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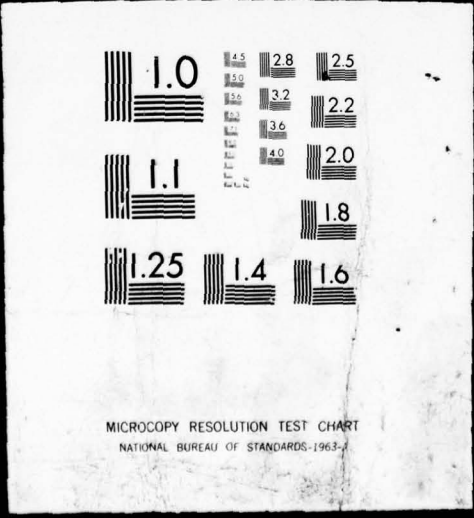


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**BIOLOGICAL EFFECTS
OF NONIONIZING ELECTROMAGNETIC RADIATION**

A Digest of Current Literature

**A Quarterly Publication Produced for
National Telecommunications and Information Administration
and United States Navy**

Literature Selected and Abstracted
by
Biomedical Group, Science Information Services Organization

Bruce H. Kleinstein, Ph.D., J.D., Project Manager
Elena P. Saboe, Managing Editor

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BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

December, 1978 Volume III, Number 2

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PREFACE

Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Research Center, Science Information Services Organization, under contract with the U.S. Navy and administered by the National Telecommunications and Information Administration.

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 III, 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.

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 Standard
NIH - National Institutes of Health
NSF - National Science Foundation
NIOSH - National Institute for
Occupational Safety and
Health
NTIA - National Telecommunications
and Information Administration
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--

NEWS ITEMS

BROADCASTERS INVESTIGATING REPORT OF MICROWAVE RADIATION ILLNESS

The Corporation for Public Broadcasting (CPB), headquartered next to the Soviet Embassy in Washington, is conducting tests to determine whether its employees possibly could be exposed to high doses of microwave radiation. The tests were prompted by a published report indicating that one employee might be suffering from ills caused by such radiation. The report stated that a CPB employee had lost 20% of the hearing in one ear and had periodic "instant sweats." Although the report said the symptoms were those of microwave radiation exposure, a number of radiation experts disagree.

Philadelphia Inquirer August 6, 1978

SALES OF HOUSEHOLD MICROWAVE OVENS SHOW STEADY GROWTH

Sales of microwave ovens exceeded 2.2 million units in 1977, and manufacturers of household microwave ovens foresee promise of sustained growth for several years to come. Although only 5.5% of American households owned microwave ovens in 1976, projections indicate that the level of saturation (percentage of households owning a microwave oven) will reach 22.2% by 1980. However, D. R. McConnell, Senior Vice President, Sales, Major Appliances at Amana Refrigeration, Inc., points out that the "continued development of the market will require that all manufacturers pay close attention to product safety, emission control, and basic quality control." He cautions: "Any manufacturer that cuts corners and creates a highly publicized recall under stringent Federal Safety Regulations can give the entire industry a 'black eye'."

J Microwave Power 13(1): 1-2; 1978

CANADIANS DESIGN UNUSUAL NONREFLECTIVE RADIATION CHAMBER

Canadian researchers, investigating the effects of exposure of low-level microwave radiation on the brain and sexual organs of rabbits, have designed an unusual chamber whose contoured walls are completely nonreflective. Because the walls are entirely nonreflecting, it is possible to deliver a precisely measured dose of radiation from a single source to the test animals. This is particularly important because the project, conducted by the National Research Council of Canada, aims to help establish radiation safety standards.

New Scientist 79(1114): 327; 1978

BRH STUDY SHOWS CATARACTS NOT LINKED TO LOW-LEVEL MICROWAVES

A study by the Bureau of Radiological Health's Division of Biological Effects has shown that repeated exposure to low-level microwave oven radiation (less than 10 mW/cm²) does not cause cataracts in rabbits. The results confirm earlier observations on rabbits exposed repetitively to 10 mW/cm² in an anechoic chamber. Rabbits--whose eyes closely resemble the human eye in size--were placed in front of a microwave oven that was deliberately altered to leak at a rate of 10 to 12 mW/cm². (The Federal microwave oven performance standard limits leakage radiation to 1 mW/cm² at the time of purchase and to 5 mW/cm² over the lifetime of the oven.) After 1 hr of exposure every day for 12 wk, the rabbits' eyes were as clear of cataracts as they were before the experiment began. The lowest exposure level at which cataracts have been observed is 180 mW/cm², accumulated at the rate of 1 hr a day for 20 consecutive days.

BRH Bulletin 12(13): 1; 1978

BRITISH CLAIM THEIR MICROWAVE OVEN STANDARD ENSURES SAFETY

In a rebuttal to claims that microwave oven users risk cataract development, the British National Radiological Protection Board has stated that ovens manufactured in compliance with the 1976 British Safety Standard pose no health risk. Cataracts can be produced by exposure of the eye to microwaves at levels of hundreds of mW/cm² for more than an hour, but ovens meeting the 1976 British standard will not cause exposure at levels higher than 5 mW/cm² at 5 cm distance. "Exposure decreases inversely with the square of the distance from the source and it is therefore highly unlikely that the domestic use of such ovens--given they are in good condition--could injure the eyes."

Lancet 2(8088): 536; 1978

BIOELECTROMAGNETICS SYMPOSIUM--CALL FOR PAPERS

The Bioelectromagnetics Society and the USNC/URSI (Commissions A and B) will cosponsor the Bioelectromagnetics Symposium to be held at the University of Washington, Seattle, Washington on June 18-22, 1979. Authors are invited to submit papers on the following topics: behavioral effects, central nervous system effects, diagnostic applications, dosimetry, extra low frequency effects, exposure systems and instrumentation, acoustic energy ef-

NEWS ITEMS

fects, static and modulated magnetic field effects, hyperthermia and therapeutic applications, immunological and hematopoietic effects, macromolecular and cellular effects, mutagenic and developmental effects, sensory effects, thermometry, and static electric field effects. Consideration will be given to papers on other subjects. All summaries and abstracts must be submitted before February 16, 1979 to Professor Akira Ishimaru, 1979 AP-S/National Radio Science Technical Program Chairman, c/o Department of Electrical Engineering, FT-10, University of Washington, Seattle, WA 98195.
Bioelectromagnetics Symposium--
University of Washington--Call for Papers

BRITISH ORGANIZE RADIO FREQUENCY SCHOOL

The British IEE Professional Group S4 (Measurements), in association with the British Calibration Service, IERE and UKRI Section of the IEEE, is organizing a fourth vacation school on "R.F. Electrical Measurements," to be held at the University of Lancaster, Lancaster, England in July 1979. The school will provide lectures and demonstrations on the essential theoretic background and an up-to-date exposition of the practical techniques of measurement using modern instruments. Lectures will cover modern practice in radio frequency and microwave measurements and their relation to standard, coaxial line and waveguide techniques for frequencies up to about 40 GHz, and measurements in stripline and on active devices. Further details are available from the Secretary, IEE, Savoy Place, London WC2R 0BL, England.

IEE News 32(6):6; 1978

NEWLY DEVELOPED MICROWAVE DIATHERMY APPLICATORS MINIMIZE STRAY RADIATION

The designs for three new microwave diathermy applicators have recently been accepted by the FDA. The applicators, developed by Transco Products, Inc., according to Bureau of Radiological Health specifications, are of the direct contact type and are intended for delivery of therapeutic tissue heating when in very close proximity to the prescribed tissue of the patient. One of the new designs operates at 2,450 MHz and is a circularly

polarized horn with a microwave choke around a 15-cm diameter aperture. The other two, which operate at 915 MHz, are designed with four ridges inside a circular waveguide to provide circular polarization. The larger of the 915-MHz applicators has a 25-cm diameter aperture with three concentric annular chokes, while the smaller has a 15-cm diameter aperture with one annular choke. For the 2,450-MHz applicator the net power needed to deliver 235 W/kg in a planar muscle phantom with a 1-cm layer of simulated fat is 19.3 W, and the maximum leakage at this power level is 0.2 mW/cm². For the large 915-MHz applicator the corresponding heating and leakage values are 36.4 W and 0.15 mW/cm², while for the smaller model they are 33 W and 2.5 mW/cm². Results of clinical tests on the leakage suppression characteristics of the 2,450-MHz applicator indicate that for particular treatments, phantoms can be used effectively to predict the leakage levels existing under actual clinical situations. Further information about the availability of drawings for the new designs are available from Dr. Gideon Kantor, Bureau of Radiological Health, 5600 Fishers Lane, Rockville, Maryland 20857.

BRH Bulletin 12(16): 1-2; 1978

SHORT COURSE ON MICROWAVE AND UV RADIATION HAZARDS

The British National Radiological Protection Board (NRPB) has scheduled a one-day course for March 1, 1979 on the hazards associated with the use of various microwave and UV sources. The background leading to the establishment of the accepted protection standards will be discussed in addition to the effects of their application to specific sources. Requests for information may be directed to NRPB Northern Centre, Hospital Lane, Cookridge, Leeds LS16 6RW, England.

British National Radiological
Protection Board Course Announcement

CANADIANS GRANT PATENT FOR MICROWAVE RADIATION PROTECTION DEVICE

The Canadian Patent Office has granted a patent for an "Apparatus for Protection against Microwave Radiation." The patent, granted June 27, 1978, bears the number 1,033,602.

Patent Office Record, Canada 106(26): 26-9; 1978

ITEMS FROM THE COMMERCE BUSINESS DAILY

- INVESTIGATIONS INTO THE PERIPHERAL AND CENTRAL RECEPTORS MEDIATING EFFECTS OF MICROWAVE RADIATION ON BRAIN ACTIVITY.

The Procurement Office, National Institute of Environmental Health Sciences, Building 11, Room 1101, P.O. Box 1233, Research Triangle Park, NC is soliciting proposals for the above study. (June 29, 1978)

- BASIC RESEARCH AND DEVELOPMENT WORK IN CONNECTION WITH THE ASSESSMENTS OF THE EFFECTS OF EXPOSURE TO MICROWAVE ENERGY ON HEALTH AND THE ENVIRONMENT.

The Satellite Power System Environmental Assessment Program, Energy and Environmental Systems Division, Argonne National Laboratory, Argonne, IL is soliciting proposals for the above study. (August 9, 1978)

- RESEARCH ON MICROWAVE EFFECTS ON THE CENTRAL NERVOUS SYSTEM.

The Office of Naval Research, Arlington, VA has contracted with the George Washington University, Rice Hall, Washington, DC for the above study. (August 18, 1978)

- LITERATURE SURVEY AND PROBLEM DEFINITION STUDY ON THE BIOLOGICAL EFFECTS OF MILLIMETER WAVES (35-220 GHz).

The Eglin Air Force Base, FL is soliciting proposals for the above study. (August 23, 1978)

- ELECTROMAGNETIC AND NUCLEAR RADIATION ENVIRONMENTS STUDY.

The Naval Surface Weapons Center, White Oak, Silver Spring, MD is negotiating with Stanford Research Institute International, Menlo Park, CA for the above study. (October 2, 1978)

MEETINGS AND CONFERENCES

AMERICAN THERMOGRAPHIC SOCIETY/CANADIAN THERMOGRAPHIC ASSOCIATION JOINT MEETING

Date: March 31-April 1, 1979
Place: Toronto, Canada: Sheraton Center
Sponsor: American Thermographic Society; Canadian Thermographic Society
Requests for Information: W. B. Hobbins, M. D., 7803 Mineral Point Road, Madison, WI 53717
Content: Clinical research in medical thermography; biological applications; veterinary and industrial applications

INSTITUTE OF ELECTRICAL & ELECTRONICS ENGINEERS SOUTHEAST CONVENTION (SOUTH-EASTCON)

Date: April 1-4, 1979
Place: Roanoke, VA: Hotel Roanoke
Sponsor: Institute of Electrical & Electronics Engineers (IEEE)--Region 3
Requests for Information: K. R. Thompson, Room 244, 1501 Roanoke Blvd., Salem, VA 24153

AMERICAN OCCUPATIONAL HEALTH CONFERENCE

Date: April 29-May 4, 1979
Place: Anaheim, CA: Disneyland Hotel
Sponsor: American Occupational Medical Association (AOMA); American Assoc. of Occupational Health Nurses (AAOHN)
Requests for Information: H. N. Schultz, AOMA, 150 N. Wacker Dr., Chicago, IL 60606

INTERNATIONAL MICROWAVE SYMPOSIUM

Date: April 30-May 2, 1979
Place: Orlando, FL: Sheraton Twin Towers
Sponsor: Institute of Electrical & Electronics Engineers (IEEE), Microwave Theory & Techniques Society
Requests for Information: R. E. Henning, College of Engineering, Univ. South Florida, Tampa, FL 33620

SIXTH INTERNATIONAL CONGRESS OF RADIATION RESEARCH

Date: May 13-19, 1978
Place: Tokyo, Japan: Zenkyoren & Nihon Toshi Centers
Sponsor: International Assoc. Radiation Research (IARR); Science Council Japan (JSC); Japanese Association Radiation Research
Requests for Information: Professor S. Okada, Hongo Box 152, Bunkyo-ku, Tokyo 113-91, Japan

Content: Physics, chemistry, biology, and medicine and their interdisciplinary areas of radiation research (including nonionizing radiations) will be covered.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS CONFERENCE (ELECTRO 79)

Date: May 24-26, 1979
Place: New York, NY: The Coliseum
Sponsor: Institute of Electrical & Electronic Engineers (IEEE), Region One & METSAC sections; Electronic Representatives Assoc., New England and New York chapters
Requests for Information: W. C. Weber, Jr., ELECTRO, 999 N. Sepulveda Blvd., El Segundo, CA 90245

BIOELECTROMAGNETICS SYMPOSIUM

Date: June 18-22, 1979
Place: Seattle, WA: Univ. Washington
Sponsor: USNC/URSI (Commissions A and B); Bioelectromagnetics Society
Requests for Information: A. W. Guy, Technical Program Committee Chairman, Bioelectromagnetics Symposium, c/o Dept. Rehabilitation Medicine, Univ. Washington School of Medicine, Seattle, WA

WESTERN OCCUPATIONAL HEALTH CONFERENCE

Date: October 11-13, 1979
Place: San Francisco, CA: Fairmont Hotel
Sponsor: Western Occupational Medical Assoc. (WOMA); American Industrial Hygiene Assoc. (AIHA); Health Physics Society (HPS); American Society Safety Engineers (ASSE); Western Assoc. Occupational Health Nurses (WAOHN)
Requests for Information: B. H. Bravinder, WOMA, Box 201, Alamo, CA 94507

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS MIDWEST CONFERENCE (MIDCON '79)

Date: November 6-8, 1979
Place: Chicago, IL
Sponsor: Institute of Electrical & Electronics Engineers (IEEE), Regions 4 & 5, Chicago & Dallas Sections; Electronic Representatives Assoc. (ERA), Mid USA Council, Chicago & SW Chapters

MEETINGS AND CONFERENCES

*Biological Effects of Nonionizing Electromagnetic
Radiation III (2), December 1978*

Requests for Information: W. C. Weber, Jr.,
EC1, 999 N. Sepulveda Blvd., El Segundo, CA
90245

RADIOLOGICAL SOCIETY OF NORTH AMERICA: ANNUAL MEETING

Date: November 25-30, 1979
Place: Atlanta, GA
Sponsor: Radiological Society of North
America (RSNA)
Requests for Information: Ms. A. Swenson,
RSNA, Suite 1150, Oak Brook Regency Towers,
1415 W. 22nd St., Oak Brook, IL 60521

CURRENT RESEARCH

0378 ELECTROMAGNETIC RADIATION PRODUCT INVESTIGATION—MICROWAVE DIATHERMY APPLICATORS. Kantor, G. (Electromagnetics Branch, U.S. Dept. Health, Education, and Welfare, Bureau Radiological Health, 5600 Fishers Lane, Rockville, MD 20852).

In support of the proposed microwave diathermy standard, direct contact applicators are being developed that meet the standard's requirements of leakage, radiation safety, and effectiveness in heating simulated muscle tissue. Thermographic heating patterns in phantoms of simulated fat and muscle tissue were investigated to determine the spatial distribution of the energy deposition. Associate leakage radiation from the surface of applicators during exposure of planar phantoms was also measured. The emphasis was on diathermy operating at the industrial, scientific, and medical (ISM) frequency of 2,450 MHz. Presently, direct contact applicators operating at the ISM frequency of 915 MHz are being evaluated to demonstrate the feasibility of the standard provisions concerned with leakage radiation and effectiveness in heating. (10/76-9/77)

Supporting Agency:HEW, PHS, FDA, BRH

0379 RADIO FREQUENCY ENERGY FOR INSECT CONTROL. Nelson, S. O.; Stetson, L. E. (Univ. Nebraska, U.S. Dept. Agriculture, Agricultural Res. Div., Lincoln, NB 68503).

Information and methods for more efficient control of stored-grain and seed-infesting insects using radio frequency (RF) electric energy will be developed. Additionally, methods will be developed for determining the temperature and frequency dependence of the dielectric properties of insects and grain in the frequency ranges where selective absorption of energy by the insects can be obtained. The dielectric relaxation frequencies for insects and grain as functions of temperature will be determined. After obtaining new measurement data, researchers will assess the improvement in efficiency of stored-grain insect control with RF energy and evaluate the degree of success in controlling chalcid-infesting tree seeds. Earlier studies have shown that all developmental stages of stored-grain insects can be controlled by exposures of a few seconds to RF electric fields of sufficient intensity in the frequency range between 10 and 50 MHz. Measurements of the dielectric properties of insects and grain revealed that, in this frequency range, the insects absorb energy from the electric field much more rapidly than the grain and therefore can be selectively heated and killed by dielectric heating. Since the dielectric properties of insects and grain are temperature as well as frequency dependent, information on the variation of dielectric properties with temperature is important. If the frequency of maximum energy absorption shifts as the temperature of the insects increases, a major improvement in the efficiency of RF treatment for insect control might be achieved by varying the

frequency during treatment. A series of dielectric measurements on adult rice weevils and hard red winter wheat using existing measurement equipment (modified to provide temperature control for the samples) showed that the dielectric constant of both insects and wheat increased with temperature in the range from 25 to 60 C. The dielectric loss factor of the insects also increased with temperature at most frequencies in the range (0.5 MHz to 2.4 GHz). (10/76-9/77)

Supporting Agency:U.S. Dept. Agriculture, Agricultural Res. Service

0380 MORTALITY, INDUSTRIAL HYGIENE STUDY OF WORKERS EXPOSED TO MICROWAVE AND RADIO FREQUENCY ENERGY. Egan, E.; Ness, G.; Johnson, P. (Survey Hazard Evaluation Field Study Div., U.S. Dept. Health, Education, and Welfare, Natl. Inst. Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226).

Little research has been conducted in the U.S. to determine the long-term health effects of low-level microwave radiation on humans. The consequence of undervaluing or misjudging the biologic effects of long-term, low-level exposure could become a critical public health problem since virtually every person in the U.S. is exposed to some form of electromagnetic radiation. Recent evidence indicates that the development of certain forms of cancer may be associated with exposure to electromagnetic radiation. At a naval air station at Quonset Point, Rhode Island, three civilian employees among a group of eight technicians who were engaged in the overhaul and repair of Tactical Airborne Navigation Equipment (TACAN workers), which is similar to radar in operation, either have developed or died of cancer since 1970. Two of the men (aged 31 and 35) developed pancreatic cancer, a form of cancer that occurs in only 1% of persons under 40. These two men worked side by side at a test bench at Quonset Naval Air Station for several years. NIOSH plans to conduct a retrospective mortality study to further investigate the health effects resulting from long-term, low-level exposure to electromagnetic radiation. (10/78-9/79)

Supporting Agency:HEW, PHS, Center Disease Control, NIOSH

0381 BIOPSYCHOLOGICAL STUDIES OF MICROWAVE IRRADIATION. Justesen, D. R.; Sheridan, C. L.; Levinson, D. M. (Neuropsychology Res. Lab., U.S. Veterans Admin. Hosp., 4801 Linwood Blvd., Kansas City, MO 64128).

