec), or by dislocation of the spine 1, 5, 10, or 20 min after intravenous injection of 15 nmol ^{3}H-Ch. The brain temperature was measured in different locations 10 to 60 sec after irradiation. The slope of the temperature time curves indicated a brain temperature of about 85-90°C at the termination of exposure to both types of irradiation. Acetylcholinesterase (AChE) and choline acetyltransferase (CAT) were almost completely inactivated when measured 1 to 2 min after sacrifice. To study the rate of turnover of ACh, the brains were dissected into six regions, extracted, and analyzed. No significant difference (except in cortex) in the amount of endogenous ACh was found when whole body irradiation was used in comparison with dislocation of the spine. However, the amount of ^{3}H-acetylcholine (^{3}H-ACh) was much higher in the striatum, hippocampus and cortex. Endogenous ACh (in nmol/g) was markedly increased in the brain regions of head-irradiated animals (shorter inactivation time) compared with spine-dislocated animals: medulla oblongata, 29.1 ± 1.10 versus 19.8 ± 1.07; midbrain, 29.4 ± 1.65 versus 21.1 ± 1.24; striatum, 75.3 ± 1.84 versus 37.1 ± 2.06; cortex, 24.2 ± 1.52 versus 13.2 ± 0.74. However, there was no further increase in the radioactive ACh. The difference regarding the postmortem sensitivity of endogenous and radioactive ACh does not seem to have been due to methodologic artifacts but rather sug-

gests that they are handled differently by the brain tissue. Plots of the specific radioactivity of Ch and ACh versus time indicated fairly distinct precursor-product relationship in the different regions, when the animals were sacrificed by irradiation of the head. (24 refs.)

4951 ELECTROMAGNETIC RADIATION: EFFECTS ON THE EYE. (Eng.) Mitchell, J. C. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

Animal and human studies concerning the ocular effects of electromagnetic radiation (EMR) exposure were surveyed to assess and synthesize the principal findings. An overview of the studies revealed that the acute thermal insult from high intensity EMR fields is cataractogenic if intraocular temperatures reach 45-55°C. The EMR exposure threshold is about 100-150 mW/cm^2 applied for about 60-100 min. Additionally, there does not appear to be a cumulative effect from EMR exposures unless each single exposure is sufficient to produce some irreparable degree of injury to the eye. A review of retrospective studies on actual or suspected exposure of human populations to EMR fields shows that human data alone do not provide conclusive evidence that EMR produces cataracts in man. Some surveys indicate statistically significant increases in lenticular defects in microwave-exposed workers, but none shows any clinically significant defects in terms of decreased visual acuity, i.e., apparent loss of functional vision. Case reports indicate that diathermy treatment in the area of the eye using multiple exposures at power densities from 80-240 mW/cm^2 does not result in cataractogenesis. The exposure levels with which clinically significant cataracts have been tenuously associated indicate the cataractogenic threshold is over 100 mW/cm^2 for man. Human populations, including groups that work with or near EMR emitters, are rarely subjected to fields having average power densities greater than about 1 mW/cm^2, and in most cases the fields are lower. While the emphasis in past research has been on acute EMR cataractogenesis, the author suggests that future studies should consider more subtle indications of energy transfer, such as, alterations in lens protein, and/or ultrastructural changes, and any possible long-term adverse effects. (26 refs.)

4952 BIOLOGIC AND PATHOPHYSIOLOGIC EFFECTS OF EXPOSURE TO MICROWAVE OR ULTRASONIC ENERGY--AN OVERVIEW. (Eng.) Michaelson, S. M. *In: AGARD Lecture Series No. 78 on Radiation Hazards*, 1975. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A015200].

The increased use of processes and devices that utilize or emit nonionizing radiation, such as, microwaves and ultrasound is discussed and the biologic effects of such radiation are briefly reviewed. A significant and growing portion of the U.S. population is exposed in varying degrees to microwaves from various sources including communications devices, microwave ovens, and medical diathermy treatments. It is estimated that by 1980 there will be approximately 5 million microwave ovens in use. The biologic effects of microwaves can be divided into three categories: high average intensities (>10 mW/cm^2) at which distinct thermal effects occur, which in some instances may be hazardous; the range below 1 mW/cm^2 in which gross thermal effects are improbable; and the range of intermediate or subtle effects from about 1-10 mW/cm^2 in which weak but noticeable thermal effects occur as well as direct effects and perhaps effects of a microscopic or macroscopic nature. The border limits of these regions are approximate and may differ for various species of animals and may also depend on frequency and modulation. In view of the expanding use of microwave energy and the complexity of the interactions of nonionizing radiation in biologic systems, it is concluded that an interdisciplinary approach is necessary to assess and elucidate the possible biomedical effects. (13 refs.)

4953 INFRARED SPECTRA OF ERYTHROCYTE SHADOWS IN THE REGION OF AMIDE I AND AMIDE II BANDS UNDER MICROWAVE IRRADIATION. (Rus.) Ismailov, E. S. (Dagestan Polytechnical Inst., Mkhachkala, USSR). *Biofizika* 21(5): 940-942; 1976.

The effect of ultra-high frequency irradiation (1,009 MHz, 30 min at 25°C) on the ultrastructure of human erythrocyte membranes was studied by infrared spectrometry. Irradiation with an intensity of 45 mW/cm^3 resulted in small conformational reconstructions of membrane molecules without inducing a notable transition of alpha-helix into beta structure. Both pulsed and permanent irradiation with 45 mW/cm^3 caused a marked decrease in the intensity of the shoulder at 1,740 cm^{-1}. The deuterium exchange in the peptide molecules, and the corresponding shift of the amide II band from 1,540 cm^{-1} to 1,450 cm^{-1} proceeded faster under irradiation with 45 mW/cm^3 than they did in the control. These changes were dose-dependent and were not manifested at radiation intensities of 5-8 mW/cm^3. (12 refs.)

4954 EFFECT OF LOW-FREQUENCY ELECTRIC STIMULATION OF THE CAUDATE NUCLEUS ON THE CORTICAL ELECTRIC ACTIVITY AND THE WAKEFULNESS-SLEEP CYCLE. (Rus.) Oniani, T. N. (Inst. Physiology, Acad. Sciences Georgian SSR, Tbilisi, USSR); Keshelava-Gogichadze, M. V. *Fiziol. Zh.* 62(1): 29-37; 1976.

The effect of low-frequency electric stimulation (0.8-12/sec, 4-7 V) of the caudate nucleus on the electric activity of the neopallium and archipallium and on the wakefulness-sleep cycle was studied in nonimmobilized cats with implanted electrodes. The δ, θ, α, β_1 and β_2 rhythms of the sensorimotor area of the neopallium and of the dorsal hippocampus were analyzed. After single stimulation, evoked potential occurred more readily in the neopallium than in the

dorsal hippocampus. In the hippocampus, the evoked potentials became facilitated and stable at a frequency of 4-6/sec. The evoked potentials are most pronounced, though variable, at 6-8/sec frequency in the sensorimotor cortex, and spindling occurs at 8-12/sec. As a behavioral correlation of the synchronized activity in the neopallial and archipallial structures during the low-frequency stimulation of the caudate nucleus, drowsiness may develop, which along with the electroencephalographic signs disappears with the cessation of stimulation. Low-frequency stimulation during the paradoxical phase of sleep also provokes synchronization of the electrocardiogram, but the structure of the paradoxical phase recurs after stimulation. The synchronizing stimulation of the caudate nucleus causes considerable changes in the wakefulness-sleep cycle after the stimulation (reduction in the overall duration of short-wave sleep, and increase in the duration of the paradoxical phase). (35 refs.)

4955 EFFECT OF SMALL DOSES OF UHF ELECTROMAGNETIC WAVES ON SOME INDICES OF RENAL FUNCTION AND WATER-SALT METABOLISM. (Rus.) Grin, A. N. (A. N. Marzeev Kiev Scientific Res. Inst. of General and Communal Hygiene, Kiev, USSR). *Vrach. Delo* (10): 130-132; 1976.

The effect of ultra-high frequency electromagnetic fields (5, 10, and 50 $\mu W/cm^2$, 3 hr/day, 10 days) on the renal function and water-salt metabolism was studied in 231 adult male and female rats. Significant but rather moderate increase was observed in the diuresis and in the urinary excretion of chlorides after exposure to 5, 10, 50 5+10, and to 5+10+50 $\mu W/cm^2$. The most pronounced changes in the renal function were produced by a single, 3-hr exposure to 500 $\mu W/cm^2$. The functional changes caused by this high dose, as well as the time required for the normalization of the renal function, were considerably less marked in animals pretreated with 5, 10, and 50 $\mu W/cm^2$ doses prior to exposure to a single $\mu W/cm^2$ dose. (No refs.)

4956 THERMAL AND ELECTRONIC CONTRIBUTIONS TO SWITCHING IN MELANINS. (Eng.) Filatovs, J. (Sch. Engineering, North Carolina A & T State Univ., Greensboro, NC 27411); McGinness, J.; Corry, P. *Biopolymers* 15(11): 2309-2312; 1976.

The recent discovery that melanin responds to applied electric and acoustic fields has led to a new variety of possible biologic roles *in vivo* as well as the design of a potential new modality for treating melanoma. Criteria useful in separating thermal from electrical contributions to switching are presented. Synthetic melanins and melanosomes extracted from human malignant melanoma were prepared and a cylindrical sample of melanin was compressed between carbon electrodes in a teflon holder whose temperature could be controlled between 24° and 200°C. A regulated power supply was used to apply direct current voltage across the sample and load resistor; the resistor was chosen at a low value to ensure memory switching. The threshold electric field and threshold temperature required to activate memory switching for a 0.1-sec pulse were determined for synthetic melanin and melanosomes. The latter showed essentially the same results as purified melanins for the initial critical temperature, but they degraded below 110°C (where synthetic melanin switches off), and the off state could not be reached by heating. Increasing the hydration of the bulk sample lowered the threshold temperature and electric field required for activation but did not change the temperature at which samples switched back off. Neither the hydration, temperature, current, applied field, nor power alone is sufficient to ensure switching; the temperature, hydration, and either the applied field, current, or power must be specified. Melanins offer a unique experimental system for development of a working concept of biologic semiconductivity, since they are stable, can absorb other molecules, and express this interaction by a conductivity change of as much as ten orders of magnitude. (10 refs.)

4957 MICROWAVE-POWER ABSORPTION BY RECTANGULAR-SHAPED CONDUCTIVE DIELECTRIC SAMPLE IN STRIPLINE. (Eng.) Joines, W. T. (Dept. Electrical Engineering, Duke Univ., Durham, NC 27706); Dakermandji, G.; Seaman, R. L.; Wachtel, H. *IEEE Trans. Microwave Theory Techniques* 24(8): 536-538; 1976.

The microwave power absorbed by a rectangular sample of seawater in a plexiglas container (.775 x 1.04 x 1.7 cm) within the uniform field of a stripline is calculated and measured over the 1-2-GHz range. Equations, which account for the sample's disturbance of the otherwise uniform plane-wave field of the stripline, are given, and restrictions on sample size for best accuracy are stated in terms of stripline dimensions. The power absorption measurements on the sample of seawater are compared with calculations using the developed equations. (12 refs.)

4958 THE EFFECT OF 1.6 GHz RADIATION ON NEUROTRANSMITTERS IN DISCRETE AREAS OF THE RAT BRAIN. (Eng.) Merritt, J. H.; Hartzell, R. H.; Frazer, J. W. (USAF Sch. Aerospace Medicine, Aerospace Medical Div., Brooks Air Force Base, TX 78235). 11 pp; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A023677].

The effects of thermogenic microwave power densities on the neurotransmitter content of discrete areas of the rat brain were investigated and compared with the hyperthermic effects caused by exposure to a warm environment. When male Sprague Dawley rats were exposed to 1.6 GHz radiation at a measured power density of 80 mW/cm^2 for 10 min, their body temperature rose 4°C. Hyperthermal control rats were then exposed to a warm air environment to raise core body temperature 4°C. The norepinephrine content of the hypothalamus of the irradiated animals was significantly reduced compared with control animals (50% of control content). Hippocampal serotonin was de-

creased in the irradiated but not in the hyperthermal group, as was the dopamine content of the corpus striatum and hypothalamus. The changes in the neurotransmitters in the brain areas were in the same direction for both irradiated and hyperthermal animals. It is suggested that these changes are a result of thermoregulation mechanisms on brain cells and not a direct effect of 1.6 GHz radiation on neuronal components. (13 refs.)