Completed studies in this research project have assessed longevity of tumor-bearing and tumor-free mice, determined optimal microwave doses for experimental treatment of intracranial neoplasms in rats, evaluated avians incubated in an intense microwave field, and analyzed the spatio-temporal fac-

CURRENT RESEARCH

tors that control a microwave-induced, classically conditioned hyperthermia in rats. Ongoing studies of longevity and development of tumor-prone mice, whose dams were subjected to LD₁₀ radiation, are entering the second year; few behavioral differences were observed between radiated and control mice. There was no incidence of spontaneous tumors in both groups but close monitoring will continue in the months ahead. Nearing completion is a study in which rats are being observed for evidence of escape learning during trials in an intense 918-MHz field. Although marked behavioral and physiologic signs of overheating have been observed, there has been no evidence of purposive escape. Diffuse whole-body heating--lack of directional cueing--is believed responsible. (6/77-N/A)

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

0382 MICROWAVE RADIATION AND THERMOREGULATION. Adair, E. R. (John B. Pierce Foundation of Connecticut, 290 Congress Ave., New Haven, CT 06519).

In recent years, the U.S. research effort in dealing with the biologic effects of nonionizing radiation has increasingly been directed toward the effects produced by low levels of irradiation. These levels have been characterized as having no obvious thermal biologic consequences. This research emphasis has been generated partly by the discrepancy between permitted exposure levels in this country and the Soviet Union and partly by reports from several eastern European countries regarding central nervous system (CNS) malfunctions resulting from prolonged low-level microwave irradiation. If such CNS malfunction could be rigorously demonstrated at any level (from cellular organization to complex behavioral patterns), definitive grounds for reconsideration of the U.S. maximum permissible exposure levels would be provided. The primary goal of this project is to learn whether low levels of microwave radiation can influence or interfere with normal responses, both physiologic and behavioral, that regulate body temperature. The ultimate goal is to evaluate the impact of such disturbances on the human thermoregulatory system with reference to current maximum permissible exposure standards. The research proposed will expose restrained squirrel monkeys to specific durations and intensities of microwave irradiation during ongoing behavioral thermoregulation and during measurement of autonomic responses of heat production and heat loss at a variety of discrete ambient temperatures. (9/77-11/78)

Supporting Agency: U.S. Dept. Defense, Air Force

0383 VALUE ISSUES IN RESEARCH ON THE BIOLOGIC EFFECTS OF MICROWAVE RADIATION--A CASE STUDY. Steneck, N. H. (Dept. History, Univ. Michigan, Sch. Liberal Arts, Ann Arbor, MI 48104).

This project will explore the value presuppositions that operated within the scientific community and society-at-large to determine priorities for research on the biologic effects of microwave radiation between 1945, when microwave technologies became available for non-military purposes, through 1965 when the widespread deployment of microwave devices made it imperative to have scientific data on which to base adequate safety standards. These standards depend critically upon the specific biologic effects of microwave radiation. Until the early 1960's it was assumed that only thermal effects were significant. As a result, inadequate research on the nonthermal biologic effects of microwave radiation was pursued, despite the fact that such research was being pursued for shorter wavelength electromagnetic radiations. This project will try to determine why neither the scientific community nor social pressures stimulated research in this area of potential importance to public health. The results will be analyzed as a case study in changing perspectives about ethical standards and social expectations of science. The staff, which consists of a physicist, a physiologist, an historian of science, and a philosopher, will study the scientific and technical literature on microwave radiation research and development and will interview persons involved in those fields to develop a detailed historic and normative case study. The project will result in a book suitable for use in college courses on science, technology and values, and will be accessible to the general public. (6/78-7/80)

Supporting Agency: NSF

0384 HYPERTHERMIA AND RADIATION--X RAYS VS FAST NEUTRONS. Nagle, W. A.; Moss, A. J.; Baker, M. L.; Prior, R. M.; Straub, K. D. (Dept. Radiology Univ. Arkansas, Sch. Medicine, 4301 W. Markham St., Little Rock, AR 72201).

Recent results suggest that hyperthermia combined with X or gamma radiation may simulate the effects of high linear energy transfer (LET) radiation, since radiation sensitivity of hypoxic cells is increased. If this observation is confirmed and can be exploited clinically, radiotherapy can be improved greatly. Patients may derive the expected benefits of high LET radiotherapy without the expense of constructing and maintaining sources of high LET particles. To be clinically useful, heat must be delivered to some depth in tissue, while at the same time, the skin is not heated significantly. This is necessary to maintain a therapeutic margin between the tumor and the incidentally irradiated normal tissues. Two modalities now available for heating deeply-seated lesions are ultrasound and microwaves. An in-depth study of the interaction of agents that cause heating (thermal heat, ultrasound, and microwaves) and ionizing radiations of both low (250 kVp X-rays) and high (fast neutrons) LET will be performed. Cultured cells of three different mammalian lines will be used, and cell populations will be synchronized where appropriate. The experiments

will be performed under conditions of hypoxia as well as normal oxygenation. Both cellular proliferative integrity and molecular (production and repair of DNA single strand breaks) effects will be measured. The results will help to establish a biologic base from which rational clinical trials can be formulated. (7/77-6/79)

Supporting Agency:HEW, PHS, NIH, NCI.

0385 RADIATION AND HYPERTHERMIC CANCER THERAPY. Robinson, J. E.; Scott, R. (Dept. Radiology Univ. Maryland, Sch. Medicine, 1420 N. Charles St., Baltimore, MD 21201).

The action of hyperthermia alone and in combination with ionizing radiation will be investigated to answer current questions on the use of this combined modality in cancer therapy. Laboratory data show that radiation sensitivity is markedly enhanced at elevated temperatures. The objectives of research, which are aimed at clinical applicability, are: (1) to develop and evaluate a technique of microwave heating of animals and animal tumor systems that are clinically relevant; (2) to assess the relative thermal sensitivities and radiosensitivities of normal and malignant tissues under microwave-induced hyperthermic conditions and (3) to compare results with existing experimental data in which elevated temperatures were obtained by tumor immersion in water baths. Localized and generalized hyperthermia, as an adjunct to radiotherapy, offers the potential of further increasing rates of local tumor control. (7/77-6/79)

Supporting Agency:HEW, PHS, NIH, NCI

0386 DEVELOPMENT OF SPECIFICATIONS FOR COMPUTER PROGRAMS TO OBTAIN ELECTROMAGNETIC FIELDS IN DIELECTRIC MEDIA OF GENERAL GEOMETRY. Kellogg, R. B. (Univ. Maryland, Inst. Physical Science & Technology, College Park, MD 20742).

Existing computer programs will be converted and adapted to the computation of induced electromagnetic fields in media of arbitrary geometry exposed to microwave and radio frequency radiation. Programs are nearing completion for 3-dimensional, arbitrary geometry and dosimetric calculations. (9/77-9/78)

Supporting Agency:HEW, PHS, FDA, BRH

0387 BIOLOGIC RESPONSES TO A CHRONIC MICROWAVE ENVIRONMENT. Lebovitz, R. M.; Seaman, R. L.; Guterman, L. (Univ. Texas, Sch. Biomedical Sciences, 5323 Harry Hines Blvd., Dallas, TX 75235).

As microwave energy becomes increasingly present in the environment, an unmonitored population is placed at risk even though there is an insufficient body of data regarding the biologic effect of such ex-

posure. The basic aim of this project will be to determine the effects of a long-term (4 mo) exposure to microwave radiation (MWR) at low incident power densities. The behavioral effects of administratively safe MWR (i.e., less than 10 mW/cm² incident power density) will be examined. Data will be obtained from several behavioral variables, and a dose/response curve over the range of 0-20 mW/cm² will be defined. The chronic MWR environment will comprise individual radio frequency chambers into which control and experimental animals will be individually introduced for 3-4 hr of whole body MWR exposure/day. Pulse-modulated MWR at 1.3 GHz will be used. In the first part of the study, the effects of 0, 2, 5, 10, and 20 mW/cm² MWR on open field behavior and on instrumental behavior for food reward will be determined in rats. Besides the 0 mW/cm² group, additional control groups will be exposed to a mild thermal and acoustic stress. In the second part of the study, the changes in instrumental behavior relevant to learning will be determined and extrapolated to humans. Again, dose/response curve will be defined, via radiation at 5, 10, and 20 mW/cm² with dual control groups. These studies will provide needed data regarding the origin of chronic low level MWR effects on cognitive behavior and learning. (5/77-4/79)

Supporting Agency:HEW, PHS, FDA, BRH

0388 CHROMOSOMAL EFFECTS OF 2.45 GHZ MICROWAVE NON-THERMO EXPOSURE. Yao, K.; Seeke, F.; Fuchs, T. (U.S. Dept. HEW, BRH, Genetic Studies Section, 5600 Fishers Lane, Rockville, MD 20852).

The effects of non-thermal microwave exposure on the chromosomes of cultured cells will be investigated. A specially designed microwave exposure chamber that disperses heat quickly into a temperature-controlled waterbath will be used. Cells will be irradiated at G2 and M stages, since cells at these two stages are more sensitive to irradiation than at other stages. Temperature of the waterbath will be 25 C, 37 C, and 42 C. In earlier studies, cells were exposed at S and G1 stages. Results showed that only the cells exposed at 42 C had a moderately significant increase in chromosome aberration frequency. (11/77-10/78)

Supporting Agency:HEW, PHS, FDA, BRH

0389 ASSESSMENT OF RADIATION LEVELS AND HAZARDS. Sinclair, W. K.; Ney, W. R.; Maletskos, C. J. (Nat'l. Council on Radiation Protection, 7910 Woodmont Ave., Suite 1016, Bethesda, MD).

The National Council on Radiation Protection and Measurements (NCRP) seeks to collect, analyze, develop, and disseminate information and recommendations on radiation protection and measurements and to foster cooperation among organizations concerned with radiation protection and measurements. This project is concerned with: (1) quantities, units, measurement techniques,

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biologic effects and exposure criteria for radio frequency electromagnetic radiation; (2) radiation hazards resulting from the release of radionuclides into the environment (with particular attention directed to examination of the problems associated with the release of ^{129}I); (3) bioassay for the assessment of control of intake of radionuclides; and (4) radon sources and dosimetry. Initial work on NCRP studies is carried out by scientific committees that draft preliminary recommendations. This involves a detailed examination of existing pertinent information, identification of areas in which information is meager or unavailable, and an assessment of the scientific thinking on the relevant problem. The final result of the scientific committee's work is usually a draft of a proposed NCRP report which is submitted to the members of the council for review, modified on the basis of council members' comments, and after membership approval, published. (7/77-7/80)

Supporting Agency: EPA

0390 COMPUTER STUDIES OF DOSE DISTRIBUTION IN BIOLOGICAL MODELS EXPOSED TO ELECTROMAGNETIC RADIATION. Meijer, P. H. (Dept. Physics, Catholic Univ. America, Sch. Arts & Sciences, 620 Michigan Ave. N.E., Washington, DC 20017).

Theoretic dose distribution calculations for man exposed to nonionizing electromagnetic radiation will be performed utilizing newly-developed computer programs. Theory and programs have been perfected using finite element numeric approximation techniques for the calculation of induced fields and power deposition in biologic tissue of two-dimensional geometry and irregular cross sections. (9/77-8/78)

Supporting Agency: HEW, PHS, FDA, BRH

0391 MAPPING OF FREE SPACE ELECTRIC FIELDS ASSOCIATED WITH MICROWAVE DIATHERMY APPLICATORS. Witters, D. M. (U.S. Dept. HEW, BRH, Electronic Products Div., 5600 Fishers Lane, Rockville, MD 20852).

The objective of this project is to map the electric field distribution of electromagnetic radiation in the vicinity of various prototype and clinical microwave diathermy applicators. Also, relative effectiveness in terms of field uniformity and polarization in the therapeutic beam is being determined, and the hazards due to radiation leakage outside the therapeutic beam (applicator side lobes) are being assessed. A miniature (3 mm) dipole/diode isotropic probe and optically-linked telemetry system was used to map the fields in the immediate vicinity (2-5 cm) of the aperture. The data were analyzed using a digital minicomputer, and transverse versus radial electric field components were correlated with thermographic camera heating patterns in planar muscle-equivalent phantoms. The data are being used in a paper entitled "Free Space

Electric Field Mapping of Spaced Microwave Diathermy Applicators" by D. Witters and G. Kantor. Further mapping of leakage around applicators during exposure of various anatomic phantoms is planned. A computer-controlled scanning system located in an anechoic chamber is under development to facilitate this concept. (10/76-9/77)

Supporting Agency: HEW, PHS, FDA, BRH

0392 PRIMATE TRACKING PERFORMANCE DURING MODULATED 1.2 GHz EXPOSURES. Scholl, D. M.; Allen, S. J. (U.S. Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

The possible biobehavioral effects of radio frequency (RF) exposures that meet or exceed current safety criteria will be investigated, and reports in the literature concerning low power level RF effects will be evaluated. Nonhuman primates will perform a 2-hr RF compensatory visual tracking task, a condition considered to be "worst case." The task requires considerable attention/vigilance and is believed to affect the emotional state. Selection of RF parameters will be based upon known energy deposition and wave penetration factors and upon reports of emotional, behavioral, and neurophysiologic effects to low power level RF exposures at specific frequencies and modulations. Tracking performance under RF will be contrasted with stable pre- and post-exposure data. (10/76-N/A)

Supporting Agency: U.S. Dept. Defense, Air Force

0393 BROADBAND MEASUREMENTS OF DIELECTRIC PROPERTIES. Swicord, M.; Athey, T. W. (U.S. Dept. HEW, BRH, Electronic Products Div., 5600 Fishers Lane, Rockville, MD 20852).

Measurement of the dielectric properties of biologic materials is required to synthesize and fabricate simulated biotissue for the modelling of man or animals in support of the dosimetry associated with biologic effects and electromagnetic radiation therapy projects performed at the Bureau of Radiologic Health (BRH). Also, these measurements are being developed to allow BRH investigators to predict or explain the possible existence of frequency-selective biologic effects from electromagnetic radiation. A method was developed for making routine, broadband (0.5-18 GHz), dielectric measurements that is particularly suited for use with automated systems but can also be used with slotted lines. A modified two-impedance method was used that gives results that are approximately independent of the sample size. X-band waveguide sample holders have been constructed and measurements have been published on several materials. Coaxial sample holders for broadband measurements are being tested. A semi-automated network analyzer system has been developed and is being tested. (10/76-9/77)

Supporting Agency: HEW, PHS, FDA, BRH

0394 ELECTROMAGNETIC RADIATION PRODUCT INVESTIGATION AT RADIO-FREQUENCIES. Ruggera, P. S. (U.S. Dept. HEW, BRH, Electronic Products Div., 5600 Fishers Lane, Rockville, MD 20852).

Products that generate high levels of potentially hazardous radio frequency (RF) electromagnetic radiation must be identified, and their emissions quantified. Three classes of RF-emitting products, investigated in light of their potential for significant impact on public health through direct radiation emission or through interference to critical life support equipment, have been studied in detail. The electric and magnetic field strengths from industrial RF sealers, citizen-band radios, and electrosurgical units have been quantified utilizing state-of-the-art instrumentation developed by the Bureau of Radiological Health (BRH). All preliminary investigations have confirmed that under typical use conditions these products can exceed the applicable safety exposure standards set by the American National Standards Institute and/or could severely affect the function of critical equipment through electromagnetic interference. Through cooperation with involved governmental agencies and manufacturers, BRH will define and attempt to minimize the potential hazard through

technical and regulatory activities. The measured field strength data are available to researchers through presentation and publication to promote research under the exposure conditions of amplitude and frequency. (10/76-9/77)

Supporting Agency:HEW, PHS, FDA, BRH

0395 REPRODUCTIVE EFFECTS OF MICROWAVES/X RAYS. Rugh, R.; McManaway, M. (U.S. Dept. HEW, BRH, Biological Effects Div., 5600 Fishers Lane, Rockville, MD 20852).

The extent to which microwaves and x-ray radiation can be teratogenic to the CF1 mouse, and how such radiation affects reproductive capacity of exposed male and female mice will be determined. CF1 mice, time-mated to obtain pregnancies of known gestation age, will be exposed either to x-rays or microwaves under strictly controlled dosimetric conditions. On day 18 of gestation, the pregnant females will be sacrificed and dissected, and the mouse fetuses will be examined for anomalies. (10/76-9/77)

Supporting Agency:HEW, PHS, FDA, BRH

CURRENT LITERATURE

5774 THE INFLUENCE OF ELECTRICAL STIMULATION OF THE HYPOTHALAMIC SUPRAOPTIC ZONE ON THE LIPID METABOLISM AND DEVELOPMENT OF ATHEROSCLEROSIS. (Rus.) Zavodskaja, I. S. (Dept. Pharmacology, Inst. Experimental Medicine of USSR Acad. Medical Sciences, Leningrad, USSR); Moreva, E. V.; Sinitsyna, T. A.; Ryzhenkov, V. E.; Nikul'cheva, N. G.; Mosina, I. V. *Biull Eksp Biol Med* 85(6):661-664; 1978. (14 refs)

The effect of electrical stimulation (50 Hz, 1.5-2 V, impulse duration 0.1 msec, 1 hr/day for 7-25 days) of the supraoptic zone of the hypothalamus on lipid metabolism and the development of atherosclerosis was studied in 30 male rabbits. The animals had been on an atherogenic diet (0.5 mg/kg/day cholesterol administered through gastric tube) for 3-8 wk prior to and during stimulation. The control rabbits received cholesterol only. The stimulation of the supraoptic zone of the hypothalamus of test animals caused a greater increase in the blood cholesterol level and increased blood levels of free fatty acids, glucose, and triglycerides. There were, however, no significant differences between the test and control groups in the cholesterol and triglyceride levels in the liver and in the plasma 11-oxycorticosteroid level. After 3 wk of electrical stimulation of the supraoptic zone and the atherogenic diet, metabolic disorders in the myocardial tissue (reduced creatin phosphate and norepinephrine levels and increased inorganic phosphate and lactic acid levels) were observed. Similar disorders were observed in the control animals by a 4-mo diet of cholesterol only. The electrical stimulation also caused venous plethora, hyperemia of the capillary network, stasis, and hemorrhages. The findings indicate that the electrical stimulation of the supraoptic zone of the hypothalamus accelerates the development of the pathomorphologic and biochemical disturbances in the cardiovascular system in induced atherosclerosis.

5775 POSSIBLE ROLE OF THE HYPOTHALAMUS IN THE PATHOGENESIS OF VEGETATIVE DISTURBANCES DURING A BRIEF EXPOSURE TO CONSTANT MAGNETIC FIELD. (Rus.) Smirnova, N. P. (Moscow, USSR); Klimovskaia, L. D. *Patol Fiziol Eksp Ter* (3): 28-31; 1978. (17 refs)

The effect of whole-body exposure to constant magnetic field (1,000-4,000 Oe, length of exposure 1 or 24 hr) on the hypothalamic functions was studied in 20 rabbits with electrodes implanted into the hypothalamus. The exposure caused a shift toward higher frequencies in the hypothalamic bioelectric potentials, with rapid normalization after exposure. Exposure to 3,000-4,000 Oe caused a 130-150% increase in the hypothalamic potentials; a smaller increase was observed during exposure to lower intensities. The magnetic field enhanced the effect of high-frequency electrical stimulation (300 impulses/sec) of the hypothalamus on the rate of respiration (130% of the normal value before and 170% during exposure) and heart rate (97% of the normal value

before exposure, and 80% during exposure). The findings suggest the involvement of the hypothalamus in the development of autonomic disturbances in response to exposure to high-intensity magnetic field.

5776 BONE MARROW CELL PROLIFERATION UNDER THE INFLUENCE OF CONSTANT MAGNETIC FIELDS OF VERY HIGH INTENSITY. (Rus.) Strzhizhivskii, A. D. (Inst. Medical-Biological Problems, Ministry of Public Health of the USSR, Moscow, USSR); Galaktionova, G. V. *Tsitologiya* 20(6):717-720; 1978. (3 refs)

The effects of constant electromagnetic fields (intensity 9.9-42.4 kOe, intensity gradient 0.2-3.5 kOe/cm, length of exposure 0.5-24 hr) on cellular mitotic activity, number, and chromosome aberrations of bone marrow cells were studied in 768 anaphase slides from 390 mice. The mitotic activity was increased by short-term exposure and reduced by long-term irradiation. The degree of mitotic inhibition caused by long-term treatment increased with increasing intensity and gradient, but even the fields with the highest intensity failed to inhibit the mitotic activity when the intensity gradient was below a critical range of 0.2-1.1 kOe/cm. The reduced mitotic activity returned to normal more slowly with increasing field intensity, but it was independent of the intensity gradient. The bone marrow cell count was reduced only by exposure to the field with very high intensity ($78.6 \pm 5.1\%$ of the normal value following 3-hr exposure to a 39.4 kOe field with 1.1/cm gradient). The anaphase analysis showed no chromosome aberrations, but the possibility of subtle changes escaping analysis cannot be ruled out.

5777 EFFECTS OF X-RAYS AND MICROWAVES ON THE ABSORPTION FUNCTION OF THE SEROUS MEMBRANES IN RABBITS. (Rus.) Faitel'berg-Blank, V. R. (Odessa Agricultural Inst., Odessa, USSR); Kotova-Khromenko, L. K. *Radiologiya* 18(3): 386-388; 1978. (3 refs)

The effects of whole body x-ray irradiation (500 r, dose rate 43.1 R/min) and microwave irradiation (2,307 MHz, 12, 20 or 30.5 mW/cm² for 10 min, or 20 mW/cm² for 20 min) on the resorption of ³²P from serous cavities were studied in 473 chinchilla rabbits. The radioactivity in the blood, lungs, liver, spleen, stomach, kidneys, muscles, and knee joint was determined 3-120 min after isotopic administration into the serous cavities. Increased release of ³²P into the blood was seen after 10- and 20-min exposure to microwaves with 20 mW/cm² intensity. Exposure to 12 and 30.5 mW/cm² caused only slight increase in the permeability of the serous membranes compared with the normal values. The x-ray irradiation alone caused highly significant increase in the permeability of the serous membranes, but permeability was reduced by subsequent exposure to microwaves. The permeability of the serous membranes of the pleura, epicardium,

peritoneum and knee joint were normalized by microwaves in some experiments.

- 5778 EFFECT OF HYPERTHERMIA ON THE IMMUNOCOMPETENCE OF VX2 TUMOR-BEARING RABBITS. (Eng.) Shah, S. A. (Cancer Res. Unit, Univ. Dept. Clinical Biochemistry, Royal Victoria Infirmary, Newcastle upon Tyne, England); Dickson, J. A. *Cancer Res* 38(10):3523-3531; 1978. (49 refs)

The effect of local radio frequency (RF) heating and total body hyperthermia on the immunocompetence of VX2 tumor-bearing rabbits was investigated. Rabbits bearing a 15-20-ml tumor in the hind limb were treated by local heating of tumor to 47-50 C for 30 min using an RF generator operating at 13.56 MHz. Nine of 13 rabbits treated were cured, with the tumor regressing completely within 60-80 days after local heating. The nine cured rabbits are alive with no signs of tumor 2 yr after treatment and are immune to intramuscular challenge with up to 30×10^6 VX2 cells. In six of eight rabbits subjected to total body hyperthermia (42 C for 60 min on 3 successive days) 7 days after local RF heating, temporary restraint of tumor growth was followed by a return to an exponential increase in tumor volume and in the case of five animals, rapid death. The primary tumor in two rabbits regressed completely; however, one of these rabbits died with metastases in the iliac lymph node and lungs. At 4 wk after curative RF heating alone, only one of ten rabbits had a primary tumor with a volume greater than 40 ml; whereas, five of eight rabbits treated by local and total body hyperthermia had tumors with a volume of 40 ml or greater at 50 days. After curative RF heating, the change in skin reactivity to antigen and the increasing titer of antibodies was marked enough to be used as an index of successful treatment. Attempts to immunize normal rabbits with 7- and 17-day in situ RF-heated VX2 tumor resulted in tumor formation. Therefore, the only method found to produce immunity in the rabbit to the VX2 tumor was RF heating of the tumor in the host.

- 5779 ELECTROMAGNETIC THERAPY OF INFLAMMATORY DISEASES OF LARYNX AND TRACHEA. (Rus.) Tsyganov, A. I. (Dept. Oncology, Kiev Scientific Res. Inst. Otolaryngology, Kiev, USSR); Ozinkovskii, V. V. *Zh Ushn Nos Gorl Bolezni* (3): 38-41; 1978. (24 refs)

Treatment with pulsed electromagnetic field (50 Hz, intensity 500 Oe, 15 min/session, 3-15 sessions) was given to 34 patients (28-80 yr old) with inflammatory diseases of the larynx and trachea. Acute catarrhal laryngitis was diagnosed in 6 patients, chronic hyperplastic laryngitis in 10, reactive postoperative inflammation of the trachea and larynx in 4, and radiogenic chondroepichondritis of the larynx in 14. Marked improvement was seen in all 6/6 patients with acute laryngitis after 1-3 sessions, in 8/10 patients with chronic hyperplastic laryngitis, in 4/4 patients with reactive

postoperative inflammations, and in 4/14 patients with radiogenic chondroepichondritis of the larynx. Two patients with chronic hyperplastic laryngitis and 8 with radiogenic chondroepichondritis showed no change, while two patients with radiogenic chondroepichondritis showed exacerbation. The findings indicate the effectiveness of electromagnetic treatment, however, it is contraindicated in patients with marked cardiovascular disorders.

- 5780 RADIOFREQUENCY RADIATION DOSIMETRY HANDBOOK (SECOND EDITION). (Eng.) Durney, C. H.; Johnson, C. C.; Barber, P. W.; Massoudi, H.; Iskander, M. F.; Lords, J. L. Ryser, D. K.; Allen, S. J.; Mitchell, J. C. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). 144 pp.; 1978. [available through USAF School of Aerospace Medicine, Aerospace Medical Division (AFSC) Brooks Air Force Base, TX 78235]. (115 refs)

A second edition of the radiation dosimetry handbook that extends dosimetric data presented in the first edition (limited mostly to the 10 kHz-1.5 GHz range) to frequencies in the range of 10 MHz-100 GHz is presented. Other improvements in the second edition include ground plane data, compilations of references to both theoretic and experimental work in the literature, empiric relations, heat response data, and results obtained from additional mathematic models of humans and animals (cylindrical model and block model). Some data are also given for inhomogeneous models of humans. The data are limited to the specific absorption rate for plane wave irradiation. Reference should be made to the first edition of the handbook (SAM-TR-76-35) for dosimetric data in the frequency range of 10 MHz to 10 kHz.

- 5781 TRANSIENT EFFECTS OF LOW LEVEL MICROWAVE IRRADIATION ON BIOELECTRIC MUSCLE CELLS PROPERTIES AND ON WATER PERMEABILITY AND ITS DISTRIBUTION: FINAL REPORT. (Eng.) Portela, A.; Llobera, O.; Michaelson, S. M.; Stewart, P. A.; Perez, J. C.; Guerrero, A. H.; Rodriguez, C. A.; Perez, R. J. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A050805]. (100 refs)

The effects of pulsed microwave radiation on electrical and osmotic properties of cells from sartorius muscles of the South American frog (*Leptodactylus Ocellatus*) were studied. Nerve muscle preparations were irradiated in a constant temperature perfusion chamber for 120 min at a power density of 10 mW/cm². The microwave generator had a frequency of 2.88 GHz, a pulse width of 0.67 μ sec, and a pulse repetition rate of 900 pulses/sec. Transient changes were observed in specific membrane resistance, in membrane capacitance, and in the space constant of irradiated muscle cells. Microwave irradiation also evoked a transient increase in the maximum rate of rise and fall of the action potential, overshoot potential, sodium equilibrium potential, and maximum amplitude of the ac-

tion potential. Peak inward sodium current and membrane negative conductance were also increased in irradiated cells. Microwave irradiation also transiently increased the rate constants for the foot of the action potential and for the terminal region of the action potential. Water membrane permeability and the fraction of the cell volume that is osmotically available were also transiently altered by microwave irradiation. The transient changes in the above parameters were greater in muscle cells from winter frogs than from summer frogs, recovering their initial control values within time constants of approximately 20 and 3 min, respectively. No such seasonal differences were observed in nonirradiated control frog muscle cells. Thermal effects on electrical parameters produced by non-electromagnetic heating at pre-set temperatures of 20-30 C were eliminated after setting the perfusion Ringer solution at 25 C, corresponding to time constants of between 1 and 2 min. These preliminary studies may indicate that the above observed transient effects may not be mainly due to thermal effects but rather to additional specific microwave actions on highly ordered macromolecular membrane functional activities.

5782 SLOW AND RAPID RESPONSES TO CW AND PULSED MICROWAVE RADIATION BY INDIVIDUAL *APLYSIA* PACEMAKERS. (Eng.) Seaman, R. L. (Dept. Physiology, Univ. Texas Health Science Center, 5323 Harry Hines Blvd., Dallas, TX 75235); Wachtel, H. *J Microwave Power* 13(1): 77-86; 1978. (30 refs)

Transmembrane potentials of individual pacemaker neurons in the abdominal ganglion of *Aplysia californica* were recorded during microwave irradiation to study the effects of microwaves on excitable cells. For every beating pacemaker studied, a slow change in firing rate, measured as interspike interval (ISI), was observed when the specific absorption rate (SAR) of the microwaves was sufficient. The firing rate reached a steady value with a time constant of about 1 min. For about half of the cells, radiation of sufficient intensity consistently reduced the firing rate; for the remainder of the population, effective intensities reduced the firing rate during most irradiations but increased the firing rate during others. For all beating pacemakers, post-irradiation firing rate returned to the pre-irradiation rate after 1-2 min. The smallest SAR that produced slow changes of firing rate was determined for 39 beating pacemakers from 29 ganglia and was found to be 7 mW/g. In addition to the slow, graded ISI changes, rapid changes in ISIs were also observed in eight beating pacemakers from eight different ganglia. A rapid change consisted of an increase in firing rate within one ISI of the onset of irradiation. Within 25 sec after the immediate decrease in ISI, the ISI gradually increased until it nearly reached the pre-irradiation value. The smallest SAR causing a rapid change in ISI was 1 mW/g. The microwave pulses in this case were of 0.5 μ sec duration at a repetition rate of 5,000/sec, giving a peak SAR of 400 mW/g. Rapid changes in firing rate were seen for 2.45-

GHz continuous wave (CW) and pulsed wave (PW) and for 1.5-GHz PW microwaves. The rapid changes appeared to be better defined for PW than for CW radiation, and the rapid changes also tended to occur at smaller averaged SARs for PW radiation. When 29 beating pacemakers were subjected to heating by microwaves versus warming by convection, some differences in slow responses were observed, and no rapid changes in firing rate were seen when cells were warmed or cooled by convection. The rapid changes seen in beating pacemakers as well as some phasic responses seen in experiments with bursting pacemakers could not readily be attributed to a thermal mechanism. One possible mechanism for the above changes is an effect on one or more of the membrane's components, perhaps by changing the ionic conductance or by altering a receptor's ability to combine with a chemical agent.

5783 ANALYSIS OF THE EFFECTS OF MICROWAVE ENERGY ON ENZYMIC ACTIVITY OF LACTATE DEHYDROGENASE (LDH). (Eng.) Bini, M. (Istituto de Ricerca sulle Onde Elettromagnetiche del C.N.R., Pisa, Italy); Checcucci, A.; Ignesti, A.; Millanta, L.; Rubino, N.; Camici, G.; Manao, G.; Ramponi, G. *J Microwave Power* 13(1): 95-99; 1978. (8 refs)

The effects of 3-GHz microwave energy on the enzymatic activity of lactate dehydrogenase (LDH) was studied under thermostatic and dynamic conditions at power levels of up to 6 W delivered into the sample. Under thermostatic conditions, no significant effects of microwave irradiation on LDH activity were seen. Similarly, no effect was observed when samples were irradiated with low intensities (100 mW) that caused no measurable significant temperature variations. Experiments under dynamic conditions for increasing microwave power levels showed two effects: a progressive acceleration of the enzymatic reaction, and starting from a power level of 4 W upward, a progressive increase in the enzyme denaturation process. The increase in enzymatic reaction velocity was due to the temperature rise consequent to microwave energy absorption. The thermal activation of the reaction velocity, caused by microwave irradiation, was in itself sufficient to give a good fit with the experimental time evolution of the enzymatic reaction.

5784 A REVIEW OF MICROWAVE OVEN SAFETY. (Eng.) Osepchuk, J. M. (Raytheon Res. Div., Waltham, MA 02154). *J Microwave Power* 13(1): 13-26; 1978. (32 refs)

Data on microwave leakage from noncertified and certified microwave ovens operating at a frequency of 2,450 MHz are reviewed. Typical leakage values imply exposure values well below the most conservative exposure standards in the world. The percentage of noncertified ovens leaking over 10 mW/cm² remains relatively constant at 10%, and the percentage of these noncertified ovens leaking less than 1.0 mW/cm² has remained between 45 and

60% over the years 1972-1977. The percentage of certified ovens leaking less than 0.1 mW/cm² according to the Bureau of Radiological Health's data has been increasing from about 30% in 1972 to about 60% in 1977. Continuing evidence that small numbers of ovens are leaking over the United States emission standard of 5 mW/cm² at 5 cm reflects the fact that some manufacturers still have not adopted the most advanced door-seal technique. However, adoption of the latter appears to be growing as field surveys disclose more and more ovens with leakage values below 0.1 mW/cm². Since 1973 emission standards on microwave ovens roughly equivalent to the United States' standard have been developed throughout the world. These include the emission standard in Canada, which specifies 1 mW/cm² at 5 cm with a minimum load, a standard of 5 mW/cm² at 5 cm developed by the International Electrotechnical Commission, and an emission standard of 0.01 mW/cm² at 50 cm in front of the door of an oven that is being developed in the USSR.

5785 MICROWAVES. (*Fre.*) Anonymous (No affiliation given). *Radioprotection* 13 (2):121-122; 1978. (0 refs)

Papers on the biologic effects of microwaves (300 MHz to 300 GHz) are reviewed. Distinction should be made between primary interactions and the biologic (specific) effects of microwaves. Continuous and pulsed microwaves have different biologic effects, and biologic effects are, in general, a function of frequency. The biologic effects of microwaves on cells, endocrine glands, and on the central nervous system cannot be explained simply by the thermal effects. Microwaves have been found to exert mutagenic effect on yeast cells and to kill such cells under certain circumstances during their action of DNA.

5786 ELECTROMAGNETIC RADIATION HAZARDS. (*Eng.*) Etheridge, J. D. (No affiliation given). *fathom* 10(1): 24-28; 1978. (0 refs)

Electromagnetic radiation hazards to shipboard Naval personnel are reviewed. Radio frequency (RF) burn hazards are caused by the existence of RF voltages on a ship at places where they are not intended and expected. Long lengths of metallic lines, particularly vertical lines, are efficient interceptors of RF energy. Potentially hazardous voltages have been found on lifelines, vertical ladders, launchers, gun mounts, rigging for underway replenishment, boat davits, and on aircraft spotted on carrier and helicopter flight decks. The Naval Ship Engineering Center has established that an open-circuit RF voltage exceeding 140 V on an object in an RF radiation field is hazardous. The primary shipboard sources of direct illumination of personnel by high-power microwave electromagnetic radiation, which may cause biologic, thermal, and neurologic effects are radars. Missile control radars are the most hazardous of all radars as they combine high-power transmitters with high-

gain, narrow-beam antennas. Power densities as high as 300 mW/cm² may be achieved. The eyes and testes are the most vulnerable body organs to microwave radiation, and the overwhelming danger appears to be the hazard from thermal effects that are a function of radiation intensity and frequency, particularly in the 1-3 GHz range. The Bureau of Medicine and Surgery has established the following maximum personnel exposure levels in the frequency range between 10 MHz and 100 GHz: 10 mW/cm² average incident power density for exposures greater than 30 sec and 300 mJ/cm² for intermittent exposures between 3 and 30 sec.

5787 A REPORT ON ELECTROMAGNETIC RADIATION SURVEYS OF VIDEO DISPLAY TERMINALS. (*Eng.*) Moss, C. E.; Murray, W. E.; Parr, W. H.; Messite, J.; Karches, G. J. (Nat'l. Inst. Occupational Safety and Health, Div. Biomedical & Behavioral Science, Cincinnati, OH 45226). 25 pp.; 1977. [available through Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. DHEW (NIOSH) Publication No. 78-129]. (14 refs)

The results of a 1977 National Institute of Occupational Safety and Health's (NIOSH) survey of electromagnetic radiation hazards from visual display terminals (VDTs) at a newspaper facility are reported. Medical examinations had revealed the presence of bilateral cataracts in two newspaper employees (men: 29 and 35 yr old) at this facility who were operating the VDTs. Radiation measurements, with the detector probes in contact with the VDT screen face, were made of ultraviolet, visible, infrared, and radio frequency radiation from three VDTs located at the newspaper facility. The terminals surveyed were a Telco Model 40, a Harris Model 1500A, and an Incoterm SPD 10/20. The first two terminals had been used by the two employees who developed cataracts. Selected measurements were also made on numerous other terminals on various floors of the newspaper building. All of the radiation levels emitted from these VDTs were either non-detectable or well below the current safety standards. Data from previous radiation surveys of VDTs by NIOSH and others are also referenced.

5788 IMMUNE RESPONSE OF MICE TO 2450-MHZ MICROWAVE RADIATION: OVERVIEW OF IMMUNOLOGY AND EMPIRICAL STUDIES OF LYMPHOID SPLENIC CELLS. (*Eng.*) Wiktor-Jedrzejczak, W. (Cellular Immunology Div., Clinical and Experimental Immunology Dept., Naval Medical Res. Inst., Bethesda, MD 20014); Ahmed, A.; Czerski, P.; Leach, W. M.; Sell, K. W. *Radio Sci* 12(6s): 209-219; 1977. (34 refs)

Inbred male CBA/J mice received either single or triple exposures to 2,450-MHz microwave radiation over 30-min periods to investigate the effects of such exposures on their immune responses. The averaged microwave dose for single exposures was 13 ± 2.5 mW/g. The averaged dose rates for mice

that were exposed three times were 15.6 ± 1.2 , 15.5 ± 0.9 , and 13.3 ± 0.6 mW/g for the first, second, and third exposures, respectively. These studies demonstrated that the exposure of mice to 2,450-MHz microwaves in an environmentally controlled waveguide produced weak stimulatory effects on bone marrow derived (B) lymphoid cells of the spleen but not on thymus-derived (T) lymphoid cells of the spleen. A single exposure of mice neither increased the total number of splenic cells nor the frequency of either theta-bearing (T) cells or immunoglobulin (Ig)⁺ (B) lymphoid cells. However, the single exposure caused a highly significant increase in the frequency of cells possessing complement receptors (CR) on their surface, which is a characteristic of mature B cells. In contrast, three 30-min exposures of mice to 2,450-MHz radiation induced an increase in the total number of splenic cells, in the total frequency of Ig⁺ (B cells), and further increased the frequency of CR⁺ B cells but had no significant effect on the total number of T cells. The results indicate, at least at the dosages used, that microwaves act primarily on B-lymphoid cells and produce quantitative changes in the absolute frequency of B-cell subpopulations.

5789 NON-IONIZING RADIATION. (Fre.) Francois, H. (No affiliation given). *Radioprotection* 13(2): 120; 1978. (0 refs)

The problem of increased exposure of the public as well as industrial workers to nonionizing radiation was addressed at one of the sessions of the Fourth International Congress of the International Radiation Protection Association. It was proposed that an international organization be formed that would establish criteria, fundamental principals of protection, and standards.

5790 A NEW MICROWAVE DEVICE FOR RAPID THERMAL FIXATION OF THE MURINE BRAIN. (Eng.) Maruyama, Y. (Section Biochemical Pharmacology, Japan Upjohn Res. Lab., 168 Ohyagi, Takasaki, Gunma 370, Japan); Iida, N.; Horikawa, A.; Hosoya, E. *J Microwave Power* 13(1): 53-57; 1978. (23 refs)

The ability of a 2.45-GHz microwave applicator with an output power of 1.3 kW to rapidly fix enzymes in the mouse brain was compared with that of a 5-kW commercial microwave device and with that of other conventional fixation techniques. Whole-brain acetylcholine levels in ICR strain mice after microwave fixation for 1.5 sec with the 1.3-kW applicator (28.2 ± 0.76 nmols/g) were comparable to those observed after fixation for 0.3 sec with the 5.0-kW microwave device (26.4 ± 0.51) and were significantly higher than those observed after fixation by freezing with liquid nitrogen (16.6 ± 0.88) or by decapitation (10.6 ± 1.45). When decapitation was followed by microwave irradiation, acetylcholine levels of 24.0 ± 2.00 and 26.3 ± 2.06 nmols/g were observed for a 1.0-sec treatment with 5.0-kW microwave irradiation and for a 5.0-sec treatment

with 1.3-kW microwave irradiation, respectively. Since enzymes that catalyze the synthesis and degradation of acetylcholine are destroyed when heated to 75-85 C, the temperature was measured in the midbrain of the mouse or rat as a function of the duration of microwave heating. With the 1.3-kW applicator, the temperature was elevated above 75 C within 2 sec in 25-35-g mice and to 85 C within 6 sec in 350-450-g rats. Microwave irradiation not only allows fast fixation of enzymes but also provides a clearer chromatogram when pyrolysis-gas chromatography is used for the analysis of acetylcholine.