4959 A PROBE FOR MEASURING TEMPERATURE IN RADIO-FREQUENCY-HEATED MATERIAL. (Eng.) Bowman, R. R. (Electromagnetics Div., U.S. Dept. Commerce, National Bureau Standards, Boulder, CO 80302). *IEEE Trans. Microwave Theory Techniques* 24(1): 43-45; 1976.

The sensitivity, stability, and range of a newly-developed temperature probe, which measures material heated by radiofrequency fields, are discussed. The probe consists of two pairs of very-high-resistance leads connected to a small high-resistance thermistor. The thermistor resistance is sensed by injecting a constant current through one pair of leads and measuring the voltage developed across the thermistor by means of a high-impedance amplifier connected to the other pair. The design goals are described, and the performance of the test model is discussed. (9 refs.)

4960 ELECTRIC-FIELD DISTRIBUTION ALONG FINITE LENGTH LOSSY DIELECTRIC SLABS IN WAVE-GUIDE. (Eng.) Liu, L. M. (Dept. Electrical Engineering, Washington Univ., St. Louis, MO 63130); Rosenbaum, F. J.; Pickard, W. F. *IEEE Trans. Microwave Theory Techniques* 24(4): 216-219; 1977.

Calculations are presented on the magnitude of an electric field along a dielectric slab, on the transmission and reflection coefficients, and on the percentage of incident power absorbed. The biologic speciman was modeled as a lossy dielectric slab of finite length inserted along the center line of a rectangular waveguide. The magnitude squared of the electric field along the slab was calculated to predict the inhomogeneous heat input to the sample. These results were compared with experimental measurements on several materials and the pupae of *Tenebrio molitor*. (16 refs.)

4961 EFFECTS OF MICROWAVE RADIATION ON THE LENS EPITHELIUM IN THE RABBIT EYE. (Eng.) Van Ummersen, C. A. (Biology Dept., College II, Univ. Massachusetts, Harbor Campus, Boston, MA 02125); Cogan, F. C. *Arch. Opthalmol.* 94: 828-834; 1976.

To determine the effects of continuous wave microwaves on the lens epithelium, the right eye of 82 New Zealand white rabbits (4-5 mo old) was exposed for 7 min to 280 mW/cm^2 radiation at 2.45 GHz. After microwave exposure, the animals were killed at intervals from 6 hr to 1 mo. One hr before animals were killed, tritiated thymidine was injected into the anterior chamber of both eyes. Epithelial peels (74 experimental and 21 control) were made, and each irradiated and control nonirradiated eye was examined to identify and count tritium-labeled cells and mitotic figures. Comparison of counts from experimental and control lens epithelia revealed two patterns, depending on the presence or absence of vesicle strings. The lens with vesicle strings displayed a rise in DNA synthesis on the fourth to fifth day after irradiation. The lens without vesicle strings showed a suppression of mitotic activity followed by a gradual return to normal levels. (17 refs.)

4962 ANESTHESIA AS AN EFFECTIVE AGENT AGAINST THE PRODUCTION OF CONGENITAL ANOMALIES IN MOUSE FETUSES EXPOSED TO ELECTROMAGNETIC RADIATION. (Eng.) Rugh, R. (U.S. Dept. Health, Education, Welfare, Public Health Service, Food Drug Admin., Bureau Radiological Health, Div. Biological Effects, 5600 Fishers Lane, HFX-120, Rockville, MD 20852); McManaway, M. *J. Exp. Zool.* 197: 363-367; 1976.

To determine if immobilization during radiation alters the production of congenital anomalies, deaths, and resorptions, 130 pregnant mice (CF_1) were individually subjected to microwave radiation at 7.3 W for 4 min with and without anesthesia (2,450 MHz wavelength). The fetuses of irradiated but unanesthetized (free to move) mice showed the greatest damage: 32% resorption, 5.7% deaths, and 2.3% anomalies. Anesthetized mice held in one of three positions during irradiation showed the least mean absorbed dose, the lowest incidence of resorption, only one anomalous fetus, and one death. Immobilization, particularly in the broadside position, protected the fetuses against teratogenic damage from radiation. Although microwave radiation elevated the body temperature, anesthesia caused a reduction in body temperature that balanced it out and protected the mother and fetus against the thermal effects of microwave radiation. The results indicate that the primary effect of high level microwave radiation are thermal. (9 refs.)

4963 ON THE INDUCTION OF CHROMOSOMAL ABERRATIONS BY 2450 MHz MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Leach, W. M. (Bureau Radiological Health, Food Drug Admin., U.S. Dept. Health, Education, Welfare, Rockville, MD 20852). *J. Cell Biol.* 70: 387a; 1976.

The chromosomal effects of 2450 MHz radiation were examined in Chinese hamsters (*Cricetulus grisens*). Animals were injected with 0.1% solution of Colcemid either 0.25 hr before or after, or 2 hr after irradiation (incident power density, 200 mW/cm^2, duration, 0.25 hr). Bone marrow cells were removed from femurs and prepared for mitotic and chromosomal evaluations. The mitotic index was depressed in preparations made at 5 hr from animals irradiated after injection, compared with either sham irradiated injected animals or animals irradiated prior to

injection. The overwhelmingly prevalent chromosomal response at 5 hr was chromosomal stickiness between chromosomes and sister chromatids. Chromatin bridges were also observed between nuclei suggesting that cells with chromosomal stickiness escaped the Colcemid block. In one series, such bridges were evident in 10-15% of cells completing cytokinesis. One week after irradiation, bone marrow cells from irradiated animals showed a reduction in stickiness phenomena, but chromosome structural aberrations were significantly higher than in controls. The appearance of chromosomal aberrations after microwave radiation exposure suggests that multiple mechanisms may exist for radiation breakage of chromosomes. (No refs.)

4964 ALTERATION OF BBB: A STUDY TO EXPLORE NEW THERAPY FOR CNS LEUKEMIA (ABSTRACT). (Eng.) Chang, B. K. (Dept. Medicine, Duke Univ. Medical Center, Durham, NC); Huang, A. T. *Blood* 48(6): 994; 1976.

Modification of the central nervous system with low power density microwave radiation was undertaken to facilitate drug transfer across the blood brain barrier (BBB) to circumvent the difficulties in treating meningeal leukemia. This report presents initial attempts to alter the BBB. In three dogs, the penetrance of a test substance, ^{131}I-albumin, increased transiently 4- to 10-fold over baseline values 60 min after the animals received cranial microwave radiation at density of 2 mW/cm^2. Cerebral spinal fluid (CSF) was sampled serially via a cisternal puncture, and penetrance was expressed as the ratio of CSF to plasma concentrations of ^{131}I-albumin (C_{CSF}/C_{plasma}). Furthermore, radiation at this density also caused a 50% increase in the uptake of ^{3}H-methotrexate (0.06-0.2 μM) by human lymphocytes, granulocytes, and leukemic cells. The data suggest that 20 min of low power density microwave radiation not only enhances entry of substances into the CSF that do not ordinarily pass the BBB but also increases the intracellular concentration of methotrexate in human leukocytes. (No refs.)

4965 CYTOGENETIC EFFECT OF VARIABLE ELECTROMAGNETIC SHF FIELD. (Rus.) Kapustin, A. A. (Kiev Scientific Res. Inst. General and Communal Hygiene, Ukrainian SSR Ministry Public Health, Kiev, USSR); Rudnev, M. I.; Leonskaia, G. I.; Knobeeva, G. I. *Tsitol. Genet.* 10(5): 400-402; 1976.

The effect of a variable super high frequency electromagnetic field with a wavelength of 12 cm and intensities of 50 and 500 μW/cm^2 on chromosome aberrations was studied in the bone marrow of inbred albino rats *in vivo*. The animals were irradiated for 10 days, 7 hr daily. Irradiation at both intensities caused a significant initial increase in the frequency of cells with chromosome aberrations, mainly in the form of polyploidy, aneuploidy, chromatid deletion, acentric fragments, and chromatid gaps. The incidence of the aberrations was higher 2 wk after the irradiation than immediately after irradiation in the group exposed to 50 μW/cm^2, but the aberration frequency decreased by the end of wk 2 in the group exposed to 500 μW/cm^2 due to the elimination of damaged cells. Hypoxia (corresponding to 8,000 m altitude for 20 min) during and after irradiation reduced the incidence of cells with chromosome aberrations. (7 refs.)

4966 CHANGES IN THE SELF-STIMULATION REACTION IN RATS UNDER THE ACTION OF MODULATED ELECTROMAGNETIC FIELD. (Rus.) Antimonii, G. D. (P. K. Anokhin Inst. Normal Physiology, USSR Acad. Medical Sciences, Moscow, USSR); Badikov, V. I.; Kel, A. A.; Krasnov, E. A.; Sudakov, S. K. *Biull. Eksp. Biol. Med.* 82(10): 1163-1165; 1976.

The effect of modulated electromagnetic field (39 MHz, field intensity 100-120 W/m; modulation frequency 2, 7, and 50 Hz) on the self-stimulation reaction was studied in 30 male and female rats with electrodes implanted in the anterior or posterior lobes of the hypophysis or in the septum. The modulation frequency of 2 Hz caused a primary increase in the self-stimulation reaction, followed by a depression. The 7 Hz frequency first failed to alter the self-stimulation reaction, and then led to a gradual reduction of the incidence of this reaction and to complete disappearance in 10 min. The modulation frequency of 50 Hz depressed the self-stimulation reaction practically from the very beginning. The above changes in the self-stimulation reaction were independent of the localization of the electrodes. (6 refs.)

4967 LOW INTENSITY MICROWAVE EFFECTS ON THE SYNTHESIS OF THYROID HORMONES AND SERUM PROTEINS (MEETING ABSTRACT). (Eng.) Travers, W. D.; Vetter, R. J. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 91; 1976.

The effects of chronic low level microwave exposure on the levels of triiodothyronine, thyroxine, and thyroid-stimulating hormone and on the serum protein composition in rats were investigated. Animals were exposed to no more than 10 mW/cm^2 of 2,450 MHz microwaves 8 hr per day for 21 consecutive days. Serum hormone levels were determined weekly by radioimmunoassay techniques, and serum protein composition was analyzed electrophoretically. The results and their significance on the low level exposure of man to microwave radiation are discussed. (No refs.)

4968 OBSERVATIONS CONCERNING BIOLOGICAL ACTIVE, NATURAL ELECTROMAGNETIC RADIATION OF EXTREMELY LOW INTENSITY (MEETING ABSTRACT). (Eng.) Szul, R.; Szul, M. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 118; 1976.

Data concerning biologically active natural electromagnetic radiation of extremely low intensity are reviewed. Existence of the natural sources of the coherent electromagnetic radiation in the frequency range of about 1,420 MHz has been stated. This radiation is supposedly generated by molecular generators exposed to geomagnetic fields. In those generators, magnetic dipole transitions occur under the influence of the perturbations of these fields. The main source of this radiation is water excited by alternating magnetic or electromagnetic fields. Other natural materials and plastics exhibit similar effects. Using indirect methods the power densities can be estimated from a dipole antenna fed with power in the range of 10^{-18} to 10^{-22} W. The shape of the radiation pattern of the field sources depends upon the mode of excitation and the shape of the source. It has been confirmed that for some power densities this radiation is attenuated very little in material media immersed in magnetic field. This phenomenon can be explained by quantum physics. The radiation reacts only with molecular and macroscopic resonant elements, causing changes of the radiated field and other parameters. It has been found that man and animals have specific centers generating coherent electromagnetic radiation in the frequency range of about 1,420 MHz that react with radiation generated by natural and artificial sources down to the threshold value of extremely low intensity. (No refs.)

4969 RADIOFREQUENCY RADIATION DOSIMETRY HANDBOOK (MEETING ABSTRACT). (Eng.) Johnson, C. C.; Durney, C. H.; Barber, P. W.; Massoudi, H.; Allen, S. J. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 119-120; 1976.

A radiofrequency radiation dosimetry handbook is described that attempted to develop theoretic methods for relating absorbed energy in man and animals to the incident radiation intensity to provide a link between biologic effects observed in irradiated animals and corresponding biologic effects that might occur in man. Homogeneous spheroidal and ellipsoidal models of humans and animals were used to calculate the data. Extensive graphs of calculated specific absorbed power versus frequency for typical monkeys, baboons, dogs, rabbits, guinea pigs, rats, mice, eggs, pupae, as well as several typical human forms in plane wave radiation were included. The handbook should prove valuable to researchers in microwave biologic effects because it will provide a convenient means of estimating the specific absorbed power in the animal in terms of the incident fields or power density, and extrapolating observed animal effect to humans. For example, an experimenter who desires to study possible effects produced in humans irradiated by a plane wave of 10 mW/cm^2 power density at 20 MHz with a specific orientation in the fields could look at a curve in the handbook and find the calculated specific absorbed power density in an average man. He could then look at other curves and find the required incident plane wave power density required to produce the same specific absorbed power density in experimental animals. As an example, the incident plane wave power density required for a mouse would be about 27 times greater than that for the man for the same average specific absorbed power. (No refs.)

4970 HYPERTHERMIA BY LOCAL EM HEATING (MEETING ABSTRACT). (Eng.) Chen, K. M.; Guru, B. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 139; 1976.

A study was conducted to investigate the distribution of power deposition in a biologic body with a cancerous part, when the body was illuminated partially by an electromagnetic (EM) field. It was found that the cancerous part with a lower conductivity dissipated more power, causing a high temperature increase. The scheme of heating a local region of a biologic body by utilizing the whole-body EM illumination and changing the conductivity of the local region was also studied. It was found that when the frequency of the EM field was in the range of 1 to 100 MHz, the increase of the conductivity of the local region usually caused a decrease instead of an increase in the absorbed power in that local region. It is suggested that for a microwave EM field, there may exist an optimum conductivity for the local region to gain the most effective EM heating. (No refs.)

4971 A COMPARATIVE HEATING PATTERN STUDY OF DIRECT CONTACT APPLICATORS IN MICROWAVE DIATHERMY (MEETING ABSTRACT). (Eng.) Kantor, G.; Cetas, T. C. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 139; 1976.

A comparative study of direct contact applicator heating patterns was conducted that included inhomogeneously filled rectangular waveguides, circularly polarized antennas, and other radiators appropriate for microwave diathermy. In addition, low power emitters (usually operating at power levels of less than 10 W), the only direct contact radiators presently in clinical use, were investigated. Multilayered planar and limb phantoms consisting of simulated bone (1 cm thick) and muscle material were irradiated at a frequency of 2.45 GHz, and the midplane of each phantom was then exposed to an infrared thermographic camera. Temperature profiles parallel to fat-muscle interface, as well as normal to it, were obtained to study maximum heating and depth of penetration of microwave energy in muscle tissue. The temperature profile produced in a planar phantom by an applicator, consisting of an open WR(430) rectangular waveguide partially filled with teflon slabs to excite the transverse electromagnetic mode in the unloaded middle portion, has a broad uniform center region. A birefringent crystal optical ther-

mometer was placed in the mid-plane of each phantom to obtain temperature readings and cooling rates in the region of heating. It was found that leakage radiation levels could be maintained below 5 mW/cm^2 (equivalent plane wave power density), if the applicator aperture size was considerably smaller than the phantom size. (No refs.)

4972 DUAL BEAM TEM APPLICATOR FOR DIRECT CONTACT HEATING OF DIELECTRICALLY ENCAPSULATED MALIGNANT MOUSE TUMOR (MEETING ABSTRACT). (Eng.) Cheung, A. Y.; Dao, T.; Robinson, J. E. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 140; 1976.

A microwave heating technique that employs a direct parallel to parallel opposed treatment field for use in ionizing radiation therapy is described. The sources of irradiation are two opposite-directed "TEM" applicators operating at 2,450 MHz. The applicator design consists of an open-ended rectangular waveguide, partially loaded with low loss dielectric slabs. Such a structure can support a TEM mode of propagation. The impedance mismatch generated from the TE to TEM transition and from the aperture-tissue boundary are compensated by a properly designed taper and a quarter-wave transformer. On direct contact with a tissue-equivalent slab, the TEM applicator heats uniformly in the transverse plane (± .2°C at 45°C). To test the apparatus, exposed C3H mouse tumors, 1 cm in diameter and transplanted to grow on the flank of mice, were encapsulated within simulated phantom materials with dielectric properties similar to that of the tumor to form a rectangular slab. The thickness of the slab along the direction of propagation was designed so that the super-position of two exponentially decreasing heating fields from opposite directions would generate a uniform temperature distribution. Two TEM applicators in direct contact with the slab were used to heat from opposite sides at alternate time intervals of 5-50 sec. Alternating at 30 sec, two applicators operating at 30 W for 10 min, produced a temperature of 42 ± .1°C over the entire tumor volume, compared with a 2°C front to back drop when a single applicator was used alone under the same condition. (No refs.)

4973 THE USE OF SPONTANEOUSLY OCCURRING ANIMAL TUMORS FOR PRECLINICAL TESTING OF HYPERTHERMIA TREATMENTS (MEETING ABSTRACT). (Eng.) Connor, W. G.; Roth, H. B.; McKelvie, D. H.; Wilson, S. E.; Cetas, T. C. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 141; 1976.

Tumor systems occurring spontaneously in animals are being used as experimental models for the development of heating and thermal dosimetric techniques to be used in hyperthermia treatments of human tumors. The animals, mostly dogs and cats, are referred by local veterinarians. Treatments consist of heat alone, e.g., 43°C for 30 min; x-irradiation alone, e.g., 4,000 rads/4 wk; or a combination of the two. Localized heating is induced by radio-frequency current fields (500 KHz), microwave diathermy (2,450 and 915 MHz), or shortwave (27.1 MHz) diathermy. Temperatures are monitored with a non-perturbing fiber optic thermometer incorporating a birefringent crystal as a sensor and with thermistor probes. Thermographic techniques both in phantoms and, when possible, on the actual subjects are used to determine the thermal pattern. All thermometry is tied to a laboratory standards facility, which is accurate to better than 0.01°C. The biologic aspects are supported by cell culture and laboratory animal studies in adjacent laboratories. Radiation oncologists consult regularly on the treatments. (No refs.)

4974 WHOLE BODY DOSIMETRY OF ANIMALS: THE EFFECT OF WEIGHT AND EXPOSURE GEOMETRY (MEETING ABSTRACT). (Eng.) Kinn, J. B. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 42; 1976.

Whole body energy absorption of 2,450 MHz radiation was measured in rats over a weight range of 9-440 g and in mice ranging from 30-50 g to determine the effect of weight and exposure geometry on such absorption. Simultaneous exposures of groups of animals in various configurations were made in a free field condition in an anechoic chamber. Measurements of whole body absorption were made with twin-cell calorimeters. Preliminary results indicated that the range of energy absorption may vary by a factor of 2-7 within specific weight groups. The implication of this spread on the choice of incident power levels used in dose-effect studies is discussed. Comparison of the measured dose of theoretic values produced by a spherical shell model showed considerable variations of the observed from the predicted. Specific relationships of absorbed dose to power density and size are presented. (No refs.)

4975 COMBINED EFFECT OF MICROWAVE HYPERTHERMIA AND PURIFIED BACTERIAL TOXINS ON DEVELOPMENT OF SARCOMA-180 AND GUERIN TUMORS (MEETING ABSTRACT). (Eng.) Szmigielski, S.; Bielec, M.; Janiak, M. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 141-142; 1976.

Mice with transplantable Sarcoma 180 or rats with transplantable Guerin tumor were exposed to microwave hyperthermia (40 mW/cm^2, 3 hr daily) at various periods after transplantation of the tumor to study the combined effect of microwave hyperthermia and

bacterial toxins on tumor development. Rectal temperature was measured during irradiation (liquid crystall probe), and distribution of temperatures on the body surface was observed. The animals were treated with highly purified Streptolysin O, staphylococcal phospholipase C (beta-hemolysin), or with cyclophosphamide (positive controls). The toxins were administered daily and given alone or in combination with microwave hyperthermia. Survival rate, weight and size of tumors, and incorporation rate of ^{3}H-thymidine, ^{3}H-uridine, and ^{3}H-glycine into tumor tissue were studied. Microwave hyperthermia resulted in inhibition of tumor growth in about 25-30% of animals. The combined treatment with microwave hyperthermia and Streptolysin O resulted in regression of tumors in 50-70% of animals, depending on the time schedule of the treatment. The best results were obtained in animals treated in the phase of logarithmic growth of the tumors. (No refs.)

4976 ELECTROMAGNETIC POWER DEPOSITION IN MAN AND ANIMALS WITH AND WITHOUT GROUND AND REFLECTOR EFFECTS (MEETING ABSTRACT). (Eng.) Gandhi, O. P.; Hunt, E. L.; D'Andrea, J. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 42; 1976.

Experimental results are given for electromagnetic power deposition in man models and rats in the presence of flat and 90°-corner reflectors. Whole body absorptions 5-20 times that at resonance values were observed for spacings to the reflecting surfaces accurately predicted from antenna theory. Projected energy deposition rates for man and animals subjected to incident fields of 10 mW/cm^2 are presented with and without ground and reflector effects. Resonance values as high as 3000-6000 W for adult humans are predicted. The times to convulsion of 100 and 400 g rats for incident field intensities of 5-20 mW/cm^2 confirmed some of the highest projections in the presence of reflecting surfaces. (No refs.)

4977 USE OF HEATING AND COOLING CURVES TO MEASURE MICROWAVE ENERGY ABSORPTION IN BIOLOGICAL SAMPLES (MEETING ABSTRACT). (Eng.) Allis, J. W.; Blackman, C. F.; Fromme, M. L.; Benane, S. G. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 43; 1976.

A method is described that uses the entire heating or cooling curve to measure rate of microwave energy absorption in biologic samples rather than relying on the estimation of the initial slope. The cooling constant and temperature rise of the sample due to irradiation can be obtained directly from either a heating or a cooling curve. The method does not require the determination of the heating curve constant, which contains the absorption cross-section of the sample. The latter constant is not necessary for calculation of the rate of energy absorption. Data are presented demonstrating the use of the method for far field exposure of samples contained in tissue culture flasks and petri dishes as well as for exposure of a sample at the end of a waveguide transmission line. (No refs.)

4978 MICROWAVE IRRADIATION OF ISOLATED RAT HEARTS TREATED WITH ANS BLOCKING DRUGS (MEETING ABSTRACT). (Eng.) Reed, J. R., III; Lords, J. L.; Durney, C. H. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 115-116; 1976.

In the work reported here rat hearts in which both systems, parasympathetic and sympathetic, are blocked by the respective drugs showed no significant effect upon irradiation. With respect to these data, it is hypothesized that the microwave energy interacts with the autonomic nerve remnants present in the excised hearts. Although the mechanism is as yet undetermined, it is believed that neurotransmitter is likely to be involved in the process. The dose rate (absorbed power density) in the heart was calculated from the rate of temperature rise during irradiation. The temperature was measured by the liquid crystal optical fiber probe, which being nonmetalic, is not disruptive to the microwave field. (No refs.)

4979 BEHAVIORAL AND PHYSIOLOGICAL EFFECTS OF CHRONIC PULSE-MODULATED MICROWAVE RADIATION IN RATS (MEETING ABSTRACT). (Eng.) Lovely, R. H.; Myers, D. E.; Johnson, R. B.; Guy, A. W. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 92; 1976.

To determine the behavioral and physiologic effects of chronic microwave exposure, eight male rats were irradiated for 3 mo with 918 MHz microwaves pulse-modulated at 11 Hz, for 10 hr/night, and at an average power density of 2.5 mW/cm^2 (spatially averaged over the cross-section of the exposure chamber). The exposure apparatus consisted of cylindrical waveguide capable of delivering circularly polarized guided waves (TE_{11} mode) and a living chamber designed to be compatible with laboratory conditions required by rodents. The cylindrical waveguide allowed for easy quantification of the fields in terms of incident power, total absorption, and specific absorption rate for each exposed animal, independent of other rodents being simultaneously exposed. Physiologic and behavioral comparisons between the eight irradiated and eight sham-irradiated control rats included daily food and saccharin/water intake. In addition, aperiodic assessments were made of deep colonic temperatures, behavioral repertoire during

radiation, and serum chemistry (i.e., calcium, sodium, potassium, chlorine, blood-urea-nitrogen, CO_2, ion gap, glucose, as well as basal and ether-stress-induced levels of corticosterone). The results of these assessments are discussed in terms of the biologic effects of equivalent continuous wave average power density, as well as in terms of the existing literature. (No refs.)