5791 DIELECTRIC PROPERTIES OF HYDRATED PROTEINS AT 9.9 GHZ. (Eng.) Bone, S. (Workshop Natl. Foundation for Cancer Res., Sch. Electronic Engineering Science, Univ. Coll. N. Wales, Dean St., Bangor, Gwynedd LL57 1UT); Gascoyne, P. R.; Pethig, R. *J Chem Soc Faraday Trans I* 73(10): 1605-1611; 1977. (12 refs)

Dielectric measurements for bovine serum albumin, cytochrome-c, and lysozyme powders were made using a microwave resonant cavity technique at 9.95 GHz, and the hydration contents of the test powders were monitored using a sensitive quartz crystal technique. The hydration contents did not exceed 19% by weight, and the dielectric behavior at 9.95 GHz was considered to arise essentially from relaxations of sorbed hydration layers and was not influenced by effects associated with free bulk water. For hydration contents below 3% by weight, the permittivity components were relatively insensitive to changes in hydration but thereafter began to vary more rapidly. The permittivity values were found to be reversible and reproducible on changing the water vapor pressure. Multilayer hydration content analyses confirmed earlier conclusions that the dielectric loss at a frequency of about 10 GHz is principally associated with water in the secondary sorption sites. The results also indicate that the monolayer hydration layer is more strongly bound and rotationally hindered than previous measurements, using a standing wave method, indicated. Dielectric measurements such as these should aid in the development of electromagnetic cancer therapy techniques.

5792 SEAFARER: IMPACTS AND STUDIES OF THE EXTREMELY LOW FREQUENCY COMMUNICATION SYSTEM: A BIBLIOGRAPHY WITH ABSTRACTS. (Eng.) Lehmann, E. J., ed. (Dept. of Commerce, Natl. Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161). 174 pp; 1978. [available through National Technical Information Services, Springfield, VA 22161, Document No. NTIS/PS-78/0062]. (167 refs)

A bibliography containing 167 abstracts, 42 of which are new entries to a previous edition, of Government-funded research relating to the United States Navy's Seafarer global communication system, which employs extremely low frequency (ELF) radiowaves

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is presented. The bibliography is divided into four parts and covers the following: the biological effects of ELF radiation on humans, animals, plants, and ecosystems; research on equipment, performance, feasibility, design, and transmission of ELF radio-waves; and environmental surveys for the Seafarer antenna in Texas and Michigan. The search period covered by this bibliography is from 1964 to January 1978.

- 5793 SUDDEN INFANT DEATH SYNDROME AND ELECTRO-MAGNETIC FIELDS: POINT OF VIEW. (Eng.)
Schaefer, H. (Im Neuenheimer Feld 326, D-6900 Heidelberg, W. Germany); Silny, J. *Med Klin* 72(19): 871-872; 1977. (11 refs)

Criticism is presented of E. E. Ekert's work concerning the relationship between sudden infant death syndrome (SIDS) and electric and electromagnetic fields. The original work does not comply with the simplest rules of epidemiology: there were no controls used in the test made on children living near power lines. The original work misinterprets the significance of the epidemiologic findings: deaths/100 residents/hectare were made even when only one death was observed. The original work contains misinterpretations of physical parameters: no epidemiologic model was prepared, and no model exists showing a cause and effect relationship between power lines and crib death. Finally, there was not enough scientific information in the report on the relationship of low and high frequency fields on humans.

- 5794 CONCLUSION. (Ger.) Eckert, E. E. (14 Green Briar Lane, Newtown, CT 96470).
Med Klin 72(19): 872-874. (11 refs)

Reply is presented to a criticism of a study by the author on possible relationships between electromagnetic fields and sudden infant death syndrome (SIDS). Many cases of SIDS occur in the vicinity of electric power lines, especially in basement and first-floor apartments. One-third of all cases are clustered in space, and many cases are clustered in time. The epidemiologic data suggest a relationship between man-made and abnormal natural electric and electromagnetic fields and SIDS. The study of the biologic potential of electromagnetic fields must take into account frequency, magnetic atmospheric components, abnormalities in terrestrial currents, modulations, interference, and ground interference of technical origin, and these parameters must be related to the habitats of SIDS victims over a period of two years.

- 5795 EFFECT OF SUPER-HIGH-FREQUENCY ELECTRO-MAGNETIC FIELDS ON THE CENTRAL STRUCTURES OF THE BRAIN. (Rus.) Faitel'berg-Blank, V. R. (Odessa Agricultural Inst., Odessa, USSR); Perv-alov, G. M. *Dokl Akad Nauk SSSR* 239(1): 242-244; 1978. (8 refs)

The effect of an electromagnetic field (460 MHz, field intensity 2 and 5 mW/cm², length of exposure 10 min) on the overall and light-flash-stimulated impulse activity of the central structures of the brain was studied in 35 Chinchilla rabbits weighing 2-3 kg. The overall electrical activity was determined by means of nickel chromium electrodes; the impulse activity, by means of glass microelectrodes. The exposure caused desynchronization of the specific and nonspecific nuclei of the thalamus, hypothalamus, and reticular formation of the midbrain during the first minute after irradiation. The number of slow waves and spindles increased in the thalamic and hypothalamic nuclei 2-3 min after exposure to the 5 mW/cm²-field. The electric activity of the brain returned to normal in 10-15 min. Light stimulation at 5-7 Hz frequency and exposure to 2 mW/cm² caused a considerable reduction of the potential synchronization coefficient and of the energy of the synchronized oscillations in the thalamus and hypothalamus, but an increase of these parameters was seen following stimulation at higher frequencies (13-25 Hz). Exposure to 5 mW/cm² improved the adoption of the light stimulation frequency in the sensorimotor cortex and hypothalamus at 5-11 Hz frequency, but it impaired the frequency adoption at higher frequencies. Following exposure to 2 mW/cm², the discharge frequency increased in 45.6% of the nerve cells and decreased in 39.7%, versus an increase in 2% and a decrease in 4% in the nonexposed controls. The number of neurons, which responded to the 2 mW/cm² field with increased impulse frequency, was highest in the hippocampus (64.3%) and hypothalamus (58.3%). The number of the nonresponding nerve cells was lowest in the medial preoptic region of the hypothalamus. Following exposure to 5 mW/cm² the number of brain cells, which responded by increased discharge frequency, was considerably lower than it was following exposure to 2 mW/cm². The findings indicate that the 2 mW/cm²-field intensifies the electric activity of the brain and increases the discharge frequency of the nerve cells, while the 5 mW/cm²-field intensifies the synchronization of the electrical activity, inhibits the adoption of the light flash rhythm during high-frequency stimulation, and reduces, in most cases, the discharge frequency of the nerve cells of the brain.

- 5796 CHEMILUMINESCENCE OF THE BLOOD SERUM DURING EXPERIMENTAL EXPOSURE TO PHYSICAL FACTORS. (Rus.) Baraboi, V. A. (Kiev Scientific Res. Inst. Roentgenology and Radiology, Kiev, USSR); Motuzkov, I. N.; Orel, V. E.; Sbirnaia, A. F.; Tatsii, lu. A.; Shutenko, O. I. *Gig Sanit* (1): 49-51; 1978. (5 refs)

The effects of x-ray, ultraviolet (UV), and high-frequency electromagnetic radiation on the chemiluminescence of the blood serum and on other physiologic parameters were studied in rats. The effect of UV radiation was studied in 30 rats in a 2-mo experiment: one group was kept under UV deficiency conditions (exposed to 1/30-1/40 of the optimal UV dose); the second was exposed to the physiologically optimal dose, and the third group,

to 3 times the optimal dose. The chemiluminescence of the blood serum was highest in the second group (544 impulses/10 sec versus 294/10 sec in the first group and 301/10 sec in the third). The oxygen consumption (in ml O_2 /100 g·hr) was 135 in the first group, 158 in the second, and 122 in the third. The serum alkaline phosphatase activity (in conventional units) was 18.4 in the first group, 15.4 in the second, and 21.7 in the third. The duration of hexenal-induced sleep was 37 min in the first group, 27 min in the second, and 38.5 min in the third. Forty other rats were exposed to high-frequency electromagnetic field (2,840 MHz, 100 μ W/cm², 3 hr/day), low-frequency noise (8 Hz, 110 dB, 2 hr/day) or their combinations (2 hr/day exposure to noise, followed by 3-hr exposure to the electromagnetic field) in a 3-mo experiment. The electromagnetic field alone increased the luminescence of the blood serum (365 impulses/10 sec versus 309/10 sec in the controls) and reduced the oxygen consumption (15-.8 ml/100 g·hr versus 201 ml/100 g·hr in the controls). Noise alone had a similar effect. Combined exposure diminished the differences from the control parameters, indicating the differences in the biologic action of noise and electromagnetic field. The chemiluminescence of the blood serum was 262 impulses/10 sec, and the oxygen consumption, 182.7 ml/100 g·hr.

5797 METHOD FOR RECORDING ELECTROCARDIOGRAMS OF THE INTACT FROG DURING SUPER-HIGH-FREQUENCY IRRADIATION. (Rus.) Parsadaniyan, A. Sh. (Inst. Biological Physics, USSR Acad. Sciences, USSR); Khafizov, R. Z.; Tigranian, R. E. *Biol Zh Akad Nauk* 30(7): 50-53; 1977. (13 refs)

A new method for recording the electrocardiogram (ECG) of intact frogs without opening the thoracic cavity during irradiation with super-high-frequency (SHF) field is described. The skin is removed in a small area (1 cm²) in the cardiac region, and two artefact-free liquid electrodes are applied on the denuded area. The other end of the electrodes is connected with silicon rubber tubes, which are placed into a metallic screen at the boundary of the irradiated zone. The liquid-metal (silver electrode) contact is outside of the irradiated zone. Preliminary tests revealed that the artefact-free liquid electrodes permit the stable recording of the ECG of intact frogs and eliminate the interference of SHF signals in the ECG.

5798 CHANGE OF SOME PARAMETERS OF THE CLOTTING SYSTEM OF THE BLOOD IN SUPER-HIGH-FREQUENCY FIELD. (Rus.) Moskvitina, L. T. (Irkutsk Inst. Organic Chemistry, Siberian Branch of the USSR Acad. Sciences, Irkutsk, USSR); Platonova, A. T. *Gig Sanit* (1): 113; 1978. (1 ref)

The effect of single-time exposure to high-frequency electric field (wavelength 3 cm, intensity 10 mW/cm², length of exposure 6 hr) on the blood clotting system was studied in 10 rabbits weighing 2.5-3 kg. Ten other rabbits served as controls. The animals were followed up for 18 days. Compared with con-

trols, the beginning of blood clotting was delayed immediately after exposure and remained so throughout the observation period. The thrombocyte count was increased immediately after exposure and remained so throughout the experiment; it was highest (157% of the control value) on day 8 after exposure. The stickiness of the thrombocytes increased highly significantly throughout the experiment, especially between days 4 and 6 after irradiation. The findings indicate that 6-hr exposure to a 10 mW/cm² electrical field causes substantial changes in blood clotting, and therefore the maximum permissible value, as adopted in the USA, must be revised.

5799 TOPICAL APPLICATION OF ULTRA-HIGH FREQUENCY IMPULSE THERAPY IN PROSTATITIS. (Rus.) Braitsev, A. V. (Central Scientific Res. Inst. Dermatology and Venereal Diseases, USSR Ministry of Public Health, Moscow, USSR); Grachev, Iu. I.; Ovchinnikov, V. I.; Voskresenskaia, G. A.; Kochetkov, V. D. *Vestn Dermatol Venereol* (5): 87-90; 1978. (10 refs)

Twenty-seven patients with subacute and 45 patients with chronic prostatitis received combined topical ultra-high-frequency impulse treatment with a 40-W generator (10 min/day, 6-10 sessions) and antibiotic therapy with penicillin, bicillin-3, monomycin, tetracycline or levomycetin. Three patients were under 20 yr of age; 32 were 21-30 yr of age; 20 were 31-40 yr of age; 10 were 41-50 yr of age; and 7 were aged over 60 yr. The prostatitis was of gonorrheal etiology in 23 patients. The length of the disease before combined treatment was less than 2 mo in 27 cases, 2-6 mo in 13, 6-12 mo in 11, and 1-3 yr in 6. The patients with chronic prostatitis had been treated unsuccessfully with antibiotics. The pulsed electric treatment caused complete disappearance or considerable alleviation of pains in all patients; it occurred after 2-3 sessions in 39 cases, after 4-5 sessions in 14, after 6-8 sessions in 19. Complete disappearance of the infiltration was observed after 5-7 sessions in 31 patients; considerable regression was seen in 29 patients; no regression, in 12. The electric therapy had no unfavorable effect on the spermatozoa. The investigation of spermatozoa from 18 patients for up to 60 days after the treatment and from 20 untreated healthy controls showed no differences in the morphology of the ejaculate, in the spermatozoa count per ml, nor in their motility. The findings indicate the therapeutic effectiveness of pulsed electric treatment in subacute and chronic prostatitis.

5800 ELECTRICAL ACTIVITY IN BONE. (Eng.) Simonis, R. (St. Thomas' Hosp., London, England). *Bull Hosp Joint Dis* 38(2): 87-89; 1978. (0 refs)

Literature dealing with the manifestation of physiologic electric currents in living bone and with the possibility of artificial stimulation of osteogenesis by the use of electricity is reviewed. Stud-

ies have shown that when a bone is fractured the whole limb becomes more electronegative with the highest negative point being over the fracture site itself. As the fracture unites, the electric potentials gradually revert to normal. Based on the assumption that where new bone is being laid down (at the metaphysis and fracture sites) there is a negative charge, attempts at stimulating osteogenesis and increasing the rate of fracture healing by the introduction of an artificial negative charge have been made. Three techniques appear to be successful at producing osteogenesis: invasive methods with the insertion of a battery, semi-invasive techniques with wires inserted through the skin from an external power source, and non-invasive techniques with the application of an electrostatic or magnetic field. Following animal experiments, these three methods have been used in humans in attempts to treat cases of non-union, and individually the results have been quite impressive. Following a double blind trial on dogs with non-union of the tibia, which showed that the application of a direct current significantly enhanced bony union, a multi-center trial on non-unions in humans has been initiated. Three case reports of the successful use of electrical stimulation to enhance bone healing in humans with non-unions of the tibia are briefly presented. Details concerning the electrical parameters employed are not specified.

5801 COHERENT EXCITATIONS IN BIOLOGICAL SYSTEMS. (Eng.) Froehlich, H. (Dept. Electrical Engineering, Univ. Salford, Liverpool, England). *Biophysics* 22(4): 777-778; 1977. (6 refs)

That coherent electric vibrations in the frequency of 10^{11} Hz excite biologic systems if an energy supply above a threshold is available is supported by a model calculation. Objections to the model are discussed. In the mathematic model used, a band of polarization waves with certain frequencies is considered to be in strong interaction with a heat bath and to have a supply of energy from metabolic energy sources at a certain rate of quanta. Coherent excitation is expressed in the form of a Bose condensation.

5802 THE APPLICATION OF PULSED MAGNETIC FIELDS TO THE STIMULATION OF BONE HEALING IN HUMANS. (Eng.) Watson, J. (Dept. Electrical and Electronic Engineering, Univ. Wales, Swansea, Wales); Downes, E. M. *Jpn J Appl Phys* 17(1): 215-217; 1978. (11 refs)

An orthopedic stimulator that produces a pulsed magnetic field for inducing small currents in human limbs is described along with its use in the non-invasive treatment of three cases of non-union of bones. The stimulator consists of a 30-V square wave generator, which is connected to an electromagnet. In use, the electromagnet pole ends slide into Textolite guides built into each side of the plaster cast. Hence, it can be withdrawn and replaced by the patient. A prototype of the stim-

ulator was first used successfully to treat a 53-yr-old woman who had suffered a segmental open fracture of the tibial shaft, followed by complications and non-union over some 5 yr. In another case, the stimulator was used on a 28-yr-old man who had received conventional treatment for a severe open fracture of the distal shaft of the left tibia and fibula. X-ray evidence had shown that the fracture line was still visible 18 mo after the fracture had occurred and after initial treatment had been started. The stimulator was applied for 4 wk; after this, a below-knee weight-bearing cast was applied. After 3 wk, the fracture was no longer mobile, and X-ray examination showed evidence of new bone formation, which continued to full consolidation of the fracture after a further 8 mo. In the third case, the stimulator was applied on a 71-yr-old woman who had undergone an arthrodesis of the left knee for osteoarthritis. Sound bony union did not occur, and 14 mo later there was severe pain with obvious mobility of the arthrodesis. She underwent treatment with the stimulator for 4 wk, and 2 mo after the completion of this treatment, the arthrodesis united clinically, and X-rays showed progress towards sound consolidation.

5803 MICROWAVE-INDUCED HAZARDOUS THERMAL STRESSES IN THE OCULAR LENS OF THE HUMAN EYE. (Eng.) Neelakantaswamy, P. S. (Dept. Electrical Engineering, Indian Inst. Technology, Madras-600036, India); Ramakrishnan, K. P. *Biomed Tech (Berlin)* 23(5): 109-113; 1978. (11 refs)

A theoretic evaluation of microwave-induced thermal stresses in the human eye are presented, and the potential pathogenic conditions are discussed. A dielectric spherical shell model depicting the human eye was used to evaluate the temperature distribution within the eye exposed to a plane microwave irradiation at a frequency of 2,450 MHz. The rise in the temperature on the surface of the ocular lens was then used to calculate the thermal stresses developed in the lens medium. A thermoelastic equation of motion was formulated to examine the vibrating motions of the lens, which was assumed to be an isotropic circular plate clamped along its periphery. Although the maximum stress developed and the resulting bending moments were small in magnitude, it is concluded that the constancy of the strains developed as a result of prolonged microwave exposure, leading to micromassaging. Thus, mechanical strains and deformations, however small, can cause physico-chemical processes in the delicate tissue medium of the eye that result in pathogenic conditions which permanently impair the adaptive and accommodative actions of the eye.

5804 MAGNETIC FIELD DETECTION IS DISTINCT FROM LIGHT DETECTION IN THE INVERTEBRATES *TENEBRIO* AND *TALITRUS*. (Eng.) Arendse, M. C. (Lab. Comparative Physiology, State Univ., Utrecht, The Netherlands). *Nature* 274(5669): 358-362; 1978. (20 refs)

Orientation experiments with *Tenebrio molitor* L. (flour beetle) and *Talitrus saltator* Mont. (sand-hopper) were performed to determine if light is a prerequisite for magnetic field detection. In a first experiment, *Tenebrio* cultured in an anisotropic light field were placed in darkness 2 days before directional preference was examined. From previous experiments, orientation was expected in a direction 26 degrees east of magnetic north, the dark direction in the culture container. The distribution of trail directions (on a starch covered platform) was not uniform, and their mean direction compared with the predicted direction. In a second experiment with *Tenebrio*, two tests were performed in total darkness at two different relative humidities, and a frequency distribution in 12 direction classes was obtained. From the tests it was concluded that *Tenebrio* displays a nonvisual orientation in total darkness that has all of the characteristics of the magnetotaxis observed previously in an isotropic light field. In a third experiment, *Talitrus* was placed in total darkness, and two frequency distributions were obtained—one for a local geomagnetic field (0.47 Oe) and one for a rotating magnetic field of the same strength. It was concluded that *Talitrus* is able to orientate in an ecologically important direction using magnetic field information. In a fourth experiment, *Tenebrio* was tested in an artificial magnetic field (0.44 Oe) with zero vertical component, which was supplied in an isotropic light field. As before, the beetles had been cultured in an anisotropic light field. Three tests were performed with beetles from containers differing in relative humidity and dark direction. In each of the experiments, the mean direction compared with the predicted direction. Overall, it is concluded that light is not a prerequisite for magnetic field detection in *Tenebrio* and *Talitrus* and that in *Tenebrio* the reaction is polar rather than axial.