4980 DRUG-INDUCED ECTOTHERMIA IN SMALL MAMMALS: THE QUEST FOR A BIOLOGICAL DOSIMETER (MEETING ABSTRACT). (Eng.) Putthoff, D. L.; Justesen, D. R.; Levinson, D. M.; Ward, L. B. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 43; 1976.

The use of chemical agents to render mammals ectothermic, thus enabling the conversion of pre- and post-radiation temperatures of the animal into estimates of quantities of absorbed energy, is reported. Sodium salicylate and cortisone acetate were administered to mice, rats, guinea pigs, and rabbits of both sexes and of pigmented and albino strains, and their effects on colonic and rectal temperature were studied. While the salicylate produced a marked hypothermal response in mice and rats, it was less effective in guinea pigs and rabbits and was otherwise variable with respect to strain. Cortisone produced a more uniform hypothermal response; studies of mice and rats revealed that increments of colonic temperature from short periods of moderately thermalizing microwave radiation yielded estimates of energy dosing that were accurate within ± 10%. It is concluded that cortisone is useful in microwave dosimetry studies in the free field where an empirical fit between measures of incident and absorbed energy is the objective. (No refs.)

4981 EFFECTS OF CHRONIC ATHERMAL MICROWAVE RADIATION ON INNATE AND LEARNED BEHAVIORS IN RATS (MEETING ABSTRACT). (Eng.) Mitchell, D. S.; Switzer, W. G.; Bronaugh, E. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 92; 1976.

A multimode microwave exposure chamber was designed, calibrated, and employed to investigate the effects of chronic 2.45 GHz continuous-wave radiation at an equivalent plane-wave power density of 5 mW/cm^2 on innate and learned behaviors in rats. Relative to sham-irradiated controls, irradiated subjects displayed statistically significant increases in locomotor activity, reliable evidence of disrupted differential responding during asymptotic discriminative operant reward conditioning, but no significant differences in Sidman avoidance conditioning performance . Comparisons with pre-irradiation baseline data revealed that the observed effects emerged almost immediately following the initiation of microwave exposures and persisted throughout the course of a 5-hr per day, 22-wk irradiation sequence. Daily core temperature sampling produced no evidence of whole-body heating in irradiated rats. It was concluded that the observed behavioral effects are consistent with a general activation hypothesis, suggesting the possibility of microwave-induced alterations in central nervous system activity, although the exact mechanism remains unclear. Evaluation of the present findings in conjunction with those reported by other investigators suggests that a given behavioral outcome may depend in complex ways upon specific combinations of irradiation parameters. The need for increased standardization in laboratory techniques and paradigms was stressed, with particular emphasis on modes and procedures of irradiation. (No refs.)

4982 RADIATORS FOR MICROWAVE BIOLOGICAL EFFECTS RESEARCH--WAVEGUIDE SLOT ARRAY WITH CONSTANT RADIATION INTENSITY (MEETING ABSTRACT). (Eng.) Hagmann, M. J.; Gandhi, O. P. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 66; 1976.

A longitudinal shunt slot array having a pattern with nearly constant radiation intensity over the beamwidth and zero intensity outside was designed for use in microwave biologic studies with large or multiple targets. A beamwidth of 12.5° was chosen as being small enough for a radiated beam to approximate a plane wave yet give enough divergence for convenient chamber dimensions. Discontinuities in the desired pattern force the Fourier-synthesized pattern to have significant errors due to overshoot and ripple. Solutions developed on the basis of Fejer sums and Lanczos' σ factors gave patterns with objectionable rounding. A new procedure based on weighted least squares was developed for optimum characteristics. The test design at 10.4 GHz used 9 slots and had a calculated variation of ± 5% in radiation intensity over the 12.5° beamwidth with 80% of the total radiated power contained within the beamwidth. Experimental results on this antenna are presented. (No refs.)

4983 A MICROWAVE EXPOSURE SYSTEM FOR PRIMATES (MEETING ABSTRACT). (Eng.) Heynick, L. N.; Polson, P.; Karp, A. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 66; 1976.

A set of cavity/cage units for chronic irradiation of macaques and smaller animals at 2.45 GHz was developed. Each cavity was a three-foot, multimode, mode-stirred cube excited by a magnetron. Forward and reflected powers were measured by calibrated diode detectors in a bidirectional coupler between the magnetron and cavity. Power values were set by phase-angle selection and maintained constant by

detector-output feedback to a thyristor control circuit. The cage was of low radiofrequency-loss-tangent materials. Calorimetry with saline-filled bottles and dolls was used to determine energy absorption values as related to net input power and time. Calorimetric measurements were taken with plane-wave irradiation in an anechoic chamber to establish total absorbed power equivalence between the two irradiation methods. Scanning infrared thermography was also performed on macaque carcasses irradiated in the cavity/cage unit. Twelve units are currently in use for investigating behavioral effects on squirrel monkeys subjected to chronic irradiation. (No refs.)

4984 INTERNAL EM FIELD AND ABSORBED POWER DENSITY IN HUMAN TORSOS INDUCED BY 1 TO 500 MHz EM WAVES (MEETING ABSTRACT). (Eng.) Guru, B. S.; Chen, K. M. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 39; 1976.

Numeric results are presented on the internal electromagnetic (EM) field and absorbed power density inside a human torso induced by EM waves of frequencies ranging from 1 to 500 MHz with vertical and horizontal polarizations. The induced fields inside the torso were dependent on the frequency and the torso geometry. Resonance phenomena at particular frequencies were evaluated. Theoretic results were obtained based on the tensor integral equation method, and some of the theoretic predictions were compared with existing experimental results. (No refs.)

4985 MEASUREMENT OF THE DIELECTRIC CONSTANT AND CONDUCTIVITY OF BIOLOGICAL MATERIALS BY MICROWAVE CAVITY PERTURBATION METHOD (MEETING ABSTRACT). (Eng.) Ma, C. H.; Deaton, D. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 47; 1976.

The electrical properties of blood and solid biologic materials were determined from the measurements of the resonant frequency and Q of the resonance curve of microwave cavities with and without samples inside the cavities. Unlike the commonly used transmission line and waveguide methods in which the accuracy and repeatibility are critically dependent upon the accurate measurement of the sample dimensions, the smoothness of the sample surfaces, slicing and packing techniques, it was found that the accuracy of the cavity perturbation method relied only on the accuracy of mass measurement of the sample, if the sample was small compared with the cavity and was placed in the region with approximately uniform field. Circularly cylindrical cavities with sample filled glass tube as a central rod were used in the experiments. Initially, measurements to verify the accuracy of the technique were performed, resulting in accurate determination of the dielectric constant and conductivity in dielectric materials of known properties. The electrical properties of blood and various solid biologic materials were determined, and the properties of the white blood cells were measured as a function of temperature. The results were summarized in the plots of the electrical properties of the biologic materials with temperature and quantities of the samples as parameters, and good repeatibility was observed throughout the range of investigation. (No refs.)

4986 MICROWAVE DOSIMETRY VIA ELECTRIC FIELD MAPPING WITHIN FULL-SIZE AND SCALED PHANTOM MODELS (MEETING ABSTRACT). (Eng.) Herchenroeder, P.; Cheung, A. Y.; Swicord, M.; Bassen, H. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 40; 1976.

Electric field strengths and patterns induced by plane wave irradiation within various tissue structures were examined using a calibrated, nonperturbing, isotropic electric field probe. The probe was implanted inside simulated tissue phantoms of various shapes and sizes. To establish the reliability of the probe for implantation measurement, the values of the electric field detected by the probe inside plane wave irradiated phantoms of simple geometry (planar slabs and spheres) were compared with theoretic predictions at 915 MHz and 2,450 MHz. Under all conditions, the magnitude and relative pattern of electric field distributions agreed closely with existing theoretic predictions. Using the same probe, absolute electric field intensity at various locations were made within half-sized and quarter-sized human phantoms (with properly adjusted electrical properties) developed for simulated total body exposure studies at 915 MHz and 2,450 MHz. One-dimensional and two-dimensional E-field distributions throughout the body were mapped using data generated from continuous single-axis probe-scans and sectional thermographic presentation at various locations. The simultaneous use of the E-field probe, together with thermography, gave a complete detailed, quantitative evaluation of induced internal electromagnetic field under various exposure conditions. (No refs.)

4987 BIOLOGICAL PHANTOM MATERIALS FOR SIMULATING MAN AT DIFFERENT FREQUENCIES (MEETING ABSTRACT). (Eng.) Gandhi, O. P.; Sedigh, K. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 40; 1976.

Compositions of biologic phantom materials for simulating man over the frequency range 13-570 MHz (including the important resonance regions of 33 and 65 MHz) are given. These materials were developed to fill eight proportionately scaled man-shaped cavi-

ties of height 7.6-40.6 cm for dosimetric measurements at 300, 400, 600, 915, 985, and 2,450 MHz. Complex permittivity (ε_c) measurements at the irradiation frequencies were made using a modified version of the coaxial line method. Models reduced by β in all dimensions allowed simulation of man at frequencies given by (experimentation frequency)/β, provided materials with ε_c at (lower) simulated frequencies were used. Whole-body average values of ε_c at simulated frequencies were first calculated on the basis of 65% muscle and tissues of high water content and 35% fat, bone, and tissues of low water content on the basis of tissue values extrapolated from published data. Several compositions of salt, polyethylene powder, Superstuff, and water were first measured for ε_c's at the six experimental frequencies. Interpolated compositions were then measured and modified, if necessary, for desired permittivities. To simulate man at still higher frequencies, compositions are being developed for average electrical properties to the depth of penetration for individual parts of the body. Also, dosimetric measurements will be compared for correct and incorrect phantom materials. (No refs.)

4988 ELECTROMAGNETIC ENERGY EXPOSURE EFFECTS ON MOTOR COORDINATION OR BALANCE (MEETING ABSTRACT). (Eng.) Frey, A. H.; Gendelman, S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 19; 1976.

The effect of pulse-modulated electromagnetic (EM) energy on motor coordination or balance was evaluated in Sprague-Dawley rats. A horizontal rod was set to rotate at an increasing rate of speed until a predetermined speed was reached. The subjects were divided into two groups: sham exposed and EM energy exposed. The EM energy exposed occurred during their time on the rotating rod. In a series of experiments, different EM energy parameters were used. The animals were exposed individually on the rotating rod until they fell off the apparatus. The time scores of the animals on the rod were recorded for evaluation. The results of this evaluation are not currently available. (No refs.)

4989 LYMPHOCYTE TRANSFORMATION INDUCED BY MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Huang, A. T.; Engle, M. E.; Elder, J. A. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 21; 1976.

The effects of microwave radiation at power densities below 30 mW/cm^2 were examined in blood lymphocytes from Chinese hamsters. Animals were irradiated for 15 min on 5 consecutive days at 2,450 MHz (continuous wave) with power densities from 5 to 30 mW/cm^2 and at 9,000 MHz (pulse) with density 10 mW/cm^2. Absorbed dose measurements were determined by twin-well calorimetry. One hour after irradiation, blood lymphocytes were obtained from orbital hemorrhage. Cells were cultured for 1 day if unstimulated or for 3 days if stimulated with phytohemagglutinin (PHA) to induce mitosis. After termination, lymphocytes were processed for morphologic and cytogenetic analyses with a brief colchicine treatment to arrest cells in metaphase. Microwave radiation caused a dose-related (5-30 mW/cm^2) increase in blastic transformation (increase in nuclear size by three fold in area) of unstimulated lymphocytes. However, frequency of cell division from PHA-stimulation decreased in irradiated samples. Both effects were evident at 5 mW/cm^2. Autoradiography of cells labelled with [^{3}H]-thymidine and [^{3}H]-uridine suggested that the increased blastic transformation was associated with an enhancement of RNA synthesis, probably due to changes in chromatin structure. There was no evidence of radiation-related DNA repair. Cytogenic analysis of the irradiated samples showed no significant chromosomal aberration within these power densities. (No refs.)