5805 ELECTROMAGNETIC HYPOTHESIS OF THE TRANSMISSION OF MENTAL SUGGESTION. (Eng.) Arkad'yev, V. (No affiliation given). 20 pp; 1977. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A048995]. (2 refs)

An electromagnetic hypothesis for the transmission of mental suggestion is tested by mathematically examining the magnitude of excitation of the electromagnetic field by a given organism and the perception of this field by another organism. The radiating center of the physical stimulator is considered to be an electrical dipole with two opposing electric charges at a given distance from one another. These charges perform sinusoidal oscillations twice within a time period, which is called the period of electrical vibrations of the dipole (also can be called the oscillator). Under such oscillations electromagnetic waves of a length equal to the speed of light multiplied by the time period are formed. At a certain distance from the dipole, in the plane perpendicular to its length, an expression for the force of the magnetic field

is derived from the theory of Hertzian waves. Two different cases are distinguished: at a short distance from the dipole, which is much less than the wavelength and at a greater distance from the oscillator, which is much greater than the wavelength. Magnetic field and electric field amplitudes are solved for both of these cases, and it is concluded that the force of these fields is too small to account for the transmission of mental suggestion.

5806 SCIENTIFIC EXPERIMENTS IN THE FLIGHT OF THE 1977 BIOLOGICAL SATELLITE (DRAFT PLAN). (Eng.) USSR Academy of Sciences, Interkosmos Council (Moscow, USSR). [available through National Technical Information Services, Springfield, VA 22161, Document No. N78-11171 (NASA-TM-75032)]. (0 refs)

Soviet biosatellite experiments planned for 1977 are outlined. The purpose of the experiments is to study the principles governing the adaptation of physiologic systems to the complex of factors involved in prolonged space flight as well as to study numerous fundamental questions of general biology, particularly those dealing with the role of gravity in the growth, development, and reproduction of organisms. Experiments will be performed with higher and lower plants, insects, and rats. The presence of a centrifuge on the biosatellite will make it possible to conduct artificial gravity experiments with mammals. The biologic investigations will include a study of the growth dynamics of higher and lower plants under weightless conditions as well as the physiology, anatomy, and genetics of insects. Previous studies of the modifying effect of weightlessness on the radiosensitivity of organisms have shown that the development and course of radiation sickness in space were practically identical to its development and course under terrestrial conditions. Centrifuge experiments done aboard the Kosmos-782 biosatellite showed that the biological effects of artificial gravity under space-flight conditions were essentially the same as those of normal terrestrial gravity. Experiments on three biosatellites showed for the first time that high-intensity electric fields, which are of interest as cosmic-radiation shields, can be generated and maintained under conditions of prolonged space flight.

5807 COMBINATION HYPERTHERMIA AND RADIATION THERAPY FOR CUTANEOUS MALIGNANT MELANOMA. (Eng.) Kim, J. H. (Dept. Radiation Therapy, Memorial Sloan-Kettering Cancer Center, New York, NY 10021); Hahn, E. W.; Tokita, N. *Cancer* 41(6): 2143-2148; 1978. (15 refs)

Patients with recurrent cutaneous malignant melanomas that were refractory to conventional therapy were treated with radiotherapy (RT) alone, inductive radio frequency (RF) heating (27.12 MHz) alone, or with a combination of the two modalities to investigate if RF heating would enhance the effect of RT in such tumors. When RF hyperthermia was applied, the aim was to achieve a minimal tumor temperature of 42.5 C for at least 30 min. When employed with hyperthermia, RT was given within 3-6

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min after RF hyperthermia was terminated. Initially three lesions in two patients were treated with hyperthermia alone. One lesion responded with complete regression, but as with the other two lesions which partially responded, the lesions rapidly recurred within 3 wk. Thus, hyperthermia alone was discontinued. Treatment with RT alone was effective in producing a complete response in one lesion and produced partial responses in four other patients with seven lesions treated. Complete and permanent regression was observed in seven patients with 16 lesions that were treated with the combination of RT and RF hyperthermia. No unusual skin reactions developed after combined treatment except in two patients. The radiation dose necessary to achieve satisfactory local tumor control in combination with RF hyperthermia ranged from 3,000 rad (300 rad in 10 fractions over 4 wk) to 3,200 rad (400 rad in 8 fractions over 4 wk). The above results strongly suggest that a high local tumor control rate can be achieved by the combination of hyperthermia and RT with no disproportionate attendance of normal tissue complications.

5808 LAMINAR FLOW OF BLOOD IN AN ELASTIC TUBE IN THE PRESENCE OF MAGNETIC FIELD. (Eng.)
Sud, V. K. (Biodynamics and Bioengineering, Aerospace Medical Res. Lab., Wright-Patterson AFB, OH 45433); Suri, P. K.; Mishra, R. K. *Stud Biophys (Berlin)* 69(3): 175-186; 1978. (10 refs)

The effect of a radial magnetic field on blood flow in an infinite flexible tube of uniform cross-section is theoretically examined to determine the reduction in the movement of blood flow caused by electromagnetic fields. Basic equations and boundary conditions are given, and the mathematic solutions for the velocity distribution equations contain Bessel functions with imaginary arguments. Hence, it is not possible to obtain the exact solutions for arbitrary values of the magnetic frequency (MF) parameter. However, the velocity profile solutions can be computed in two extreme cases, either for small values of MF or for large MF values. Computed results for the case of a femoral artery of a dog indicate that the effect of the magnetic field is to decrease the movement of blood and thereby stabilize the flow.

5809 THE INFLUENCE OF MICROWAVE EXPOSURE ON FUNCTIONAL MATURATION OF THE RAT. (Eng.)
Michaelson, S. M.; Guillet, R.; Heggeness, F. W. (Dept. Radiation Biology, Univ. Rochester Sch. Medicine and Dentistry, Rochester, NY 14642). 38 pp; 1977. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A048880]. (35 refs)

In utero and neonatal exposures of Long-Evans rats to continuous wave 2,450-MHz microwaves were performed to investigate the influence of such exposures on functional maturation. In one experiment, gravid Long-Evans hooded females were exposed for 1 hr to 2,450 MHz microwaves at a power density

of 10 mW/cm² on days 9 and 16 of gestation or at 40 mW/cm² on days 9, 13, 16, or 20 of gestation. There were no apparent developmental or growth rate differences in pups from irradiated or non-irradiated dams from birth to weaning on day 21. However, at ages 0-2 days, metabolic response to cold exposure was greater among offspring of exposed rats than among offspring of sham exposed (control) animals. Plasma corticosterone levels were significantly increased in neonates of rats exposed on day 16 of gestation to 40 mW/cm². Thyroxine levels tended to be decreased among 1-wk-old rats from dams exposed to 10 mW/cm² but increased during wk 2 of life. Among pups from 40 mW/cm²-exposed dams, there was a statistically significant increase in thyroxine levels at 14-16 days of age. In a second experiment, pups were individually exposed to 2,450-MHz radiation at 40 mW/cm² for 5 min/day beginning on day 1 until day 6 of life. On day 7, adrenal responsiveness was tested by administering adrenocorticotropic hormone (ACTH: 10 units/100 g, intraperitoneally) to one-third of the pups and comparing the response with pups exposed to a seventh microwave irradiation and with pups sacrificed immediately after removal from the nest. There was no significant difference in growth rate between exposed and control pups, but the exposed rats demonstrated a slightly greater growth rate during the first 6 days of life. In 7-day-old rats the basal corticosterone level was not altered by previous microwave exposure. Pups exposed to 40 mW/cm² of radiation showed an adrenal responsiveness not quantitatively different from that produced by ACTH administration. Adrenal wet weight and adrenal-to-body weight ratios in 7-day-old rats were significantly higher in microwave-exposed rats in comparison with controls.

5810 RADIOLOGIC EVALUATION OF THE TREATMENT OF NONUNION OF FRACTURES BY ELECTRICAL STIMULATION. (Eng.) Forsted, D. L. (Dept. Radiology, Mercy Catholic Medical Center, Fitzgerald Mercy Div., Lansdowne Ave. and Baily Road, Darby, PA 19023); Dalinka, M. K.; Mitchell, E.; Brighton, C. T.; Alavi, A. *Radiology* 128(3): 629-634; 1978. (7 refs)

The use of direct current electrical stimulation for the treatment of 107 patients with nonunion of fractures is reported. Four or more cathodes were implanted in most cases, being uniformly distributed within the fracture site. A 6-cm steel mesh rectangular plate was used as the anode and was taped to the skin. A 7.5-V battery power source in circuit with a field-effect transistor and resistors that allowed a constant continuous current was used to deliver 10-20 μ A by each electrode over a 12-wk course. Of the 107 patients treated, 71 (66%) went on to osseous union. If 9 cases of congenital pseudoarthrosis and 11 patients treated with only 10 μ A of current are eliminated, then 70 of 87 patients (80.5%) healed. The presence or absence of infection had no effect on the results of therapy. It is concluded that low-dose electricity induces callous formation and speeds fracture healing.

- 5811 THE INFLUENCE OF ELECTROMAGNETIC WAVES OF SUPER-HIGH FREQUENCY AND LOW INTENSITY ON HEMODYNAMIC CHANGES IN ANIMALS WITH ACUTE INFLAMMATION IN THE ABDOMINAL CAVITY. (Rus.) Bachurin, V. I. (Dept. Surgery, Zaporozh'e Medical Inst., Zaporozh'e, USSR). *Patol Fiziol Ekspier Ter* (3): 28-31; 1978. (8 refs)

The effect of exposure to an electromagnetic field (300 MHz, 10 mW/cm², length of exposure 1 hr/day for 30 days) on the hemodynamic changes in the hind limbs and brain induced by ligation of the appendicular artery and subsequent appendectomy was studied in 26 rabbits. Fifteen other rabbits, serving as controls, were not irradiated. The hemodynamic disturbances, such as vascular spasm, blood stasis, especially of the limbs, as well as tachycardia persisted as long as 7 days after appendectomy in the irradiated rabbits. The hemodynamic changes caused by experimental appendectomy disappeared practically completely in 7 days in the non-exposed rabbits.

- 5812 EFFECT OF CONSTANT MAGNETIC FIELD ON REST POTENTIAL, IONIC CONDUCTIVITY AND NEUROMUSCULAR TRANSMISSION IN THE SMOOTH MUSCLES. (Ukr.) (Inst. Physiology, Kiev Univ., Kiev, USSR); Davydovs'ka, T. L. *Fiziol Zh* 23(5): 622-626; 1977. (16 refs)

The effect of constant magnetic field (300 and 600 Oe, impulse duration 0.2-0.3 msec) on the rest potential and inhibitory postsynaptic potentials of the isolated tenia coli was studied in guinea pigs. The constant magnetic field increased the amplitude of the inhibitory postsynaptic potentials and caused slight hyperpolarization and ionic permeability of smooth muscle cell membranes. The effects increased with the field intensity. The findings indicate that constant magnetic field increases the efficiency of synaptic transmission.

- 5813 EFFECT OF SUPER-HIGH-FREQUENCY ELECTROMAGNETIC WAVES ON THE COURSE OF EXPERIMENTAL APPENDICITIS. (Rus.) Bachurin, V. I. (Zaporozh'e Medical Inst., Zaporozh'e, USSR); Platash, V. I. *Klin Khir* (4): 71; 1978. (0 refs)

The effect of exposure to a super-high-frequency electromagnetic field (3,000 MHz, field intensity 10 mW/cm², exposure 1 hr/day for 3 mo) on the course of acute appendicitis induced by ligation of the appendicular arteries, veins and their small intestinal branches was studied in 41 rabbits. Of the 41 rabbits, 15 served as non-irradiated controls. Appendicitis was induced after exposure, and typical appendectomy was performed 12-14 hr later. Increase in the number of goblet cells with intensified synthesis and secretion of mucine, increased numbers of para-aminosalicylic acid (PAS)-positive and heparin-containing mast cells in the lamina propria, and increased phagocytic activity in the lymph follicles were found in the non-irradiated controls. The histologic investigations of the

irradiated animals revealed a reduced number of goblet cells in the crypts, reduced mucin secretion in the glands, reduced production of neutral mucopolysaccharides, the appearance of degranulated heparin-containing mast cells in the connective tissue along with a sharp reduction in their number, and reduced phagocytic activity of the lymph follicles containing PAS-positive bacterial metabolites. The findings indicate that the exposure to the electromagnetic field caused more pronounced and earlier degenerative changes in the vermiform appendix during the development of the inflammatory process and impairment of the defense capacity of the body.

- 5814 ELECTROMAGNETIC FIELDS IN BIOLOGICAL MEDIA: PART I: DOSIMETRY—A PRIMER ON BIOELECTROMAGNETICS. (Eng.) Neuder, S. M. (Div. Electronic Products, Bureau Radiological Health, Food and Drug Admin., Rockville, MD 20857). 29 pp.; 1978. [available through Bureau of Radiological Health's Technical Information Staff (HF-25), 5600 Fishers Lane, Rockville, MD 20857. HEW Publication (FDA) 78-8068]. (19 refs)

Physical and basic mathematic considerations of radio frequency and microwave radiation (10^4 to 3×10^{11} Hz) in lossy dielectric media are reviewed, and expressions for, and relationships between, the physical parameters pertinent to dosimetry are developed. The behavior of these parameters in various biologic tissues is also discussed. Specific topics covered include the dielectric constant and relative magnetic permeability, the loss tangent, the complex permittivity, the relationship between the free space wavelength and the propagation constant, perfect and lossy dielectrics, the internal wavelength, not-so-lossy dielectrics, the frequency and temperature dependence of electrical parameters, power absorption, dosimetric quantities, plane waves, normalization with respect to the incident field, and dosimetric determinations. Two appendices are also provided: one covering equivalent expressions for the Poynting vector and the other covering the conversion of normalization of incident power density.

- 5815 RAPID MICROWAVE FIXATION OF RAT BRAIN. (Eng.) Moroji, T. (Div. Psychopharmacology, Psychiatric Res. Inst. Tokyo, 2-1-8, Kamikitazawa, Setagaya-ku, Tokyo, Japan); Takahashi, K.; Ogura, K.; Toishi, T.; Arai, S. *J Microwave Power* 12(4): 273-286; 1977. (41 refs)

The use of a 2,450-MHz microwave device for rapidly inactivating rat brain enzymes is reported. In one set of experiments, two groups of rats with different body weights were exposed to two different power levels (0.8 and 4.5 kW). Temperature and weight of the brain as well as monoamine oxidase and acetylcholinesterase activities were determined at each power level. Heating at the higher power level versus the lower power level shortened the heating time and minimized the effects of animal

weight on duration of microwave irradiation, loss of brain water content, and heat-induced changes in enzyme activity during irradiation. In a second set of experiments, monoamines, their metabolites acetylcholine and choline, and cyclic adenosine monophosphate (AMP) and cyclic guanosine monophosphate (GMP) levels in the brain were measured after inactivation of relevant enzymes by microwave irradiation at a power level of 5 kW for 1.6 sec. There were no statistical differences in the levels of norepinephrine, dopamine (DA), and serotonin between microwave-irradiated rats and decapitated rats. Only the level of 3,4-dihydroxyphenylacetic acid in the brain of rats killed by microwave heating was increased significantly. A tendency towards an increase in the level of DA was also observed in irradiated brains. A significant increase in the level of acetylcholine and a marked decrease in the level of choline was observed in irradiated brains compared with levels in brains from decapitated rats. There were no statistical differences in the cyclic GMP levels between irradiated and decapitated rats, but cyclic AMP levels were markedly reduced in irradiated brains compared with brains of decapitated rats. It is concluded that rapid and uniform inactivation of brain enzymes by microwave fixation is a suitable method for the measurement of compounds with a rapid turnover rate in the brain.

- 5816 ALL-UNION CONFERENCE ON "METHODOLOGICAL QUESTIONS OF THE HYGIENIC STANDARDIZATION OF NON-IONIZING RADIATION" (MOSCOW, JUNE 1977). (Rus.) Lobanova, E. A. (Moscow, USSR). *Gig Tr Prof Zabol* (3): 60; 1978. (0 refs)

The highlights of an all-union conference on the hygienic standardization of non-ionizing radiation, sponsored by the Institute of Industrial Hygiene and Occupational Diseases of the USSR Academy of Medical Sciences, are presented. The importance of in vivo experiments as well as of clinical observations on exposed groups was emphasized in several papers, which also dealt with the problems of extrapolating experimental data obtained from laboratory animals to humans. A uniform approach was recommended for the establishment of maximum allowable levels of non-ionizing radiation for different groups of persons including the general public.

- 5817 COMPILATION AND ASSESSMENT OF MICROWAVE BIOEFFECTS: A SELECTIVE REVIEW OF THE LITERATURE ON BIOLOGICAL EFFECTS OF MICROWAVES IN RELATION TO THE SATELLITE POWER SYSTEM. (Eng.) Justesen, D. R.; Ragan, H. A.; Rogers, L. E.; Guy, A. W.; Hjeresen, D. L.; Hinds, W. T.; Phillips, R. D. (Veteran's Admin. Hosp., Kansas City, MO). 92 pp; 1978. [available through Battelle Memorial Inst., Pacific Northwest Labs, Richland, WA 99352, Document No. PNL-2634]. (138 refs)

A literature review of the biological effects of microwaves in relation to the proposed microwave Satellite Power System (SPS) is presented. The SPS is designed to collect and to convert the sun's energy to 2,450-MHz continuous wave microwaves, which would be beamed to the earth's surface where a rectifying antenna would convert the microwaves to electrical current suitable

for industrial and domestic use. An initial review of more than 1,000 English summaries and 200 original (or translated) papers on the biologic effects of microwave radiation with respect to the potential impact of the SPS on the biologic and ecologic systems indicates that verified experimental data are completely lacking with regard to the question of whether microwave radiation at a relatively high power density (about 23 mW/cm²) near the center of each rectifying antenna will produce a disruption, debilitation, or death of airborne species that may attempt to fly through the beam. With regard to the effect on resident flora and fauna, including man, of relatively low power densities near the periphery of a rectifying antenna and beyond the area of exclusion, it is concluded that threshold of relatively short-term radiation for morbid biologic effects (e.g., cataracts, heart disease, hematological effects, immunologic disturbances, and genetic developmental defects) are well above the maximal power density (1 mW/cm²) that is tentatively projected at and beyond the area of exclusion of the receiving antenna. However, no experimental study has been performed that even remotely approaches the 30 yr or more that the SPS would be operative.

- 5818 HEALTH ASPECTS OF RADIOFREQUENCY AND MICROWAVE RADIATION EXPOSURE: PART I. (Eng.) Stuchly, M. A. (Radiation Protection Bureau, Health and Welfare, Ottawa, Canada). 88 pp.; 1977. [available through Information Directorate, Dept. Natl. Health & Welfare, Brooke Claxton Building, Ottawa, KIA OK9 Canada. Document No. 77-EHD-13]. (115 refs)

Biophysical and engineering considerations relevant to the health aspects of radio frequency and microwave radiation exposure over the frequency range of 10 MHz to 300 GHz are discussed, and the biological effects of microwave radiation are reviewed including satellite communication systems, radar systems, broadcast transmitters, and microwave power devices for heat production are covered. Microwave energy absorption and distribution are discussed in terms of biological medium characteristics, the impinging of plane waves on plane tissue layers, the exposure of spherical tissue to plane waves, prolate spheroidal and ellipsoidal models of man and animals, miscellaneous models and exposure conditions, and microwave dosimetry. Mechanisms of the interaction between induced electromagnetic fields and living matter are discussed both in terms of the macroscopic approach (Maxwell field theory and Debye theory of dielectrics) and in terms of quantum mechanics considerations.

- 5819 DOES A 50-CYCLE ALTERNATING FIELD CAUSE CENTRAL NERVOUS EFFECTS? (Ger.) Fischer, G. (Hygiene-Institut der Universität, Universitätsplatz 4, A-8010 Graz, Austria); Udermann, H.; Knapp, E. *Zentralbl Bakteriol [Orig B]* 166(5): 381-385; 1978. (7 refs)

The effect of exposure to 50-Hz alternating current field (field intensity 5,300 V/m, up to 21 days)

on the norepinephrine level of the brain was studied in 24 female Wistar rats. Twenty-six intact animals were used as controls. Significant increase in the norepinephrine level was seen 15 min after the beginning of the exposure (0.415 $\mu\text{g/g}$ of brain tissue versus 0.358 $\mu\text{g/g}$; $p < 0.05$). Norepinephrine dropped to about the control level after 2 days of irradiation, and it became significantly lower than the control by day 10 of exposure (0.268 $\mu\text{g/g}$; $p < 0.01$). The norepinephrine level showed a rise on day 21 of exposure (0.302 $\mu\text{g/g}$; $p < 0.01$ relative to the control). The findings substantiate the hypothesis that the central nervous system is the site of attack of electrical fields.