4990 TEMPERATURE DEPENDENCE OF MICROWAVE AVOIDANCE (MEETING ABSTRACT). (Eng.) Monahan, J. C.; Ho, H. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 4-5; 1976.

The effect of ambient temperature on avoidance behavior induced by 2,450 MHz continuous wave radiation was investigated in CFI male mice (30-34 g). The animals were irradiated in an environmentally controlled waveguide assembly at temperatures of 20, 24, 30 or 35°C and a relative humidity of 50 ± 1.5%. Incident power levels ranged from 0.04 W to 4 W resulting in average absorbed dose rates of 0.06 to 55 mW/g. In those groups that exhibited avoidance behavior, the percentage of absorption decreased after the initial 5 min and remained lower for the duration of the exposure. The threshold incident power level at which avoidance behavior was observed decreased with an increase in the environmental temperature. The data suggest that the subjects were capable of detecting average absorbed dose rates of as little as 0.5 mW/g. Furthermore, this level of irradiation, while producing no core temperature increase, was aversive and caused the animal to actively avoid the microwave radiation when the environmental temperature was 35°C. (No refs.)

4991 EFFECTS OF PULSED MICROWAVES ON THE HEMATOPOIETIC SYSTEM OF MICE (MEETING ABSTRACT). (Eng.) Ragan, H. A.; Phillips, R. D. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 22; 1976.

To investigate the effects of pulsed microwaves on the hematopoietic system, female mice were exposed

approximately 8 hr daily for 10 days to 2.88 GHz pulsed microwaves (2.3 μsec pulses at 100/sec) in an anechoic chamber at an average power density of 5 mW/cm^2. Female littermates were sham-exposed and served as controls. All mice were killed 92 hr after the last exposure. No statistically significant effects were observed on red cell parameters, total white cell counts, or the leukocyte differential counts. Platelet counts were lower ($p<0.05$) in exposed mice. This was compatible with the relative paucity of megakaryocytes in bone marrow and spleen. Cellularity of femoral bone marrow was higher ($p<0.001$) in the exposed group. Cytologic examination revealed a decrease in megakaryocytes, but a slight increase in the myeloid-erythroid ratio of exposed mice. More nonheme iron was present in the marrow from exposed mice, suggesting an interference with iron metabolism. Splenic erythropoietic and leukopoietic activity were greater, and megakaryocytopoiesis was less in exposed than control mice. Microwave exposure did not influence serum protein concentrations or the protein electrophoretic patterns. Serum triglyceride levels were higher ($p<0.05$) in the microwave exposed group. A future experiment will compare hematologic changes observed in these mice with changes in a group exposed to continuous wave microwaves. (No refs.)

4992 MICROWAVE CONTROL OF BEHAVIOR: AN AUDITORY PHENOMENON (MEETING ABSTRACT). (Eng.) Johnson, R. B.; Lovely, R. H.; Guy, A. W.; Galambos, R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 2; 1976.

To elucidate the behavioral effect of microwaves, rats trained to make a food reinforced "nose-poke" response while held in a plexiglas restrainer were irradiated during alternating 5-min periods with 918 MHz pulsed microwaves. Three animals were trained to respond only during irradiation, and three were trained to respond during nonirradiation. Six additional animals were similarly trained with alternating periods of acoustic stimulation. All twelve animals acquired the discrimination at comparable rates, learning to inhibit responding during inappropriate stimulus conditions. The results are discussed in terms of the motivational properties of pulsed microwave irradiation and its effect on inhibitory processes. During continued training, the performance of some animals gradually deteriorated. Auditory-evoked potentials could not be recorded from these animals at the stimulus intensities employed. Examination revealed profound middle ear infections rendering these animals deaf. However, these animals demonstrated continued ability to perform when extremely intense acoustic stimulation or visual stimulation was provided. Six animals were adapted to perform the discrimination using acoustic stimulation, as well as 918 MHz and 2,450 MHz pulsed microwaves on a variable interval schedule of stimulus presentation. Comparisons were obtained for each animal between behavioral and auditory-potential thresholds for each form of stimulation. The comparisons support the conclusion that performance on the discrimination task requires adequate auditory stimulation, whether from acoustic or microwave origins. Finally, cochlear microphonic recordings from pulsed microwave irradiated rats, in addition to behavioral and physiologic threshold comparisons in a "microwave avoidance" task, are discussed. (No refs.)

4993 MICROWAVE EFFECTS ON THE BLOOD-BRAIN BARRIER OF HAMSTERS (MEETING ABSTRACT). (Eng.) Albert, E. N.; Grau, L.; Kerns, J. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 18; 1976.

To investigate the effects of microwave irradiation on the blood-brain barrier, Chinese hamsters were exposed to continuous wave microwave energy at 2,450 MHz for 1-2 hr at 10, 50, and 70 mW/cm^2 power densities. The exposed and sham-irradiated animals were anesthetized and injected with various electron dense tracers, fixed by perfusion, and prepared for gross, light, and electron microscopic examination. A positive reaction was present in the pineal body, pituitary gland, supraoptic crest, and choroid plexus at the gross and light microscopic levels in sham-irradiated animals exposed to 50 and 70 mW/cm^2. However, brains of irradiated animals displayed a positive reaction in the cerebral and cerebellar cortices, medulla, thalamus, and hypothalamus, as well as the above mentioned areas. Brains of exposed animals had lesions that varied in location and intensity. Closer observations with the electron microscope showed the tracer material present in the extracellular space of the neuropil. Furthermore, tracers appeared to have crossed capillary walls via the endothelial intercellular clefts and by increased pinocytotic activity. Preliminary observations on animals exposed to 10 mW/cm^2 appear to be consistent with those in animals exposed to 50 and 70 mW/cm^2. (No refs.)

4994 PREDICTED FREQUENCY AND THRESHOLD OF MICROWAVE-INDUCED AUDITORY SENSATION (MEETING ABSTRACT). (Eng.) Lin, J. C. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 3; 1976.

A spherical model of the head was used to analyze microwave-induced auditory sensation. The problem was formulated in terms of thermoelasticity theory in which the absorbed microwave energy represents the volume heat source, which depends on both space and time. The inhomogeneous thermoelastic motion equation was solved for the acoustic wave parameters under both stress-free and constrained surface conditions using boundary value technique and Duhamel's theorem. Numeric results showed that the predicted frequencies of vibration and threshold pressure amplitude agree well with experimental findings

over a wide range of incident microwave characteristics. It is concluded that the good agreement demonstrates the validity of the thermoelastic stress-production mechanism for microwave-induced hearing in man. (No refs.)

4995 MICROWAVE HEARING: THE RESPONSE OF SINGLE AUDITORY NEURONS IN THE CAT TO PULSED MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Lebovitz, R. M.; Seaman, R. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 1; 1976.

The response of single auditory neurons in the cat to pulsed microwave radiation (MWR) at 915 MHz was studied. The response to acoustic click stimuli of primary auditory fibers and of cell bodies in brain stem cochlear nuclei were recorded via NaCl-filled glass micropipettes. The effect of pulsed MWR on the neuronal discharge properties was then similarly determined. Threshold effects were observed at absorbed energies of 5 μJ/g per pulse; the response was independent of the MWR pulse parameters and independent of the average imposed MWR power density (less than 1 mW/cm^2). Of the more than 200 neurons studied, most demonstrated a response to acoustic clicks similar to that of pulsed MWR stimuli. Units most sensitive to acoustic frequencies below about 3 KHz were more likely to be responsive to microwave pulses than were units with higher best frequencies. It is concluded that the results refine and partially support the suggestion that microwave hearing is mediated by a thermoelastic absorption of the microwave pulse. (No refs.)

4996 LOW FREQUENCY HEARING AND SEEING (MEETING ABSTRACT). (Eng.) Adrian, D. J. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 1; 1976.

Auditory and visual (phosphenes) effects generated by transcranial stimulation with low frequency electric currents were studied to aid the understanding of sensory processes. Frequency response characteristics for both effects were measured. The sensory channels were found to behave much like frequency selective filters but with a number of important nonlinearities. Several types of stimulus currents were used including sinewave, periodic bursts of sinewave, and two simultaneous sinewaves of differing frequency. Habituation to both the phosphene and auditory sensation were noted. The minimum current threshold for the phosphene and auditory effect occurred at 20-25 Hz and 60-90 Hz, respectively. The effects were also generated by the application of two simultaneous sinewaves well above the cutoff frequency when the difference frequency was near the minimum threshold frequency. A decrease in sensory "noise" was noted following some experiments. Possible application of this effect as a therapy for tinnitus is briefly discussed. (No refs.)

4997 CHARACTERISTICS OF MICROWAVE-INDUCED COCHLEAR MICROPHONICS (MEETING ABSTRACT). (Eng.) Chung-Kwang Chou; Guy, A. W.; Galambos, R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 2; 1976.

Cochlear microphonics (CM) of guinea pigs and cats during irradiation by 918 and 2,450 MHz pulsed microwaves were characterized. Both horn applicators and a cylindrical waveguide exposure system were used to radiate the animals. As the body weight of the guinea pigs varied from 0.5 to 1.0 kg, the frequency of microwave-induced CM decreased from 50 to 42 kHz. Similarly, for cats with body weights of 0.9 to 3 kg, the frequency of microwave-induced CM decreased from 38 to 29 kHz. In addition, as the body weight of the test animals was increased, the number of cycles of CM oscillation varied from 11 to 7 cycles in guinea pigs and 10 to 4 cycles in cats. The characteristics of the microwave-induced CM depended on the size of the animal head, i.e., the smaller the head, the higher the frequency of CM, and the thicker the skull, the less the oscillation of CM. For each animal, the same frequency and duration of CM were induced at both 918 and 2,450 MHz with either horn applicator or the waveguide exposure system. The measured parameters were also independent of electrical field orientation with respect to body axis. The thresholds of evoked response (CM or N_1 nerve response) were 10 mJ/kg maximum in adult cats, 2.5 mJ/kg in kittens, and 7.5 mJ/kg average in adult guinea pigs. The results indicate that the microwave auditory effect is mechanical in nature. (No refs.)

4998 AUDIOGENIC SEIZURE SENSITIVITY OF MICE AFTER REPEATED EXPOSURES TO 2.88 GHz PULSED MICROWAVES (MEETING ABSTRACT). (Eng.) Phillips, R. D.; Hjersen, D. L.; Sheldon, R. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 19; 1976.

Female SJL/J mice were exposed 2 hr daily to 2.88 GHz pulsed microwaves (2.3 μsec pulse width, 100 pulses/sec) in an anechoic chamber at an average power density of 10 mW/cm^2 to investigate audiogenic seizure sensitivity. Sensitivity to audiogenic-induced seizures was determined at 1 and 2 wk after daily exposures (5 days/wk) by subjecting the animals to white noise (110-114 dB) and measuring the latencies to running fits and full tonic-clonic seizures. All mice were primed at 21 days of age by subjecting them to 110-1.4 dB of white noise for 60 sec. The mice were then pretested at 28 days of age to score seizure sensitivity for distribution of animals into control and experimental groups on the basis of

equivalent means and variencies in seizure latencies. The latency to a full tonic-clonic seizure was significantly increased ($p<0.05$) in exposed mice compared with controls after 1 wk of exposure. The animals were retested after an additional week of exposure and treated mice continued to have longer latencies than controls ($p<0.01$). Latencies to running fits were not affected by microwave exposure for 1 or 2 wk. A parallel investigation using continuous wave microwaves is in progress. (No refs.)

4999 PAVLOVIAN CONDITIONING OF MICROWAVE-INDUCED HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Bermant, R. I.; Justesen, D. R. *In: Proceedings of the Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 4; 1976.

Rats were subjected to a trace-conditioning procedure in which an auditory signal (conditional stimulus [CS]) preceded by ≥ 30 sec and then overlapped a shorter period (≤ 5 sec) of microwave radiation at 2,450 MHz in a multimode cavity. The radiation served as the unconditional stimulus (US) and was sufficiently intense to produce a 2-3°C rise in colonic temperature. Repeated pairings of CS and US resulted in small increments (~ 0.2°C) of colonic temperature; whether these increments are true conditional response or are an artifact of sensitization or pseudo-conditioning will not be known until completion of control experiments. Preliminary data reconfirm earlier observations that microwave radiation can elicit a rise of body temperature of endogenous origin, presumably through activation of sympathetic pathways via sensory stimulation. (No refs.)