5820 HIGH-FREQUENCY PULSED CURRENTS IN TREATMENT OF BEDSORES. (Pol.) Duma-Drzewinska, A. (Klinika i Katedra Rehabilitacji, Warsaw-Konstancin, Poland); Buczynski, A. Z. *Pol Tyg Lek* 33 (22): 893-894; 1978. (6 refs)

The therapeutic effect of high-frequency electromagnetic field on the healing of bedsores was studied in 27 paraplegics (21 men, 6 women, aged 20-63 yr) who suffered traumatic injury of the spinal cord. The duration of the therapy was 10 days to 6 mo. When the bedsore proper was irradiated, the modulating frequency was 600 Hz, and the duration of one session was 20 min. When the adrenal gland and hepatic regions were irradiated, the modulating frequency was 400 Hz, and the length of one session was 15 min. Fifteen patients had deep bedsores: four patients were healed by electromagnetic therapy; six showed considerable improvement; and five medium improvement. The other 12 patients had superficial bedsores: 11 patients were healed; another showed considerable improvement. Seven patients underwent electromagnetic treatment immediately after they developed bedsores; all seven were healed. Six patients were treated up to 3 mo after they developed bedsores; three were healed; one showed considerable improvement, two medium improvement. Nine patients were treated up to 1 yr after they developed bedsores: two were healed; five developed considerable improvement, and two showed medium improvement. Five patients were treated more than 1 yr after the development of bedsores: three were healed, and one each had considerable and medium improvement, respectively. The findings indicate the therapeutic effectiveness of pulsed electromagnetic treatment in patients with bedsores.

5821 TURNOVER OF COPPER, MOLYBDENUM, IRON AND MANGANESE IN RAT TISSUES AS AFFECTED BY 50 HZ ELECTRIC FIELD. (Rus.) Gabovich, R. D. (Dept. General Hygiene, A. A. Bogomolets Kiev Medical Inst., Kiev, USSR); Koziarin, I. P.; Mikhaliuk, I. A.; Fesenko, L. D. *Ukr Biokhim Zh* 50(2): 206-211; 1978. (14 refs)

The effect of long-term exposure to an electric field (50 Hz; field potential 7, 12, and 15 kV/m; exposure time 30 min/day for 4 mo) on the turnover rate and distribution of copper, molybdenum, iron

and manganese was studied in 100 male albino rats. Of these 100 animals, 25 served as unexposed controls. The effect of the exposure increased with increasing field potential. Exposure to 7-15 kV/m caused significant ($p < 0.05$ or $p < 0.01$) reduction in the copper in the liver (586 $\mu\text{g}\%$ versus 721 $\mu\text{g}\%$ in the control) and significant increases in all other organs. The molybdenum level decreased significantly in the liver, spleen, brain, myocardium, skeletal muscles, skin, and blood and increased in the kidneys, bones, and teeth. The iron level decreased significantly in the liver, kidneys, brain, skin, bones, and blood (from 33 mg% in the controls to 24 mg% in the group exposed to 15 kV), increased in the kidneys (from 9.3 mg% in the controls to 12 mg% in the group exposed to 15 kV), and showed no change in the skeletal muscles, myocardium, and spleen. The manganese concentration increased significantly in the liver, spleen, brain, myocardium, skeletal muscles, and skin (from 5.5 $\mu\text{g}\%$ in the controls to 10 $\mu\text{g}\%$ in the group exposed to 15 kV), decreased in the bones (from 140 $\mu\text{g}\%$ in the controls to 82 $\mu\text{g}\%$ in the group exposed to 15 kV), and showed no change in the kidneys, teeth, and blood. The changes are interpreted as an adaptive response of the body to the exposure. The changes in the trace element distribution between the tissues of different organs proved to be a sensitive indicator of electric field effect.

5822 THE DEVELOPMENT OF MICROWAVE HYPERTHERMIA APPLICATORS. (Eng.) Sandhu, T. S. (Dept. Radiation Medicine, Roswell Park Memorial Inst., 666 Elm St., Buffalo, NY 14263); Kowal, H. S.; Johnson, R. J. *Int J Radiat Oncol Biol Phys* 4(5/6): 515-519; 1978. (17 refs)

The design of two types of direct-contact microwave applicators for localized hyperthermia treatment of solid tumors is discussed. A 2,450-MHz applicator was designed either to deliver microwaves alone or in conjunction with ionizing radiation. The applicator could be attached to an X-ray or electron machine head and used as a cone to deliver X-rays or electrons and microwaves simultaneously. A 915-MHz applicator was designed with provision for attaching a plastic bag at the application end through which a dielectric liquid could be circulated to cool the skin surface. Thermocouple measurements of the temperature distribution resulting from the applicators were made on the rear thigh region of pigs. For the 2,450-MHz applicator, the maximum temperature was found on the skin surface, and the temperature dropped by 3.5 C at a tissue depth of 2.83 cm. For the 915-MHz applicator, without dielectric circulating through the bag, the skin temperature was lower than that at a tissue depth of 1 cm. The temperature dropped by 1 C at a depth of 2.83 cm. With the dielectric liquid circulating through the bag, the skin temperature dropped considerably and was the same as that at a depth of 2.83 cm. The temperature peaked at about 1.5 cm where it was 1.0 C higher. By carefully manipulating the temperature of the dielectric liquid, the 915-MHz applicator could be used to heat the tissue to a depth of 3 cm with a maximum

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deviation in temperature along the central axis of ± 0.5 C. The described direct-contact applicators allow the achievement of localized hyperthermia with no background radiation reflected from the skin.

- 5823 EFFECT OF ELECTRIC FIELD OF COMMERCIAL FREQUENCY OF DIFFERENT INTENSITY ON BALANCE AND METABOLISM OF COPPER, MOLYBDENUM AND IRON IN THE ORGANISM OF EXPERIMENTAL ANIMALS. (Ukr.) Koziarin, I. P. (Dept. General Hygiene, Kiev Medical Inst., Kiev, USSR). Mikhailiuk, I. A.; Fesenko, L. D. *Fiziol Zh* (3): 369-373, 1977. (6 refs)

The effects of exposure to an electrical field (50 Hz, intensity 1-15 kV/m, 4-mo exposure, 2 hr/day) on the copper, molybdenum and iron levels in the liver, kidneys, spleen, brain, myocardium, skeletal muscles, skin, bones, and teeth were studied in male albino rats. There were 25 rats in each group (5 groups in all), and unexposed rats served as controls. Exposure to 1 kV/m caused no significant changes in the trace metal levels in the organs, and regardless of the field intensity, there were no changes in the molybdenum level in the kidneys and myocardium nor in the iron levels in the myocardium and skeletal muscles. Exposure to higher doses caused a significant intensity-dependent decrease in the copper level in the liver (from 759.3 $\mu\text{g}\%$ in the controls to 288.7 $\mu\text{g}\%$ in the group exposed to 15 kV); a significant reduction of the copper level in the other organs, a significant reduction of the molybdenum levels in the liver (from 42.7 $\mu\text{g}\%$ in the controls to 23.5 $\mu\text{g}\%$ in the group exposed to 15 kV), spleen, brain, skeletal muscles, skin, bones, and teeth; a significant reduction of the iron levels in the liver, brain, skin, bones, and teeth; and a significant increase in the iron level of the kidneys (from 9.1 mg% in the controls to 10.9 mg% in the group exposed to 15 kV).

- 5824 A TECHNIQUE FOR THE MEASUREMENT OF TISSUE IMPEDANCE FROM 1 TO 100 MHZ USING A VECTOR IMPEDANCE METER. (Eng.) Bottomley, P. A. (Dept. Physics, Univ. Nottingham, University Park, Nottingham NG7 2RD, England). *J Phys E* 11(5): 413-414; 1978. (8 refs)

The use of a commercially available variable-frequency vector impedance meter for measuring the impedance of biologic tissue is reported. Application of the device for this purpose relies on the fact that at radio frequencies the reactive component of the biologic impedance becomes comparable to the resistive component. This enables both the relative permittivity and the resistivity to be calculated from the amplitude and phase of the vector impedance. Complex impedance is measured directly over the frequency range of 0.5-108 MHz by comparing the ratio of voltage and current injected into the circuit under test. Curves for resistivity and relative permittivity as a function of frequency are shown for measurements taken from six freshly excised samples of rat liver tissue. Individual sam-

ples deviate from the curve by up to 5%. This variation can be attributed to a combination of experimental error and the natural heterogeneity of biologic specimens. The tissue results are in good agreement with results measured at 25, 50, and 100 MHz by other investigators. Results with a saline solution also agree with previously published results. Advantages of the above technique are that the specimen cell can be attached directly to the meter probe (minimizing the contribution of lead inductances to the net impedance) and that the measurements can be made easily and quickly.

- 5825 DENTAL IMPLANT FIXATION BY ELECTRICALLY MEDIATED PROCESS I. INTERFACIAL STRENGTH. (Eng.) Young, S. O. (Div. Interdisciplinary Studies, Coll. Engineering, Clemson Univ., Clemson, SC 29631); Park, J. B.; Kenner, G. H.; Moore, R. R.; Myers, B. R.; Sauer, B. W. *Biomater Med Devices Artif Organs* 6(2): 111-126; 1978. (48 refs)

Porous dental implants with solid polymethylmethacrylate cores around which platinum-13% rhodium wire electrodes were wound were implanted in the mesial socket of mandibular fourth premolars bilaterally to determine the effect of electrical stimulation on alveolar bone tissue growth in the dog. The distal root socket was used to receive the positive electrode. The wires were buried subcutaneously on the buccal crest, and power packs (1.4-V mercury battery in series with a 180,000 ohm resistor) were placed over the masseteric fossa subcutaneously. Each animal had an experimental and a control implant. The in vivo current achieved with the power pack-electrode configuration was about 4-6 μA . Mechanical push-out tests for interfacial strength measurements, which were made over implant periods ranging from 13-39 days, revealed that the electrically stimulated side had a much higher interfacial strength than the non-stimulated control side for a given experimental animal. Preliminary results of X-ray and scanning electron microradiographs showed that there was definite bony growth into the pores of the implants. As the amount of bony tissue ingrowth increased, the interfacial shear strength increased accordingly. Thus, the study showed that alveolar bone can be stimulated by the constant current employed.

- 5826 GERMINATION RESPONSE OF SOME WOODY PLANT SEEDS TO ELECTRICAL TREATMENT. (Eng.) Nelson, S. O. (Richard B. Russell Agric. Res. Center, Dep. Agric., College Station, TX 77843); Bovey, R. W.; Stetson, L. E. *Weed Sci* 26(3): 286-291; 1978. (13 refs)

Seed lots of Macartney rose, yaupon, huisache, and honey mesquite were exposed to 10- and 39-MHz electromagnetic fields at various intensities and for various durations in an effort to increase their germination. The seeds were conditioned for at least 2 wk at 24 C and 40% relative humidity. In some experiments, seed samples were conditioned at temperatures ranging from -18 to -43 C for 48 hr prior to irradiation. In most experiments contin-

uous wave (CW) radiation was used, but in some experiments the 39-MHz signal was pulse modulated. Some treatment sequences also involved exposures to high intensity direct current and 60-Hz alternating current electric fields. The radio frequency radiation treatments did not increase the germination of Macartney rose, and no germination was observed in yaupon, regardless of the treatment employed. Some significant increase in germination was obtained by radio frequency irradiation of huisache seed, but the results were inconsistent between seed lots. Honey mesquite seed responded to radio frequency treatment with increased germination, but hard-seed percentages were low in the seed lots used, probably due to mechanical scarification during harvesting of the seed. Since inhibition of seed germination for these species, especially honey mesquite and huisache, is due partially to impermeable seed coats, further studies are needed to determine why different species respond differently to radio frequency treatments with respect to changes in seed coat permeability. Pulse modulation of the radio frequency fields, which permitted the use of higher field intensities, did not produce significant differences in germination compared with CW treatments producing similar final temperatures in the seed.

5827 RF APPLICATORS FIND JOBS ON FARMS, IN FACTORIES. (Eng.) Gupta, K. C. (Indian Inst. Technology, Dept. Electrical Engineering, IIT Post Office, Kanpur-208 016, India); Bahl, I. J. *Microwaves* 17(6): 52-53, 56, 58-60, 62-64; 1978. (22 refs)

Various designs of radio frequency (RF) applicators for industrial and agricultural RF heating and drying systems are described. Three basic types of applicators have been conceived to suit a broad variety of applications. Multimode cavity-type designs are widely used for microwave ovens and can be modified for continuous processing of materials in industry. Waveguide applicators, made of rectangular, circular, elliptical, or modified transmission lines, find many applications, including the heating of liquids. Planar applicators are suitable for sheet material and conveyor belt transport systems. The most significant considerations governing the design of an applicator for a particular system are efficient RF-to-thermal energy conversion, an even distribution of dissipated power in the material, and efficient moisture or vapor removal. When low-loss materials are heated in waveguide applicators, a substantial portion of the RF power does not couple to the material, even with longitudinal material flow. Although power absorption can be improved by making the applicator increasingly long, this is often impractical. An alternative is that uncoupled power can be recirculated by using a traveling-wave (or ring) resonator. A good example of a recirculating system has been developed to increase the tensile strength of polyester rope. In this system, a traveling-wave resonator is coupled to an input transmission line through a directional coupler. Incident power from a signal source is partially

coupled into the ring resonator where it travels around the loop in a clockwise direction; energy accumulates due to recirculation.

5828 TRENDS IN NONIONIZING ELECTROMAGNETIC RADIATION BIOEFFECTS RESEARCH AND RELATED OCCUPATIONAL HEALTH ASPECTS. (Eng.) Dodge, C. H. (Science Policy Res. Div., Congressional Res. Service, The Library Congress, Washington, DC); Glaser, Z. R. *J Microwave Power* 12(4): 319-334; 1977. (25 refs)

A review of the international literature covering the period 1970-1977 on the biological effects of nonionizing electromagnetic radiation is presented. The international trend in setting exposure standards is becoming more complicated. In the USSR and East European countries, standards for exposure are becoming more frequency-dependent. There seems to be a trend toward more conservatism in the West in view of a recent proposal to change Canadian exposure standards. At the same time, the United States standard of 10 mW/cm² appears to have worked quite well in view of the lack of clinical data to the contrary. Western researchers are now more often reporting low-level microwave effects in animals similar to the effects reported by Russian and some East European researchers. American research has contributed such findings as changes in the blood-brain-barrier, changes in neuronal ion binding, and microwave hearing in response to microwave power densities well below 10 mW/cm². There continues to be no unanimous agreement as to the mechanisms of central nervous system responses to low-level microwave fields. Further complications are findings from studies of the effects of very low frequency electromagnetic fields or direct current electric and magnetic fields. It has been well established that certain birds, fish, and invertebrates can exhibit sensitivity to these weak fields as well as to the absence of such fields. There is some recent evidence to indicate that blood changes are to be expected in some animals in response to repeated exposure to relatively low-level microwaves. However, there seems to be no compelling evidence to indicate that shifts in blood chemistry are to be expected regularly in humans chronically exposed to very low-level (less than 1 mW/cm²) microwaves. The literature on radio frequency/microwave bioeffects and potential health hazards has become voluminous; presently approximately 5,000 citations have been identified.

5829 POTENTIALLY HAZARDOUS MICROWAVE RADIATION SOURCES—A REVIEW. (Eng.) Stuchly, M. A. (Non-Ionizing Radiation Section, Radiation Protection Bureau, Health and Welfare Canada). *J Microwave Power* 12(4): 369-381; 1977. (38 refs)

Various microwave radiation sources are reviewed in terms of the basic characteristics so that a discussion of microwave radiation hazards can be presented. Sources covered include satellite communication systems, radar systems, communications systems on earth, and microwave power devices for heat

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production. Satellite communication systems are the most powerful continuous wave sources of environmental microwave radiation. Although these systems produce significant radiation levels over extensive distances, the potential exposure hazard for people is relatively limited because the systems are located in sparsely populated areas and are operated by trained personnel in accordance with procedures established to minimize any dangerous irradiation possibility; the antenna beams are well collimated; and the off-axis radiation levels decrease rapidly to 0.01 of the value on the axis for angles greater than 5 degrees from the axis. Experimental results for a few typical radars with their antennas stationary show that the power density of these sources can exceed 10 mW/cm² at distances of 2-4 m from the radome (antenna cover). However, when antenna rotation was taken into account, only one of the sources was found capable of producing radiation levels exceeding 10 mW/cm² at any distance. The most widespread and publicly accessible sources of microwave radiation, such as, microwave ovens, do not appear to present any potential radiation hazard under normal operating conditions as a result of improved design and governmental efforts. There are two groups of devices that are difficult to develop any general model and method of hazard assessment. One group includes radio frequency power sources, and the other group comprises a variety of medium to low power transmitters.

5830 ONCOLYSIS DUE TO MICROWAVE HYPERTHERMIA AND CLOSTRIDIUM ONCOLYTICUM (M55). (Eng.) Gericke, D. (Hoechst AG, Frankfurt/Main, W. Germany); Dietzel, F. In: *Advances in Tumour Prevention, Detection and Characterisation: Vol. 4 Characterisation and Treatment of Human Tumours*. Maltoni, C., ed. (Amsterdam: Excerpta Medica): pp. 126-127; 1978. (5 refs)

The effect of microwave hyperthermia on the oncolysis of various solid tumors in mice by *Clostridium oncolyticum* was investigated. Tumor-bearing mice were treated with 461-MHz microwaves so that after 4 min the temperature in the middle of the tumors was 43 ± 0.5 C. After 12 hr, 10⁸ *Clostridia* spores in physiologic saline were administered intravenously. Some mice received only *Clostridia* spores. In mice bearing solid Ehrlich carcinoma, the extent of oncolysis was increased from $27.65 \pm 1.55\%$ in mice treated with *Clostridia* spores alone to $61.31 \pm 2.93\%$ in mice treated with microwave hyperthermia before *Clostridium* injection. Microwave hyperthermia also decreased the tumor weight on day 5 from 2.36 ± 0.07 g for mice treated with *Clostridia* spores alone to 1.27 ± 0.10 g for mice receiving the combined treatment. Similar results were obtained in mice bearing Harding-Passey melanoma where the increase of lysis in animals receiving the combined treatment was about 70%. Mice bearing a 3-methylcholanthrene-induced fibrosarcoma were resistant to *Clostridium* treatment but responded to combined treatment with a tumor oncolysis of $22.40 \pm 3.17\%$. These results indicate that oncolysis with *Clostridium oncolyticum* is markedly increased by microwave hyperthermia and that the effect is produced with histologically different tumor lines.

5831 SOME EFFECTS OF LOW LEVEL MAGNETIC FIELDS ON GROWTH, DEVELOPMENT, AND BIOCHEMISTRY OF THE CHICK EMBRYO, *GALLUS DOMESTICUS*. (Eng.) Boan, R. T. (Ph.D. dissertation, Univ. South Carolina, 1978); 158 pp. [available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 78-7892]. (116 refs)

The effects of low level magnetic fields on the growth, development, and biochemistry of the chick embryo *Gallus domesticus* were investigated. Embryos incubated in 60-Hz magnetic fields of 5.5 and 11 Oe showed an increased mortality, an increased developmental rate manifested in increased weight gain as well as by a speeding up of the general morphologic development of the embryos, a significantly decreased glutamate oxaloacetate transaminase activity, and a significantly increased lactate dehydrogenase activity, especially in young birds. Alkaline phosphatase activity was also increased, while leucine aminopeptidase was essentially unchanged. When 60-Hz magnetic fields of 11 and 22 Oe were applied to embryo extracts, glutamate oxaloacetate transaminase was found to increase while lactate dehydrogenase decreased. The magnitude of the effect was field strength dependent. When a permanent magnetic field was applied to the extract, the lactate dehydrogenase activity increased significantly at 35, 53, 84, 135, 175, 235, and 445 Oe. The change at 65, 100, and 305 Oe was consistently variable over several trials.

5832 HAZARDS IN THE USE OF EXTERNAL PACEMAKERS (LETTER TO THE EDITOR). (Eng.) Kostinsky, H. (Emergency Care Res. Inst., 5200 Butler Pike, Plymouth Meeting, PA 19462). *J Electrocardiol* 11(3): 306; 1978.

Hazards associated with the use of external pacemakers are reported. The Cordis Chronitor III and the Medtronic Models 5840, 5880, and 5880A external pacemakers were found to be affected by low level 60-Hz voltages applied between the case and catheter terminals. The Cordis units reverted to an asynchronous pacing mode, and the Medtronic units were inhibited. The problem seems to occur primarily when equipment used on or around the patient is not adequately grounded. This may relate to whether the interference is transmitted to the pacemaker by a person in contact with (or capacitively coupled to) a source of interference or whether that person is acting as an antenna in the radiated field. Preventive measures, such as those described in an Emergency Care Research Institute report, are necessary to avoid this problem.

5833 THE ZAPPING OF AMERICA: MICROWAVES, THEIR DEADLY RISK, AND THE COVERUP (BOOK REVIEW). (Eng.) Sharwell, W. G. (No affiliation given). *Bell Telephone* 57(3): 38; 1978. (1 ref)

A review of a book entitled *The Zapping of America: Microwaves, Their Deadly Risk and the Coverup* by Paul Brodeur is presented. The author's thesis is that microwaves, long considered benign, are in-

creasingly beamed indiscriminately into the environment from television, radio, and radar transmitters, telephone relay systems, orbiting satellites, high-voltage power lines, microwave ovens, diathermy machines, burglar alarms, and citizen band radios. The book also charges increasing emphasis on microwave weapons devices under development by the Defense Department. The author claims that there is a tight conspiracy on the part of the industrial-military establishment to be disinterested in further research or to disparage the significance of further findings. "The book is a self-styled exposé, and it is characteristic of such efforts to overstate and overemphasize evidence favoring conclusions the author wants to reach." It is noted that Bell System and its role in microwave communication development is only slightly mentioned in the book.

5834 **BIOLOGICAL EFFECTS OF LOW-FREQUENCY FIELDS**
(BOOK REVIEW). (Eng.) Cleary, S. F.
(Dept. Biophysics, Virginia Commonwealth Univ., Richmond, VA 23298). *BioScience* 28(6): 404; 1978.
(1 ref)

Biological Effects of Low-Frequency Fields, a book covering the world literature on the biologic effects of electric and magnetic fields of extremely low frequency, is reviewed. The work represents an attempt to summarize the diverse studies that have been conducted on the physiologic and psychologic effects of such fields on humans, experimental animals, and in vitro cellular and molecular systems. Studies of effects of electric and magnetic fields from direct current to frequencies of 50-60 Hz and intensities varying from low level natural atmospheric fields to electric fields of several thousand volts per meter and magnetic fields of thousands of gauss are presented, with emphasis on exposure effects at the levels encountered in the vicinity of high-voltage transmission lines and home appliances. Much of the reviewed data are confusing and contradictory, with apparently similar studies yielding opposite results. This is attributed to the fact that publications of varied quality from many countries and from many disciplines are included. A summary chapter is provided along with a tabular summary of the principal investigations included in the text.

5835 **ELECTRIC STIMULATION OF BONE GROWTH AND REPAIR.** (Eng.) Burny, F.; Herbst, E.; Hinsenkamp, M., eds. (Berlin: Springer-Verlag): 93 pp.; 1978. (145 refs)

A book dealing with topics related to the electric stimulation of bone growth and repair is presented. The chapter titles (and their contributors) are as follows: Electric Stimulation of Bone Growth and Repair: a Review of Different Stimulation Methods (Ewa Herbst); Four-Point Measurement of the Impedance of Bone in Vivo (W. Sansen, F. De Dijcker, S. Stan, and J. C. Mulier); In Vitro Study of Electric Impedance of Bone (B. Durand, P. Christel, and

J. Assailly); Achievements and Discrepancies in Understanding Bone Electric Phenomena (T. Cieszynski); Physicochemical Effect of an Electric Potential on Bone Growth (R. Wollast, M. Hinsenkamp, and F. Burny); Influence of Magnetic Fields on Growth and Regeneration in Organ Culture (H. Gerber, J. Cordey, and S. M. Perren); Effect of the Magnetic Field Component of the Kraus-Lechner Method on the Healing of Experimental Nonunions in Dogs (H. Blumlein, J. McDaniel, and S. M. Perren); Plated Cortices and Electric Potentials (M. Weigert); Effect of Direct Current on the Healing of Fractures (S. Stan, J. C. Mulier, W. Sansen, and P. De Waele); Electric Stimulation of Osteogenesis: I. Experimental Study of Bone Healing in the Rabbit Tibia. II. Clinical Study in Two Cases of Congenital Pseudarthrosis of the Tibia (G. von Satzger and Ewa Herbst); Hypothesis of Bone Remodelling and Fracture Healing by Electrostimulation (L. W. M. Janssen, J. M. M. Roelofs, W. J. Visser, and P. Wittebol); Corrosion of Implants During Electric Stimulation of Fracture Healing (M. Hinsenkamp, F. Burny, J. Jedwab, and R. Bourgois); and Necessity of Electric Standardization of Surgical Implants (T. Cieszynski).

5836 **INCREASE IN DOPAMINE IN CEREBRAL CORTEX AND OTHER REGIONS OF RAT BRAIN AFTER MICROWAVE FIXATION: POSSIBLE DIFFUSION ARTIFACT.** (Eng.) Meyerhoff, J. L. (Neuroendocrinology and Neurochemistry Branch, Dept. Medical Neurosciences, Div. Neuropsychiatry, Walter Reed Army Inst. Res., Walter Reed Army Medical Center, Washington, DC 20012); Kant, G. J.; Lenox, R. H. *Brain Res* 152(1): 161-169; 1978. (25 refs)

Dopamine (DA) and norepinephrine (NE) levels in the rat brain were studied after fixation by microwave irradiation and conventional techniques. The animals were exposed for 5.5 sec to $2,440 \pm 20$ MHz radiation. During every exposure, the number of actual pulses (120/sec) as well as both forward and reflected power were monitored. In a first experiment in which rats were sacrificed alternately by microwave irradiation at 2,450 MHz, decapitation into liquid nitrogen, or decapitation at 20 C, whole brain levels of NE and DA were similar after all three methods of sacrifice. However, in a second experiment where six rats were sacrificed by microwave irradiation at 2,450 MHz and six by decapitation, the levels of DA ($\mu\text{g/g}$ wet weight) in the frontal and parietal cortex of microwave-irradiated rats were 0.83 ± 18 and 0.85 ± 0.09 , respectively, compared with 0.19 ± 0.06 and 0.11 ± 0.03 , respectively, in decapitated animals. Significant increases in DA were also seen in the hypothalamus, amygdala, septal region, and the remainder of the cortex in irradiated animals. The NE levels in different brain regions were similar with either method of sacrifice. In a subsequent experiment, microwave irradiation at 985 MHz produced similar increases in DA levels in those regions where DA levels were elevated after 2,450-MHz irradiation. Additional experiments ruled out the possibility that DA elevations might be due to immobilization stress incidental to sacrifice by microwave irradiation or that the dis-

crepancy in DA levels between microwave-irradiated rats and rats decapitated at room temperature was due to rapid degradation in certain regions after sacrifice by decapitation. During dissections following microwave irradiation, marked softening of large myelinated structures, such as, the corpus callosum and corona radiata was observed. The brain regions where elevated DA levels were found after irradiation shared the property of proximity to the corpus striatum, nucleus accumbens, or olfactory tubercle, all of which have very high concentrations of DA. It is suggested that diffusion from regions high in DA to adjacent regions low in DA might have caused the observed DA elevations after microwave irradiation with relatively little change in the region of higher concentration.

- 5837 EFFECT OF HYPERTHERMIA ON THE IMMUNE RESPONSE OF NORMAL RABBITS. (Eng.) Shah, S. A. (Cancer Res. Unit, Univ. Dept. Clinical Biochemistry, Royal Victoria Infirmary, Newcastle upon Tyne, England); Dickson, J. A. *Cancer Res* 38(10): 3518-3522; 1978. (35 refs)

Normal male New Zealand white rabbits were subjected to either local (thigh muscle) or total body hyperthermia to investigate the effects of these treatments on cellular and humoral immune responses. The animals were subjected to either local watercuff hyperthermia (42 C for 1 hr on 3 consecutive days), local radio frequency (13.56 MHz) heating (47-50 C for 30 min), or total body hyperthermia in a humidified incubator (42 C for 1 hr on 3 consecutive days). No alteration occurred in the cellular response of heated rabbits to dinitrochlorobenzene challenge over a 3-mo period. The humoral immune response to bovine serum albumin was significantly depressed in treated animals for 3 wk starting from wk 2 following hyperthermia, and the depression was independent of the degree and method of heating. The results suggest that bone-marrow-derived lymphocytes are more susceptible to hyperthermic damage than is the thymus-derived lymphocyte population.

- 5838 FINGER TIP PAIN RELIEF. (Eng.) Yanchinski, S. (No affiliation given). *New Scientist* 79(1115): 395-397; 1978. (0 refs)

The use of transcutaneous nerve stimulators (TNS) for the relief of pain is reported. The devices are simply pulse generators, which when attached to the surface of the skin, produce currents that relieve pain by interfering with the passage of pain signals along nerves to the brain. Independently adjustable currents, pulse widths, and repetition rates allow patients to modify their own treatment. Although the small number of clinical trials with TNS units are not well documented, experience so far indicates that chronic longstanding pain, such as, causalgias (nervous disturbances caused by peripheral nerve lesions), phantom limb pain, and back pain are particularly sensitive to TNS. A survey

of five of the major pain treatment centers in the United States that have treated over 3,000 patients with TNS revealed that 25-30% of patients previously incapacitated by chronic pain were more or less completely relieved. A technique of moving the electrodes nearer the nerves by surgical implantation inside the body is offering new hope for painful conditions that do not respond to conventional TNS. In the United States some success with modified TNS has been claimed for cerebral palsy, epilepsy, and the rehabilitation of stroke victims. In Britain, direct stimulation of the spinal cord of patients with multiple sclerosis has produced worthwhile benefit in about 50% of these patients. Swedish workers have tried to improve the results of conventional high frequency TNS by replacing Chinese acupuncture needles with standard TNS surface electrodes. Of 50 patients with unspecified chronic pain conditions, only 20 responded to conventional TNS treatment, but 10 others benefited from acupuncture-like TNS. Drawbacks of the technique include the unreliability of results and complications, with contact dermatitis being the most likely problem.

- 5839 TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION FOR THE RELIEF OF POSTOPERATIVE PAIN. (Eng.) Rosenberg, M. (Dept. Anesthesiology, Tufts-New England Medical Center Hosp., Boston, MA); Curtis, L.; Bourke, D. L. *Pain* 5(2): 129-133; 1978. (14 refs)

Randomly selected patients scheduled for cholecystectomy were randomly assigned to either a control group (six patients) or a test group (six patients) to evaluate the effect of transcutaneous electrical nerve stimulation (TENS) on postoperative pain. The TENS device used has an output of $0-80 \pm 10$ mA into a 500 ohm load (adjustable), a frequency of 50-100 pulses/sec (adjustable), and a pulse width of 20-100 μ sec which automatically varied with amplitude. The patients in the test group had complete control over the use of the device as far as dosimetry, duration of use, and electrode placement. Sterile skin electrodes (45 mm by 45 mm, carbonized medical-grade silicone rubber) were placed on the upper and lower limits of the surgical incision. The control group used more than three times the total amount of narcotics administered for pain relief than did the test group, but the ranges were wide in both groups. The test group demonstrated a significant decrease in the amount of narcotics administered in the first and second postoperative days and over the entire test period. Despite this difference in the two groups, respiratory parameters were nearly identical in the two groups, though decreased as expected from the upper abdominal incision. Chest X-rays revealed one case of atelectasis in each group. The presence of ileus in both groups lasted into the evening of the second postoperative day. Scored nursing evaluations noted an increase in subjective respiratory functions in the test group. All patients using TENS felt that they derived some pain relief from the device, and several claimed that the tingling sensation lulled them to sleep.

- 5840 CHANGES IN SOMATIC SENSITIVITY DURING
TRANSCUTANEOUS ELECTRICAL ANALGESIA.
(Eng.) Callaghan, M. (Pain Unit, Veterans Admin.
Hosp., San Diego, CA 92161); Sternbach, R. A.;
Nyquist, J. K.; Timmermans, G. *Pain* 5(2): 115-127;
1978. (14 refs)

Nine patients with chronic pain in one limb who experienced pain reduction with transcutaneous nerve stimulation (TNS) were examined for sensory perception in that limb before and during TNS using seven different tests for somatosensation. Contralateral limbs and seven normal subjects served as controls. The results did not show any highly significant effects of TNS on somatosensation; however, some interesting interactions were observed. In a test for two-point discrimination, TNS in patients improved discrimination on the painful limb and impaired discrimination on the non-painful limb. There was no such effect of TNS in control subjects. In a test for kinesthetic sensation, another interaction involving TNS was observed. When patients were asked to discriminate between digit deviations of 25 degrees above level position and 0 degrees above level, TNS resulted in an increased tendency towards responding (i.e., more errors) when the non-painful side was tested. However, when the painful side was tested, an opposite effect was obtained. Controls showed virtually no changes in response bias with electrical stimulation. In tests of sensitivity to electric shock, there was an interaction effect involving TNS, shock intensity, and side tested. When subjects were asked to discriminate between higher intensity electric shocks, TNS produced a reduction in response tendency (i.e., fewer errors) when the painful limb was examined. An opposite effect was observed on the non-painful limb. In tests of sensitivity of patients to a heat dolorimeter, electrical stimulation on the affected pain side resulted in fewer errors, while stimulation on the unaffected side resulted in more errors. For the above tests, TNS improved sensitivity on the painful limb. However, on the normal non-painful limb, it appears that TNS may have impaired sensitivity. It is concluded that large fiber stimulation by TNS accounts for the impaired perception when TNS is applied to normal limbs and that the application of TNS to the painful limb decreases some of the small fiber activity more than it stimulates large fibers, accounting for both the reduction in clinical pain and the improvement in sensory perception.

- 5841 MICROWAVE AUDITORY EFFECTS AND APPLICATIONS. (Eng.) Lin, J. C. (Springfield: Charles C. Thomas): 227 pp.; 1978. (231 refs)

Selected experimental and theoretical topics dealing with microwave-induced hearing are presented in this book. In the first chapter, some relevant information about microwave radiation and biological effects of microwaves is provided. A brief description of the auditory system is outlined in Chapter 2. Major experimental evidence of pulse-modulated microwave-induced auditory effects are

presented in Chapters 3 and 4. The speculations and hypotheses regarding mechanisms are treated in the next chapter. Chapter 6 examines in detail the implications of induced thermoelastic theory using a spherical head-model. In the last chapter, the use of pulse-modulated microwave radiation as a tool in clinical medicine and laboratory investigations is given special attention. Statements regarding microwave exposure parameters are left in the terms used in the originating report. The International System of units is used exclusively; conversion factors for selected quantities are given in an appendix. A second appendix containing publications of pertinent conferences and symposia is also included. The book is indexed both by author and subject.

- 5842 THE GEOMAGNETIC FIELD AND LIFE: GEOMAGNETOBIOLOGY. (Eng.) Dubrov, A. P. (New York: Plenum Press): 332 pp.; 1978. (1228 refs)

A comprehensive review of studies dealing with the interactions between the geomagnetic field and life on earth is presented. The book is divided into five chapters, with the first giving a general account of the geomagnetic field. The second chapter discusses the role of the geomagnetic field in the vital activity of organisms on earth and includes experiments on the biological effects of artificial weak magnetic fields on man. The third deals with questions of general geomagnetobiology. Specific aspects of geomagnetobiology are covered in the fourth chapter. The last chapter discusses possible mechanisms of biological effects of the geomagnetic field in terms of the role of water molecules, biological membranes, and biomagnetic fields as well as magnetoecology. The book specifically covers the effects of the geomagnetic field on healthy humans in terms of the general state of the organism, higher nervous activity and the state of the vegetative nervous system, skin electric potentials, blood, growth and sexual development, and reproductive aspects of the female organism. The effects of the geomagnetic field on the sick human organism are discussed in terms of cardiovascular pathology, psychic disorders, eye diseases, and urolithiasis. The geomagnetic field is also discussed in relation to occupational activity. The last topic under specific aspects of geomagnetobiology deals with the biological effects of the anomalous geomagnetic field.

Meeting Abstracts

- 5843 BIOLOGICAL EFFECTS OF 60-Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Phillips, R. D. (Biology Dept., Battelle, Pacific

CURRENT LITERATURE

Northwest Labs., Richland, WA 99352). *Radiat Res* 74(3): 491; 1978. (0 refs)

A broad and comprehensive study is in progress to screen for effects on rodents of acute and chronic exposure to 60-Hz electric fields. Systems have been built for the simultaneous exposure of 228 rats and 576 mice to well-defined, uniform 60-Hz electric fields free from secondary phenomena such as corona, ozone, shocks, and hum. Fourteen major biologic areas are under investigation, ranging from membrane physiology to animal behavior. To date over 400 parameters in several thousand rats and mice exposed to 60-Hz electric fields at 100 kV/m for up to 60 days have been examined, and no adverse biologic effects have been observed. Longer term exposures are now in progress. In another project, miniature swine will be chronically exposed over several generations to determine clinically observable changes or changes in reproduction, growth, and development. To date, most of the effort on this project has been in the design and construction of an exposure system capable of simultaneously exposing 40 swine.

5844 MICROWAVE ENERGY ABSORPTION AND DISTRIBUTION IN BIOLOGICAL SYSTEMS (MEETING ABSTRACT). (Eng.) Guy, A. W. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, RJ-30 CC 814, Univ. Hospital, Univ. Washington Sch. Medicine, Seattle, WA 98105). *Radiat Res* 74(3): 491; 1978. (0 refs)

To interpret the effects observed in biologic systems exposed to non-ionizing electromagnetic fields a complete quantitative description of the fields and the rate of absorbed energy within the tissues of the subject is required. This absorption can be characterized in the form of a specific absorption rate (SAR), which is a complex function of the source configuration, shape, and size of the exposed subject, the frequency, and the environment of the subject. Depending on exposure conditions, significant levels of SAR may be limited close to the surface of the subject or may extend deep into the interior of the tissues. The SAR distributions may be theoretically determined through appropriate mathematic models of the exposed systems, or they may be experimentally quantified by means of thermocouples, thermistors, special fiber optic sensors, and thermography. Thermographic determination of SAR patterns in exposed biologic systems is facilitated by the use of phantom models fabricated from synthetic biologic tissues.

5845 INTERACTION OF BRAIN TISSUE WITH LOW LEVEL ELECTROMAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Adey, W. R. (Veterans Administration Hosp., Loma Linda, CA 92357). *Radiat Res* 74(3):492; 1978. (0 refs)

Accumulated evidence indicates that sensitivity of brain tissue to certain weak oscillating electromagnetic fields may involve a different class of

non-equilibrium processes, based on long-range atomic interactions and quantum amplification processes, occurring in the absence of significant tissue heating. In position of environmental extremely low frequency (ELF) and very-high frequency/ultra-high frequency (VHF/UHF) fields amplitude modulated at ELF cause sharply modified efflux of calcium ions from brain tissue, a phenomenon closely linked to release of synaptic transmitter amino acids gamma-aminobutyric acid and glutamic acid. ELF fields decrease calcium efflux by about 15% only in narrow amplitude and frequency "windows," between 6 and 20 Hz and between 10 and 100 V/m (approximate tissue gradients, 10^{-7} V/cm). VHF (147 MHz) and UHF (450 MHz) fields increase calcium efflux by about 15% when amplitude modulated between 6 and 20 Hz but only for incident fields in the vicinity of 1.0 mW/cm². Measured tissue gradients are around 50 mV/cm, corresponding to electroencephalographic gradients weaker by 10^4 than in synaptic excitation. They suggest transductive coupling based on coherent charge states between anionic fixed charge sites on membrane surface glycoproteins, with long-range cooperative interactions triggered by weak extracellular electric fields. There is a possibility of proton "tunneling" at boundaries between coherent and non-coherent charge zones. Thus, some forms of cell-to-cell communication in brain tissue appear to involve energy exchanges far below those necessary for impulse propagation, and to occur through slow waves generated in spreading dendrites of cerebral neurons and passively spreading in fluid around brain cells.