5000 COMPARISON OF THE AVERAGE SPECIFIC ABSORBED POWER IN THE ELLIPSOIDAL CONDUCTOR AND DIELECTRIC MODELS OF HUMANS AND MONKEYS AT RADIO FREQUENCIES (MEETING ABSTRACT). (Eng.) Massoudi, H.; Durney, C. H.; Johnson, C. C. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 39; 1976.

The results of the perturbation theory applied to a lossy dielectric ellipsoidal model are described. The average specific absorbed power in dielectric ellipsoidal models of man and rhesus monkey were calculated and compared with those of the conductor models for the six standard polarizations. The average specific absorbed power in the two models was found to be the same, if the conduction current in the body was much larger than the displacement current. Although the conductor model is inaccurate for low values of conductivity, the equations are simpler than the ones for the dielectric model, and the conductor model is, therefore, advantageous when it is valid. Since it was found necessary to use tissue conductivity values below the range of validity of the conductor model, it is concluded that the dielectric model is essential for accurate theoretic modeling. (No refs.)

5001 EFFECTS OF LOW POWER DENSITY MICROWAVES ON MACROMOLECULAR CONSTITUENTS OF THE BRAIN OF RATS (MEETING ABSTRACT). (Eng.) Catravas, G. N.; Takenaga, J.; Katz, J. B.; Abbott, J. R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 18; 1976.

Experiments were conducted to determine the biochemical changes that occur in discrete regions of the brain of rats exposed to low power density microwave radiation. Groups of rats were exposed to continuous wave microwaves of 2,450 MHz frequency and 15 mW/cm^2, 8 hr per day for 3 wk. During exposure, the animals were confined to styrofoam cages; the inner walls of which were coated with quinine to prevent the rats from chewing through the walls of the cages. The microwave-induced changes in the PGE_1-stimulated brain adenyl cyclase and serotonergic systems were investigated in this series of experiments. Preliminary results indicated an increased sensitivity of brain adenyl cyclase to PGE_1. Marginal increases in the activity of tryptophan hydroxylase and levels of serotonin in the hypothalamic-thalamic region were also observed. (No refs.)

5002 THERMAL AND NEUROENDOCRINE EFFECTS OF LONG TERM, LOW LEVEL MICROWAVE (2450 MHz, CW) IRRADIATION (MEETING ABSTRACT). (Eng.) Lu, S. T.; Lebda, N.; Michaelson, S. M.; Pettit, S.; Rivera, D. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 90-91; 1976.

To determine the thermal and neuroendocrine effects of long-term low level microwave irradiation, Long-Evans rats were irradiated with 2,450 MHz microwave (continuous wave) at 1, 5, 10 and 20 mW/cm^2 for 1, 2, 4 and 8 hr. The animals had been acclimated to the laboratory environment and procedures for 2 wk and preconditioned three times to the equilibration and exposure procedures. Before exposure, a 3-hr equilibration period was utilized for control and irradiated rats. Post-irradiation, rectal temperature varied with incident power densities and duration of exposure. None of the average group rectal temperatures exceeded that of circadian rhythmicity of the sham-irradiated except the groups that were exposed to 20 mW/cm^2 for 4 to 8 hr. Again, a consistent elevation in individual rectal temperature exceeding the confident limits for each duration of exposure could only be found in rats exposed to 20 mW/cm^2 for 4 to 8 hr. Weight loss did not exceed the fiducial limits of sham exposures, although it tended to vary from group to group. The adrenal and thyroid gland weight varied between groups without a consistent change in rats exposed to different

incident power densities and duration; pituitary weight did not vary significantly. Serum thyroxine was found to be transiently elevated at 1 mW/cm^2 for 5 hr. Consistent and significant depression of serum thyroxine was observed in rats exposed to 20 mW/cm^2 for 4 to 8 hr. Serum corticosterone levels did not vary significantly from control. It is concluded that 20 mW/cm^2 incident power density (absorption rate approximately 5 W/kg) exceeded the thermoregulatory capacity of rats. The changes in the thyroid function were a result of thermoregulation. (No refs.)

5003 EXPERIMENTAL HEATING PATTERNS IN BI-LAYERED BIOLOGICAL TISSUE CIRCULAR APERTURE SOURCES (MEETING ABSTRACT). (Eng.) Wallace, J. E.; Guy, A. W. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 41; 1976.

Three circularly cylindrical waveguide apertures, developed to heat biologic tissues, were evaluated. Each applicator was dielectrically loaded to maintain a small aperture diameter and still permit propagation of the TE_{11} mode at 918 MHz. The applicator diameters were 8.9 cm (ε_r = 6.0), 11.1 cm (ε_r = 4.0), and 11.1 cm (ringed dielectric configuration). Testing of the applicators was performed on a planar bi-layered (fat and muscle) phantom model that simulates human tissue. The heating patterns induced in the tissue were measured using an established thermographic technique. This technique uses a high power microwave source (500 W) to heat the tissue for a short period of time (10 to 20 sec). The desired tissue surface is then scanned with an infrared sensitive camera. The significant parameters that were measured included the ratio of peak heating in the fat to peak heating in the muscle, the peak specific absorption rate in both fat and muscle tissue, the uniformity of heating at a given depth into the tissue, and the depth of penetration of energy into the muscle tissue. Each applicator was compared to a 13 x 13 cm square bifurcated aperture, which is currently used clinically for diathermy purposes. This applicator also operates at 918 MHz. (No refs.)

5004 EFFECTS OF SINGLE EXPOSURES TO 2450 MHz MICROWAVE IRRADIATION ON RAT BEHAVIOR (MEETING ABSTRACT). (Eng.) Gage, M. I. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 90; 1976.

The effects of single exposures to microwave radiation on rat behavior were studied. Eight male Sprague-Dawley albino rats (Charles River CD) were trained to alternately press each of two bars in an operant conditioning task for food pellet reinforcement. After the animals learned this task and stable baseline performance was achieved, changes in this operant behavior during daily sessions immediately following exposure to 2,450 MHz microwave irradiation were observed. The rats were tested after single 1 or 15 hr exposures to 2,450 MHz continuous wave irradiation at incident power levels of 0.5, 1, 5, 10, 15 and 20 mW/cm^2. Exposures to 15 and 20 mW/cm^2 for 15 hr suppressed the rate of bar press alternations, but exposures to the same levels of microwaves for only 1 hr did not suppress the behavior. After exposure to 20 mW/cm^2, rats displayed a minimum of 40% decrease in rate of task performance, and 30% of the rats did not perform at all on this task. The results indicate that microwave power densities just above the allowable occupational exposure levels can adversely alter animal behavior. In addition, exposure duration, even in an environment where temperature and humidity are well controlled, is an important variable in determining microwave hazards. (No refs.)

5005 THE EFFECT OF MICROWAVE (2450 MHz) ON THE RESPONSE OF MICE TO T LYMPHOID CELL DEPENDENT AND T LYMPHOID CELL INDEPENDENT ANTIGENS: PRELIMINARY RESULTS (MEETING ABSTRACT). (Eng.) Wiktor-Jedrzejczak, W.; Ahmed, A.; Czerski, P.; Leach, W. M.; Sell, K. W. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 20-21; 1976.

The effect of microwaves on the response to T lymphoid cell dependent and T lymphoid cell independent antigens was studied in CBA/J adult male mice. Groups of 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 of T cells)-DNP-lysine-Ficoll. On days 1, 2, and 3 the experimental groups consisting of four animals each were exposed to 2,450 MHz microwaves. Sham-exposed mice served as controls. Exposures were performed in an environmentally controlled waveguide facility with a forward power of 0.6 W to the average absorbed dose rate about 12 mW/g body weight for each exposure. On day 4, mice were sacrificed, and their spleen cells were assayed for antibody. Cells from SRBC immunized animals were assayed using SRBC as indicator cells, while cells from DNP-lys-Ficoll immunized mice were plaqued against SRBC coated with appropriate antigenic determinant—trinitrobenzene sulfonic acid. Cells from saline injected animals were assayed against these indicators. While the number of immunoglobin antibody secreting cells increased in nonimmunized (saline) microwave-exposed mice as compared with nonimmunized 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. The results suggest that while microwaves stimulate nonspecific reactivity of B lymphoid cells, they simultaneously decrease

the number of antigen reactive cells specific for both thymus dependent and independent antigens. The exposure conditions of microwaves *in vivo* seem to be weakly immunosuppressive. Further studies on the mechanism of this reaction are in progress. (No refs.)

5006 EFFECTS OF A 60-Hz ELECTROMAGNETIC FIELD ON LOCOMOTIVE & AGGRESSIVE BEHAVIORS OF MICE (MEETING ABSTRACT). (Eng.) Smith, R. F.; Justesen, D. R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 146; 1976.

Mice in small groups were observed for 24 to 48 hr for locomotor activity and for aggression-related vocalizations during short (120-sec) but recurrent and aperiodic exposures to a 60-Hz field. The field was sinusoidal with a dominant magnetic component that was measured at 1.7 mWb/m, root-mean-square, and its effects were analyzed in terms of strain of mouse (DBA-2J, pigmented versus CD-1 Albinos), circadian periodicity, and trend. Highly reliable and persistent increases of activity of a time-locked sort were observed during exposures of mice to the field. Both the strain of mouse and circadian period were reliable sources of variation. The influence of the field on the measure of aggressive behavior was less significant, although the data suggest a two-fold reaction: inhibition during exposure followed by a rebound. Data from control experiments with anesthetized or sham-exposed animals excluded an artifactual basis of the observed alterations of activity. (No refs.)

5007 MICROWAVE INTERROGATION OF DIELECTRIC TARGETS (I) BY SCATTERING PARAMETERS (MEETING ABSTRACT). (Eng.) Larsen, L. E.; Jacobi, J. H. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 47; 1976.

Incident microwave radiation was used to interrogate the physical structure and radiofrequency electrical properties of dielectric objects. Single and multiple dielectric discontinuities of various geometries and magnitudes were investigated in a medium of dionized water. Mechanical scanning permitted the investigation of spatial resolution and aperture effects. The scattering parameters measured were the amplitude and phase of S_{11} and S_{21} for a phase locked 3,243 MHz source. These were studied as functions of space for the various dielectric discontinuities presented. Dielectrically loaded matched antennas were incorporated into a digitally controlled scanner, which was interfaced to an automatic network analyzer. The resulting complex functions of space were further processed to create a real valued function of space for intensity presentation of the data. The real valued spatial series' were also inverse filtered by digital methods to compensate for antenna patterns. Use of this system allowed the detection of single and multiple dielectric discontinuities of dimensions well below one wavelength in water. The results were sensitive to aperture size, wavelength, and antenna separation. (No refs.)

5008 IRRADIATION OF RATS BY LOW LEVEL 918 MHz MICROWAVES: DELINEATING THE DOSE-RESPONSE RELATIONSHIP (MEETING ABSTRACT). (Eng.) Myers, D. E.; Lovely, R. H.; Guy, A. W. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 91; 1976

To delineate the dose-response relationship, eight male rats were exposed for 13 wk to 918 MHz continuous wave microwaves at an average incident field strength of 2.5 mW/cm^2. The animals were irradiated 10 hr every night for a total of 910 hr. The exposure system consisted of cylindrical waveguides capable of delivering circularly polarized guided waves (TE_{11} mode) and Plexiglas living chambers, which provided standard laboratory conditions for the rodents. The waveguides allowed easy quantification of the fields for each chamber, independent of other rodents being simultaneously exposed. Daily recordings of body weight and food and water intake demonstrated no significant differences between the eight irradiated and eight sham-irradiated controls. Four-, eight-, and twelve-wk blood samples showed no differences in serum chemistry (i.e., Ca, Na, K, Cl, BUN, CO_2, ion gap, and glucose). Corticosterone levels sampled at the end of the radiation period gave no indication of stress. During the 11th wk, serial assessments were made of rectal temperatures and behavioral repertoire; neither of which demonstrated a significant effect to the microwave exposure. Finally, neither one- nor two-bottle saccharin preference tests suggested the presence of malaise. The significance of these results with respect to chronic exposure of rats to mW/cm^2 (which does influence several of the parameters assessed) are discussed. (No refs.)

5009 AN ELECTRON MICROSCOPIC AND HEMATOLOGIC INVESTIGATION OF RATS CHRONICALLY EXPOSED TO LOW-INTENSITY 2.45 GHz MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Switzer, W. G.; Mitchell, D. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherset, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 22; 1976.

An attempt was made to discover permanent changes in the fine structure of the cerebral cortex of microwave-irradiated rats that could be associated with microwave-induced behavioral changes (increased locomotor activity and disrupted operant discriminative conditioning performance) observed in the same animals. Fifteen mature female Sprague-Dawley rats were exposed to 2.45 GHz continuous-wave microwaves at an equivalent plane-wave power density of 5 mW/cm^2

for 5 hr a day, 5 days a wk, for 22 wk in a multimode chamber designed and calibrated for this purpose. Six to 12 wk after cessation of radiation, irradiated and sham-irradiated control animals were perfused with a variation of Karnovsky's fixative, and cerebral cortex tissues were examined with an electron microscope. No changes in ultrastructure that could definitely be attributed to the prior action of microwaves were observed. Hematologic analyses revealed a significant increase in erythrocytes in irradiated subjects compared with controls. No other statistically significant differences in hematologic parameters were observed. Daily core temperature sampling indicated that no whole-body heating took place in irradiated subjects. (No refs.)

5010 MICROWAVES (2450 MHz) STIMULATE MATURATION OF B LYMPHOID CELLS IN SPLEENS OF EXPOSED MICE (MEETING ABSTRACT). (Eng.) Wiktor-Jedrzejczak, W.; Ahmed, A.; Czerski, P.; Leach, W. M.; Sell, K. W. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 20; 1976.

To evaluate microwave-stimulated maturation of B lymphoid cells in spleens, CBA/J male adult mice were exposed to 2450 MHz microwaves (amplitude modulated 12 Hz) at a forward power of 0.6 W for 30 min 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 min; the other group received a total of three exposures of 30 min, each at 3-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 significantly increased the total frequency of immunoglobulin (Ig) B cells in spleens of exposed mice. The effect was most pronounced 7 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 7 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, polyinosinic:polycytidylic acid, 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 (as evaluated by response of spleen cells *in vitro)* to the T cell specific mitogens-phytohemagglutinin and concanavalin A and to allogenetic stimulator cells in mixed lymphocyte cultures. (No refs.)

5011 MICROWAVE-INDUCED TERATOLOGY IN THE RAT (MEETING ABSTRACT). (Eng.) Chernovetz, M. E.; Oke, A. F.; Justesen, D. R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 143; 1976.

Primigravid rats were exposed in a multimode cavity for 20 min to microwave radiation (2,450 MHz, ~30 mW/g) or to infrared radiation during 1 of 7 days of gestation, the 10th through the 16th, to investigate microwave-induced teratology. Increments of colonic temperatures were equated for microwave and infrared treatments. Animals from a third group of dams were given a sham-exposure during 1 of the 7 days. On the 19th day of gestation, fetuses were taken by cesarean section, and after weighing, were examined for structural abnormalities and signs of insult. Brains of fetuses that were sampled from each of the three treatment groups were analyzed for levels of norepinephrine and dopamine. It was found that (1) extensive hemorrhagic signs were present in fetuses after infrared and microwave radiation; (2) averaged fetal mass was slightly but reliably lower in infrared- and microwave-radiated subjects compared with the averaged mass of controls; (3) averaged number of fetal resorptions did not differ for the control and infrared treatments but was highly elevated in association with the microwave treatment; and (4) while the averaged whole-brain dopamine levels did not differ greatly over the three conditions of treatment, the averaged level of whole-brain norepinephrine was lower in microwave-treated fetuses than in controls or infrared-treated rats. It is concluded that highly intense microwave irradiation ($LD_{\sim 10}$) is a stressor but one with sequelae that differ somewhat from those produced by conventional sources of thermal stress. (No refs.)

5012 CAN ELECTROMAGNETIC WAVES CAUSE CONGENITAL ANOMALIES? (MEETING ABSTRACT) (Eng.) Rugh, R.; McManaway, M. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 143; 1976.

To determine whether electromagnetic waves can cause congenital anomalies, 145 CFI white mice with timed pregnancies were used either as unirradiated controls or were exposed individually for 4 min to 2,450 MHz microwave radiation in a waveguide mean of 99.12 to 114.6 mW/g average absorbed dose rate (23.79 to 27.5 J/g average absorbed dose). The temperature was controlled at 25°C and humidity at 50%. A minimum of 10 pregnant mice were exposed on each gestation

day, from 0 to 11 inclusive, to determine on which day(s) the mice were most radiosensitive with respect to the microwave induction of fetal deaths and anomalies. It was found that day 8 showed a significant increment in fetal deaths and anomalies (controls 22.3% and 8 days 68.0%). The most frequent effects were resorptions and deaths, occurring shortly after irradiation. With counts of congenital anomalies only, days 4 and 8 appeared to show percentage increments but below significant levels for the number of animals; only 10% showed exencephalia (brain hernia) compared with less than 1% for controls. Examinations were made at 18 gestation days. The results agree with those previously shown for effects of ionizing radiations, suggesting that day 8 is the most radiosensitive day for the mouse embryo and fetus. (No refs.)

5013 RESPONSE OF SWINE TO 60 Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hjeresen, D. L.; Beamer, J. L.; Kaune, W. T.; Phillips, R. D.; Richardson, R. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 146; 1976.

Experiments were conducted to determine whether Hanford Miniature Swine (HMS) could be exposed to large electric fields without acute side effects and to determine the upper limit on field strength, up to 55 kV/m, that would not produce corona (ozone) on or near the animal, shocks from a drinking watering system, or visible hair stimulation. Four HMS were trained to drink from a watering system in response to a 750 Hz tone. Observations were made to detect any changes in drinking behavior as a function of electric field strength. The drinking response and general behavior of swine appeared normal at field strengths up to 50 kV/m. No corona occurred on or near the swine at field strengths up to 55 kV/m. Animals standing on a grounded metal plate did not receive shocks from the grounded watering system at field strengths as high as 55 kV/m; swine insulated from ground received shocks at 10 kV/m. The threshold field strength for piloerection and hair oscillation was about 50 kV/m. Experimental evidence was obtained that indicated HMS perceive electric fields at 30 to 40 kV/m. (No refs.)

5014 INTERACTION OF SWINE WITH 60 Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Kaune, W. T.; Beamer, J. L.; Hjeresen, D. L.; Phillips, R. D.; Richardson, R. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 145-146; 1976.

The interaction of Hanford Miniature Swine with uniform, vertical, single-phase, 60 Hz electric fields was investigated. Four swine were individually tested during exposure to electric fields (to 55 kV/m), while housed in a Plexiglas pen with a grounded metal floor. The electrical resistance between the ground plane and the swine was about 2,000 ohms. The current between the swine's mouth and the grounded watering fixture was a linear function of field strength and in no case exceeded 165 μAmp at a field strength of 55 kV/m. The threshold for perception of a mouth to watering system current was measured in another experiment and was found to be greater than 225 μAmp for all swine. At 20 kV/m, the average short circuit current of four swine was 135 ± 11 μAmp. The electric field was markedly distorted by the swine's body and was increased by a factor of 6.7 at the top of the back. Calculations based on an ellipsoidal model of swine predicted a value of 6.6 for this enhancement factor and a short circuit current of 125 μAmp at a field strength of 20 kV/m. (No refs.)

5015 CHRONIC EXPOSURE OF PRIMATES TO ELECTRIC AND MAGNETIC FIELDS ASSOCIATED WITH ELF COMMUNICATIONS SYSTEMS (MEETING ABSTRACT). (Eng.) Grissett, J. D. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 145; 1976.

To assess the effects of chronic exposure to electric and magnetic fields associated with extra low frequency (ELF) communications systems, a group of 30 experimental animals *(Macaca mulatta)* and 30 control animals, pair-matched by age, sex, weight, and medical history were exposed continuously (experimental animals only) to magnetic and electric fields. The fields were similar to those experienced by man in contact with the soil surface directly above a buried ELF antenna. Blood samples were drawn weekly for biochemical analysis. Physical examinations were given at 6-wk intervals. Clinical and blood chemistry results for 294 days of exposure are presented. (No refs.)

5016 60-Hz ELECTRIC FIELD EXPOSURE SYSTEM FOR A MINIATURE SWINE COLONY (MEETING ABSTRACT). (Eng.) Gillis, J. L.; Beamer, R. L.; Richardson, R. L.; Allen, C. H.; Kaune, W. T. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 145; 1976.

A facility under construction is described that will permit the long-term study of electric field effects on miniature swine under well-defined conditions. It consists of a conducting-floor ground pad, nonconducting contiguous stalls, nonconducting roof and walls, and an overhead linear array of four tubular conductors connected to a high-voltage transformer. The design is intended to satisfy several criteria, including the following: (1) the voltage supply and electrode system must provide uniform, vertical 60-Hz electric fields of large magnitude; (2) the structures between the pad floor and electrode must not significantly perturb the applied field nor contri-

bute to ozone production; (3) the facility must provide for animal comfort and routine husbandry throughout the year; (4) the animals will be individually stalled to minimize mutual shielding and permit farrowing in the field; (5) remote monitoring of ambient conditions and observations of the colony, while the field is on, will be afforded by appropriate instrumentation; (6) zero-field facility, otherwise identical to the experimental colony facility, will be provided for control animals; and (7) the design should allow expansion for future animal generations with minimal expense and field interruption. (No refs.)

5017 THE EFFECT OF REPEATED MICROWAVE EXPOSURE IN NEONATAL RATS (MEETING ABSTRACT). (Eng.) Guillet, R.; Michaelson, S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 144; 1976.

The effect of repeated microwave exposure was studied in neonatal rats (Long Evans Hooded) exposed to 40 mW/cm^2, 2,450 MHz, continuous wave (CW) radiation for 5 min each day from day 1 to day 6 of life. On postnatal day 7, the rats were either sacrificed, exposed to 2,450 MHz CW for a seventh time, or injected with adrenocorticotropic hormone (ACTH). Twenty min after the final exposure or injection, the animals were sacrificed. Trunk blood and adrenal glands were saved. No difference was found in plasma corticosterone concentrations between the rats previously exposed to microwaves and control animals that were not exposed. Basal plasma corticosterone concentrations were less than 2 µg% in both groups. Following either microwave exposure or ACTH injection on day 7, plasma corticosterone levels remained low (<3 µg%) in both exposed and control animals. A statistically significant increase in adrenal net weight was noted in animals exposed to microwaves on the first 6 postnatal days. The cause and biologic significance of this enlargement is unknown. It is hypothesized that because the first 2-3 wk after birth are very critical in the development of the rat, effects of microwave exposure during this period may be manifested at this time or at a later stage of life. (No refs.)

5018 INSECT PUPAE TERATOGENESIS IN A STANDING WAVE IRRADIATION SYSTEM (MEETING ABSTRACT). (Eng.) Olsen, R. G. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 144; 1976.

Teratogenesis was studied in pupae of the mealworm beetle, *Tenebrio molitar*, irradiated in the standing wave region of a continuous wave 4 GHz signal so that some of the pupae were positioned in an E-field maximum plane, while others were positioned in an adjacent H-field maximum plane. The standing wave pattern was produced by reflecting a plane wave at normal incidence from a metal plate suspended in the far field region of a horn-irradiated anechoic chamber. The physical cross section of the irradiated pupae accounted for less than 1% of the reflecting plate area to insure a minimum field perturbation, and the long axis of each pupa was oriented parallel to the H-field vector. For the reflected plane wave system in which the microwave dose rate was calorimetrically determined to be less than 12 mW/g in phantom insects, initial results showed teratogenic effects of irradiation in pupae positioned in both the E-field maximum plane and the H-field maximum plane; furthermore, the teratologic damage appeared to occur as often in either position. This result indicates that for this frequency and orientation, each field quantity can independently produce effects similar to those previously seen at X-band in waveguide irradiation systems. (No refs.)

5019 SUPPRESSION BY HYPERTHERMIA OR BY 2450 MHz MICROWAVES OF REPAIR OF DAMAGE PRODUCED BY IONIZING RADIATION (MEETING ABSTRACT). (Eng.) Lai, P. K.; Cain, C. A.; Ducoff, H. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 142; 1976.

It has been demonstrated that the lethal effect of gamma-radiation in normal or neoplastic mammalian cells is greatly reduced when a given dose is administered in two or more fractions separated by intervals of a few hours. This sparing effect of dose fractionation (Sdf) implies repair of some of the damage during the interval between fractions; Sdf is abolished, if the irradiated cells are subjected to hyperthermia (41°-43°C) between fractions. In this investigation, the suppression by hyperthermia, or by microwaves, of repair of damage produced by ionizing radiation was studied in intact flower beetles. Hyperthermia (43°-45°C) applied for 2 hr after the first fraction not only abolished Sdf during the 2-hr interval but caused protracted suppression of Sdf. Suppression of Sdf was observed even when it was found that the treated beetles were returned to the normal incubation temperature of 30°C for several hours before the second gamma-radiation exposure. Similar suppression of Sdf was obtained by 2-hr exposure to 2,450 MHz radiation after the first gamma-irradiation. These results suggest the feasibility of using microwaves to produce localized hyperthermia in tumors, while permitting normal tissues to repair damage during fractionated radiotherapy. (No refs.)

5020 MICROWAVE HYPERTHERMIA AND Co-60 RADIATION TREATMENT OF HAMSTER MELANOMA (MEETING ABSTRACT). (Eng.) Vetter, R. J.; Stoetzel, G. A.; Shupe, R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 140; 1976.

The effect of microwave hyperthermia, alone and in combination with ^{60}Co radiation, and infrared hyperthermia alone, on an amelanotic melanoma specific to golden Syrian hamsters was investigated. In preliminary work, treatments with 250 kV x-rays as high as 800 rads per treatment given on 5 consecutive days had no effect on melanoma growth, confirming radioresistance reported in the literature. In this study, duration of hyperthermia was 12 min and ^{60}Co exposure was 200 R per treatment. Experimental groups were divided into high and low tumor temperature subgroups (46.0°C and 41.5°C for infrared). Tissue temperature was difficult to control in the microwave groups resulting in wide variation in tumor temperatures. Tumor volumes and survival times were recorded to judge treatment efficacy. Tumor regression and mean survival time in the high-temperature microwave plus ^{60}Co group were significantly greater than in all other treatment groups. It is suggested that high temperature microwave hyperthermia increases radiosensitivity and should be considered as a potential adjunct to cancer radiotherapy. (No refs.)

5021 ASCORBIC ACID LEVELS IN RABBIT EYES AFTER SINGLE AND REPEATED EXPOSURE TO MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Ferri, E. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 118-119; 1976.

It has been shown that an early response to the induction of microwave cataracts in rabbits has been a change in the ascorbic acid content of the lens. Whether this reduction continues to occur beyond that reported and whether repetitive subthreshold exposures will evoke a similar response was investigated. The right eyes of New Zealand white rabbits were exposed 2 inches from the crossover of a direct current antenna to a power density of 500 mW/cm^2 for 8 min. Cataract formation resulted after a latent period of 3-7 days. At various intervals after exposure (5 min, 1/2 hr, 12 hr, 18 hr, 1 wk, 2 wk, and 4 wk) both the right and left eyes were removed, and ascorbic acid was assayed in the aqueous, vitreous, and lens. The eyes of unirradiated control animals were assayed following the same procedure. The aqueous humor showed an immediate decrease in ascorbic acid levels in irradiated eyes, continuing up to 1 wk postirradiation. At 2 wk, values were normal. Ascorbic acid levels in the lens decreased at a slower rate and did not reach the low levels in the aqueous but again rebounded at 2 wk to normal values. Erratic results were obtained for the vitreous humor. All values for unirradiated eyes, including controls and left eyes of animals, showed normal levels. Ascorbic acid was also assayed in irradiated eyes of rabbits exposed to repetitive short durations of microwave radiation. The animals were sacrificed, and the lenses assayed 1 wk postirradiation because ascorbic acid levels are at their lowest value at that time in the eyes of acutely exposed animals. No lowering of ascorbic acid levels in the eyes of these animals was observed. The results suggest that chronic subthreshold exposures totaling over three times in duration those of an acute nature do not provoke a reaction that affects ascorbic acid levels in the eye. (No refs.)

5022 DOSE RATE RELATED EFFECTS ON THE OXYGEN CONSUMPTION OF MICE DURING AND AFTER MICROWAVE IRRADIATION (MEETING ABSTRACT). (Eng.) Ho, H. S.; Edwards, W. P. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 119; 1976.

To investigate the thermal stress due to microwave radiation, the oxygen consumption rate was used as a biologic indicator in male CFI mice irradiated singly with 2,450 MHz continuous wave microwaves. Irradiation was performed 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), 1.5, 5, 10, 25, and 45 mW/g. The environmental conditions were 24°C, 60% relative humidity, and air flow rate of 76 ml/min. The rate of oxygen consumption of the mouse was determined at 5 min intervals by means of a paramagnetic oxygen analyzer before, during, and after each irradiation. Each of the stages lasted 30 min. Results of the experiment indicated reduction of oxygen consumption in addition to the previously reported avoidance behavior at average absorbed dose rates of 25 and 45 mW/g. Significant oxygen consumption reduction was also observed at 5 and 10 mW/g, even though avoidance was not observed at these average absorbed dose rates and environmental temperature. It is concluded that the animal homeostatic mechanism balances the total heat load to the organism by reducing its total metabolic heat rate to compensate for small heat load increases due to microwave radiation. (No refs.)

5023 EFFECT OF 3 GHz MICROWAVES ON EXPERIMENTAL VIRAL INFECTIONS IN MICE (HERPES, VACCINIA) (MEETING ABSTRACT). (Eng.) Szmigielski, S.; Luczak, M.; Janiak, M.; Kobus, M.; Laskowska, B. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 117; 1976.

To study the effect of microwaves on experimental viral infections, a series of experiments was performed in mice infected with viruses (Herpes or Vaccinia) under controlled conditions and irradiated with 3 GHz microwaves (anechoic chamber, far field conditions, 40 mW/cm^2, 2 hr daily). Irradiation was performed during different periods (2-14 days) before and/or after infection with viruses. Irradiation before viral infection did not change the course of disease, as measured by number of typical lesions on tail (vaccinia) or survival rate and occurrence of encephalitis (herpes). Irradiation after viral infection resulted in strong inhibition of replica-

tion of infective virus particles and lowering of number of typical lesions on tail (vaccinia). In mice infected with herpes viruses, survival in groups irradiated with microwaves was higher compared with controls; the occurrence of encephalitis was significantly lower. The best results were obtained in animals irradiated during the first 3 days after infection (period of varemia); irradiation during later phases of the disease was less effective. (No refs.)

5024 ENHANCED CYTOTOXIC EFFECT OF 3 GHz MICROWAVES FOR CELLS TREATED WITH MEMBRANE-INJURING SUBSTANCES (MEETING ABSTRACT). (Eng.) Szmigielski, S.; Janiak, M.; Kobus, M. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 116; 1976.

To investigate the enhanced cytotoxic effect of microwaves on cells treated with membrane-injuring substances, cells were treated with subcytotoxic (not resulting in detectable increase of number of dead cells stained with supravital dyes) concentrations of highly purified enzymes that injure cell membranes—bacterial phospholipases (staphylococcal sphingomyelinase and phosopholipase C from *Clostridium perfringens*). Digitonine in concentration 10^{-6} M was used as control membrane-injuring substance (inhibition of sodium pump and Na-K-activated ATPase). The experiments were performed on established cell cultures (WISH and FL lines) in the stationary phase of growth (48 hr after passage). Control cells and cells treated with the membrane-injuring substances were irradiated with 3 GHz microwaves (anechoic chamber, far field conditions, single session of irradiation lasting 1 hr) at nonthermal (5 mW/cm^2), subthermal (20 mW/cm^2), or thermal (40 mW/cm^2) field power densities. Viability of the cells, their morphology, as well as incorporation rate of ^{3}H-thymidine, ^{3}H-uridine, and ^{3}H-glycine and intracellular level of cyclic adenosine monophosphate were observed. It was found that treatment of cell cultures with subcytotoxic concentrations of the membrane-injuring enzymes and digitonine markedly enhanced the metabolic inhibitory effect of microwaves at subthermal and thermal power densities. (No refs.)

5025 EFFECTS OF 960 MHz MICROWAVE ON ISOLATED GUT SEGMENTS (MEETING ABSTRACT). (Eng.) McArthur, G. R.; Lords, J. L.; Durney, C. H. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 115; 1976.

Low level continuous wave, 960 MHz radiation of isolated segments of rat gut causes an increase in the activity of the gut preparation. A strain gauge pressure transducer was used to monitor the wave forms in a cannulated section of rat gut comprising the pyloric region of the stomach and the first 6 to 8 cm of the intestine. The preparation was suspended in isothermal, aerated, modified Ringer's solution. Microwave radiation was applied with a parallel peak capacitor type irradiator. The dose rate was calculated from temperature measurements made with the liquid crystal optical fiber temperature probe. It has been shown that similar radiation applied to isolated turtle and rat hearts causes bradycardia. These effects are thought to be neurally mediated by the release of transmitter substances from the autonomic nervous system. Generally these effects can be modified by the addition of drugs effective at synapses within the autonomic nervous system. In the heart, sympathetic and parasympathetic effects can be separated by the application of drugs, which selectively block these two divisions of the autonomic nervous system. Experiments to determine if similar drug treatment can be used to identify neural effects in the gut are in progress. (No refs.)

5026 EFFECTS OF RADIOFREQUENCY RADIATION ON PERIPHERAL VASCULAR PERMEABILITY (MEETING ABSTRACT). (Eng.) Liburdy, R. P. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 117; 1976.

The effects of radiofrequency radiation on absorption of sheep red blood cells (SRBC) in unsensitized Sprague-Dawley rats were investigated. Radiofrequency radiation (26 MHz, 2000 mW/cm^2, causing a 1.5°C increase in rectal temperature) was administered for 10 min on six successive days to three groups of ten test animals. On day six, 4 hr postexposure, SRBC at 10^8 cells in 50 µl were injected subcutaneously into the hind footpad of each animal. Breadth of the footpad was determined by micrometer before injection and 4 hr postinjection. Radiofrequency treated animals showed decreased footpad enlargement of 47.5% ($0.05<p<0.1$) and 36.8% ($0.05<p<0.1$) over that observed in sham exposed or warm air stressed animals, respectively. Microscopic histoexamination indicated that SRBC evoked a mild localized inflammatory reaction in all animals. These results suggest that radiofrequency radiation may be associated with increased vascular permeability over that due to frank thermogenic stress. (No refs.)

5027 FREE WATER AND THE MICROWAVE CONDUCTIVITY OF TISSUE (MEETING ABSTRACT). (Eng.) Schwan, H. P.; Foster, K. R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 115; 1976.

Precision dielectric measurements on muscle tissue at frequencies of 0.1 and 10 GHz are reviewed. Over this frequency range, the tissue conductivity can be adequately represented by the sum of a Debye relaxation function and a constant term accounting for the electrolyte content of the tissue. The characteristic frequency of the Debye relaxation is 20 GHz, the same as for pure water; its amplitude is consistent

with the known water content of the tissue. These observations support two important conclusions. First, the microwave dielectric properties of tissue can be adequately predicted from measurements near 100 MHz and from the known dielectric properties of water. From an electric point of view, the tissue can be approximated by a suspension of nonconducting proteins in an electrolyte solution at these frequencies. Second, while a relatively few "bound" or motionally restricted water molecules are present in the tissue, the results indicate that they play no major role in the absorption of microwave energy by the tissue. It is concluded that the dielectric data contradict the hypothesis that most of the tissue water has motional properties significantly different from those in bulk water. (No refs.)

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13. ABSTRACT

This digest presents current awareness information on the biological effects of nonionizing electromagnetic radiation (microwave and radiofrequency) in the range of 0 Hz to 100 GHz. The effects of magnetic and electric fields (static and alternating) are also covered. Each issue contains abstracts of English and foreign current literature, summaries of ongoing research investigations, news items, and a directory of meetings and conferences.

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