5846 PHYSIOLOGICAL AND BEHAVIORAL RESPONSE TO MICROWAVE RADIATION IN MAMMALS (MEETING ABSTRACT). (Eng.) Cleary, S. F. (Virginia Commonwealth Univ., Richmond, VA 23298). *Radiat Res* 74(3): 492; 1978. (0 refs)

Recent studies have revealed that exposure of various mammalian species to microwave radiation at intensities of 10 mW/cm² or less results in physiologic and behavioral responses. Acute or short-term exposures at these intensities prominently involve reversible alterations in the reticuloendothelial and neuroendocrine systems and specific types of behavioral responses. Neither the time-intensity thresholds, the mechanisms, or the long-term consequences of such exposures have been determined. The results of selected physiologic and behavioral responses will be reviewed to define the nature of the potential health hazards associated with microwave exposure and to suggest possible interaction mechanisms. Limitations on the currently available biologic response data for the assessment of microwave effects will also be discussed.

5847 MICROWAVE ENERGY INDUCED LOCALIZED HYPERTHERMIA AND RADIOTHERAPY OF MALIGNANT TUMORS (MEETING ABSTRACT). (Eng.) Raymond, U. (Duke Univ. Medical Center, Duke Univ., Durham,

NC 27710); Noell, K. T.; Miller, L. S.; Woodward, K. T.; Worde, B. T.; Fishburn, R. I.; Joines, W. I. *Radiat Res* 74(3): 528; 1978. (0 refs)

To evaluate the response of tumors and surrounding normal skin to repeated local hyperthermia by microwave energy deposition into tissue combined with ionizing radiation, investigations were begun in 1976 on patients with cutaneous and subcutaneous metastatic tumors not amenable to conventional therapeutic modalities. The radiation dose fraction size was 200 to 700 rad 2-5 times/wk, total radiation dose of 2,000 to 7,000 rad in 2-4 wk. Microwave hyperthermia (MH) was given for 45 min per session at 41 to 43.5 C, 2-3 times/wk (maximum 14 sessions in 5 wk). No significant normal tissue injury was observed in over 150 sessions with MH alone or in combination with radiation. Photon irradiation followed by MH yielded complete tumor regression within 4 to 5 wks from initial treatment. The photon radiation dose alone was considered insufficient for such tumor control. Our clinical impression is that MH can be used without undue detrimental effect on normal tissues surrounding tumor. We frequently observed a marked differential heat induction in tumor while the temperature of normal tissue in the treatment field was considerably less.

5848 CHANGES IN TUMOR OXYGENATION INDUCED BY MICROWAVE HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Bicher, H. I. (Roswell Park Memorial Inst., 666 Elm St., Buffalo, NY 14263); Hetzel, F. W.; D'Agostino, L.; Johnson, R. J.; O'Hara, M. *Radiat Res* 74(3): 530; 1978. (0 refs)

Tissue oxygen levels (TpO_2) were determined on subcutaneous tumors in 15 patients and in implanted leg tumors in 24 mice, using a 100 μ tip floating oxygen microelectrode. Hyperthermia was induced with microwave irradiation at the frequency of 2,450 MHz. Tumor temperature was maintained below 40 C for this period for 2 hr. An increase in TpO_2 paralleled the rise in tumor temperature and was sustained throughout the test period. The elevation in TpO_2 induced by O_2 breathing was also potentiated by the hyperthermia. In a separate group of mice, the temperature was elevated to 46 C in tissue. In this group of animals, TpO_2 decreased. These findings suggest an increased tumor blood flow dependent on temperature changes up to 40 C. The influence of microwave-induced tumor oxygenation on the TCD_{50} and regrowth times of mouse leg tumors treated with X-irradiation was tested on four groups of 120 mice at ten different dose levels. One control group received X-irradiation alone. The second was treated with X-irradiation and hyperthermia at 41 C, the third, X-irradiation and hyperthermia and O_2 breathing, and the fourth, X-irradiation and O_2 breathing alone. Preliminary results confirm the possible synergistic effect on ionizing radiation of hyperthermia induced tumor oxygenation.

5849 "NON-THERMAL" EFFECTS OF MICROWAVE HEATING ON THE CELL PERIPHERY AS REVEALED BY THE BINDING OF COLLOIDAL IRON HYDROXIDE (MEETING ABSTRACT). (Eng.) Subjeck, J. R. (Dept. Radiation Medicine, Roswell Park Memorial Inst., Buffalo, NY 14263); Hetzel, F.; Sandhu, T. S.; Johnson, R. J.; Kowal, H. *Radiat Res* 74(3): 584; 1978. (0 refs)

Colloidal iron hydroxide was used to examine the cellular effects of microwave radiation in the absence of a measurable temperature change. V79 Chinese hamster cells cultured in vitro were placed in a temperature controlled 37 or 40 C water bath. Different samples were then exposed to 915 MHz microwaves at power levels of 20, 40, or 70 W for 20 min. Samples were agitated at 60-sec intervals. The samples were fixed in a dilute, isotonic glutaraldehyde solution and then reacted with the colloidal iron hydroxide probe. The average number of colloidal iron particles per unit area of cell surface was then determined for each sample from electron micrographs. A simultaneous single cell survival assay was made at each power level. A reduction in colloidal iron affinity occurred following the 70 W irradiation as compared with the control (0 W). This change was found to be statistically significant at 37 C ($P < 0.0001$) and 40 C ($P = 0.0034$).

5850 A NEW MICROWAVE HYPERTHERMIA APPLICATOR (MEETING ABSTRACT). (Eng.) Sandhu, T. S. (Dept. Radiation Medicine, Roswell Park Memorial Inst., Buffalo, NY 14263); Johnson, R. J.; Kowal, H. S. *Radiat Res* 74(3): 585; 1978. (0 refs)

A modified version of the R.P.M.I. hyperthermia applicator for inducing localized hyperthermia to treat superficial tumors in conjunction with ionizing radiation has been developed. In the previous design, the applicator was essentially a dielectric loaded waveguide, short circuited on one end. The waveguide was excited in the TE_{10} mode using the central conductor of the coaxial cable from the generator. The outer conductor was terminated on the side wall of the waveguide. The design produced an asymmetric heating pattern. This drawback was overcome in the new design by exciting the waveguide in the TE_{10} and TE_{01} mode, simultaneously. The diameter and the lengths of the excitation probes were adjusted to obtain maximum energy transfer from the cable to the waveguide. The power output pattern across the application end of the waveguide and the heating patterns produced in tissue equivalent phantom materials and in vivo are presented.

5851 THE INCREASED PASSIVE EFFLUX OF SODIUM-22 AND RUBIDIUM-86 IN THE RED CELL, BY MICROWAVE RADIATION AT CRITICAL TEMPERATURES (MEETING ABSTRACT). (Eng.) Olcerst, R. B. (New York Univ. Medical Cent., Inst. Environmental Medicine, Tuxedo, NY); Rabinowitz, J. R.; Belman, S. *Radiat Res* 74(3): 585; 1978. (0 refs)

CURRENT LITERATURE

The passive efflux of sodium-22 and rubidium-86 from the red cells of New Zealand white rabbits was measured in vitro after 1 hr irradiation with 2.45 GHz microwaves in an exposure system that controlled the temperature and the power absorbed in the sample. Water bath control effluxes were conducted simultaneously at temperatures ranging from 2.5 to 37 C. Arrhenius plots of these control experiments revealed that both the sodium and rubidium efflux have four separate linear regions with transitions at 10 to 13, 22.5, and 36 C. The efflux with microwaves was identical to control except at these critical temperatures. Microwave radiation induced an efflux of both cations that was greater than the controls in these regions. This response was examined at the 22.5 C transition at three levels of absorbed power (145, 290, 580 mW). At all three levels the cation efflux was statistically greater than that from a strictly thermal response. Furthermore, the response did not increase monotonically as a function of the absorbed power. Similar increased cation efflux was also seen, post irradiation, near the upper and lower transitions. Mechanistic interpretations of these observations are discussed.

5852 MUTAGENESIS STUDIES WITH LARGE DC ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hungate, F. P. (Battelle Northwest, Richland, WA 99352); Richardson, R. L. *Radiat Res* 74(3): 585; 1978. (0 refs)

To determine if mutations can be induced by extremely high direct current (DC) electric fields, bacteria and *Drosophila* were exposed in a simple physically characterized exposure system. Two parallel copper plates having their edges rolled back from each other and separated by a 30 cm diameter polymethylmethacrylate ring comprised the exposure chamber. A flow of sterile air into the chamber swept possible secondary products from the chamber during exposures. Preliminary data indicated mutations were produced in the Ames TA-100 strain of *Salmonella* and in *P. fisheri* but not in the TA-98 strain of *Salmonella*, with fields between 200 and 300 kV/m. Increased frequencies of X-linked recessives were also observed in *Drosophila* exposed 3 days as pupae to a 185 kV/m DC field. Results from these and related tests are discussed.

5853 LOCALIZED CURRENT FIELD (LCF) HEATING AS AN ADJUNCT TO RADIATION THERAPY (MEETING ABSTRACT). (Eng.) Connor, W. G. (Dept. Radiology, Univ. Arizona Health Sciences Center, Tucson, AZ 85724); McKelvie, D. H.; Roth, H. B. *Med Phys* 5(4): 333-334; 1978. (0 refs)

A generator operating at 500 KHz was used to produce localized electric current fields in tissue volumes. This energy was used to elevate the temperature of the volume for studying hyperthermia in the treatment of cancer. The tissue volume acted as a resistive load, and the power dissipated

was proportional to the current density. The current density within a region was determined by the electrode configuration and was tailored to the treatment volume. The localized current field heating technique is described, including illustrations of hyperthermic treatments of spontaneous tumors in domestic animals.

5854 A CONVENIENT THERMOMETRY SYSTEM FOR MICROWAVE INDUCED HYPERTHERMIA USING THERMISTORS (MEETING ABSTRACT). (Eng.) Smith, V. (Div. Radiation Oncology, Univ. California, CA 94143). *Med Phys* 5(4): 334; 1978. (0 refs)

The ideal thermometry system for microwave induced hyperthermia should be accurate, linear to 0.1 C over the range 36 C to 46 C, small enough to be implanted in tissue via a needle, insensitive to radio frequency (RF) interference, and rugged. Most available systems do not meet all of the requirements. Liquid crystal thermometers tend to be bulky and fragile. Thermocouple systems are subject to RF interference especially at 915 MHz. Thermistors, when packaged as small-diameter clinical probes, provide unmatched non-linear characteristics. A system has been devised to correct this deficiency with thermistors using a deflection bridge circuit technique. The design factors that need to be considered to give a matched linear output over a 10 C temperature range are presented.

5855 THERMAL DOSIMETRY FOR LOCAL HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Nussbaum, G. H. (Medical Physics Div., Dept. Therapeutic Radiology, Tufts-New England Medical Center, Boston, MA 02111); Rodgers, J. E. *Med Phys* 5(4): 334; 1978. (0 refs)

A patient-specific thermal dosimetry for local hyperthermia that will facilitate the production, in vivo, of localized temperature distribution is described. The dosimetry is based on a model of localized tissue heating that incorporates local energy deposition by radio frequency (RF) electric currents, heat loss by (static) tissue conduction, and convective heat loss due to transcapillary exchange of water in interstitial fluid with water in plasma. The magnitude of the convective contribution is directly proportional to the local blood flow, i.e., the local tissue perfusion. Techniques for determining both the local RF absorbed power distribution and the local tissue perfusion have been developed. These techniques, the predictive model itself, and the production of the predicted (desired) temperature distribution in a given clinical application are discussed.

5856 OPTIMIZATION OF RF ABSORBED POWER DISTRIBUTIONS FOR CLINICAL, LOCAL HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Rodgers, J. E. (Medical Physics Div., Dept. Therapeutic Radiology, Tufts-New England Medical Center, Boston, MA 02111); Nussbaum, G. H. *Med Phys* 5(4): 344; 1978. (0 refs)

Proper design and placement of electrodes is crucial to the attainment of optimal temperature distributions in local hyperthermia produced with radio frequency (RF) electric currents. The distribution in tissue of absorbed RF power (i.e., of joule heating) can be obtained from a solution of Laplace's equation for the electric potential, subject to site-specific boundary conditions on the sum of conduction and displacement current densities. Two-dimensional RF absorbed power distributions in tissue were calculated for a frequency of 1 MHz for a number of situations of clinical interest. Those distributions appropriate to localized heating of superficial tumors, tumors adjacent to the spinal column, and tumors of the oral cavity and rectum are presented and discussed.

5857 HOW TO COPE WITH THE NEW FDA EMC STANDARD (MEETING ABSTRACT). (Eng.) Goldblum, R. D. (No affiliation given). *Med Phys* 5(4): 361; 1978. (0 refs)

To comply with the intent of the new Food and Drug Administration's (FDA) electromagnetic compatibility (EMC) standard, radiologic equipment will have to be evaluated and, possibly, redesigned. Testing may not be required, since theoretic analysis techniques can predict the electromagnetic interference (EMI) emission and susceptibility characteristics of most electronic equipment with reasonable accuracy. There are obvious aspects of the equipment design that can, and should, be improved without major cost impacts, although this is not true in all cases. The general EMI design techniques that are most likely to be required in radiologic equipment for compliance to the FDA EMC standard are discussed. Such techniques include power line filtering, cable shielding, the use of EMI gaskets, and the use of conductive coating on nonconductive enclosures. A brief survey of available books, literature, courses, and services is given in addition to how the designer and user may obtain additional information on EMI control techniques.

5858 FDA STANDARDS CONCERNING EMC AND RADIOLOGICAL DEVICES (MEETING ABSTRACT). (Eng.) Segerson, D. A. (No affiliation given). *Med Phys* 5(4): 361; 1978. (0 refs)

The increased use and complexity of electronics in health care have resulted in an increase in electromagnetic interference. In many cases, electromagnetic interference is merely a nuisance; however, in some cases, it is a cause of misdiagnosis or even failure of life support systems. As a partial solution to this growing problem, the Food and Drug Administration (FDA) has prepared an electromagnetic compatibility standard for medical devices. Because of its general nature, it can be applied to a great number of medical devices. However, care must be exercised in applying the standard to any given device. This is particularly true of radiologic devices. The responsibility for the design of a radiologic system rests not only with

the manufacturer but also with the user. Both parties should assume responsibility for the electromagnetic compatibility of radiologic systems, and both should be aware of the FDA electromagnetic compatibility standard.

5859 CONSIDERATION OF THE POSSIBLE ELECTROMAGNETIC INTERFERENCE WITH PACEMAKERS IN A RADIATION THERAPY DEPARTMENT (MEETING ABSTRACT). (Eng.) Baker, R. J. (No affiliation given). *Med Phys* 5(4): 361; 1978. (0 refs)

The possibility of a hazard to a pacemaker-assisted patient, due to potential electromagnetic interference from a modern clinical accelerator is discussed. A brief review of the pertinent regulations governing such emissions is provided revealing that there is generally no special consideration given to the pacemaker-assisted patient. Measurements were undertaken at the University of California, San Francisco campus, prior to and following the installation of the Mt. Sutro commercial radio and TV tower in the immediate vicinity of the campus. These data, based on empiric values required to cause the model pacemaker to malfunction, resulted in a more stringent control of the allowable field strengths by the University Environmental Health and Safety Office than would be allowed by federal regulations. A second series of measurements were undertaken in the Radiation Oncology Department to investigate radio frequency interference emanating from the Clinac 4 linear accelerator. Initially, a Narda Survey Meter was employed, and the microwave transport system was surveyed (with the fiberglass cover removed). The most sensitive range on the survey meter had a full scale sensitivity of 0.2 mW/cm², 1/50 of the U.S. standard for continuous microwave exposure. No detectable level of radiation was observed with this instrument in the immediate vicinity of the treatment machine. A more sensitive detection instrument with a greater frequency range was then employed. A Tektronix 7L12 frequency spectrum analyzer was chosen, and one of two (depending upon frequency) calibrated antennas was placed on the treatment couch, simulating the patient. From 20 to 200 MHz a log spiral antenna was used, and for below 20 MHz, a linear wire was employed (uncalibrated). These measurements minimize the possibility of electromagnetic interference emanating from the treatment machine, as the strongest signals originated from outside the department. The commercial radio and TV signals could readily be identified, and other discrete signals were also found that were present even when the accelerator was turned off.

5860 MICROWAVE: BIOEFFECT RESEARCH: HISTORICAL PERSPECTIVE ON PRODUCTIVE APPROACHES (MEETING ABSTRACT). (Eng.) Schwan, H. P. (Moore Sch. Engineering, Univ. Pennsylvania, Philadelphia, PA). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.*

CURRENT LITERATURE

Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 2; 1978. (0 ref)

Interest in the biological and medical effects of radio waves (short waves) and microwaves began to develop during the 1930's. The history of this field will be reviewed, and highly productive research approaches will be indicated. The work of C. C. Johnson and his colleagues is a splendid example of the productivity of the bioengineering approach. Purely experimental approaches, lacking a scientific rationale, have been less useful. Implications for future research efforts are fairly obvious. A rationale for standards of safe exposure can now be formulated.

5861 RAT HYPOTHALAMIC TEMPERATURES DURING WHOLE BODY EXPOSURE TO 2450 MHz AND 2800 MHz MICROWAVES AT LOW POWER DENSITIES (MEETING ABSTRACT). (Eng.) Brainard, G.; Albert, E.; Postow, E.; DeSantis, M.; Parker, J. (Dept. Anatomy, George Washington Univ. Medical Center, Washington, DC 20006). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 4; 1978. (0 refs)

The temperature response in the rat hypothalamus was measured after exposure to 2,450 MHz and 2,800 MHz microwaves at 10 mW/cm² power density. Using standard stereotaxic procedures, a YSI 511 temperature probe was implanted in the hypothalamic regions of four rats. The thermistor lead was insulated from the microwaves to the point where it entered the skull. Each rat was exposed to the microwave field separately, and temperature was continuously recorded before, during, and after the exposures. Three of the rats were anesthetized. In these exposures, the uninsulated portion of the probe within the skull was perpendicular to the E field. Over seven exposure periods, totaling 2 hr, 25 min, the rat hypothalamic temperatures increased an average of 0.4 C (SD ± 0.1 C) per exposure. The fourth unanesthetized rat was positioned such that the uninsulated portion of the probe within the skull was parallel to the E field. This animal was exposed for three periods, totaling 1 hr, 41 min. The rat's hypothalamic temperature increased an average of 0.2 C (SD ± 0.1 C) per exposure. A diurnal cycle has been observed for the rat hypothalamic temperature that increases by 1.0-2.5 C during eating, drinking, and exercise. The observed microwave-induced heating is significantly below the normal hypothalamic temperature increases.

5862 EFFECT OF 2450 MHz MICROWAVE IRRADIATION ON PERMEABILITY OF THE BLOOD-BRAIN BARRIER TO MANNITOL IN THE RAT (MEETING ABSTRACT). (Eng.) Preston, E.; Vavasour, E. J.; Assenheim, H. M. (Biological Sciences, Nat'l. Res. Council Canada, Ottawa, Ontario, Canada K1A 0R6). In: *Abstracts*

of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): pp. 5-6; 1978. (0 ref)

Experiments were carried out to determine if 2,450 MHz continuous wave (CW) microwave exposure increases blood-brain-barrier permeability to ¹⁴C mannitol. Anesthetized rats were placed in a prone position facing a 10-dB horn in the quiet zone of a tapered anechoic chamber and were exposed for 30 min to either 0.1, 0.5, 1, 5, 10 mW/cm² or to sham exposure. Each experiment (1/day, 8 days total) required 6 rats: 1 animal for each exposure condition. After exposure, 0.2 ml of solution containing ¹⁴C and ³H-water was injected into the left common carotid artery. The animal was decapitated, and 4 left-side brain regions were excised. Brain uptake indexes (BUI) were calculated, definable as a measure (0-100%) of ¹⁴C mannitol permeation into brain relative to the reference substance, ³H water, for which the permeation was taken as 100%. Mean BUI values for cortex and hypothalamus across all six treatment groups ranged between 1.6 and 2.3%, and there was no evidence that the microwave exposure increased blood-brain-barrier permeability to mannitol.

5863 NEUROENDOCRINE FUNCTION IN RHESUS MONKEYS EXPOSED TO PULSED MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Lotz, W. G. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 7; 1978. (0 refs)

Neuroendocrine function was studied in adult male rhesus monkeys exposed to microwaves. Hormone levels were determined in sequential blood samples obtained via chronic indwelling jugular catheters. Hourly samples were obtained before, during, and after an 8-hr exposure to a pulsed microwave field, 1.29 GHz, covering a total time period of 24 hr. Rectal temperature was continually monitored during these experiments. The animals were exposed to far field conditions in an anechoic chamber. Blood samples were analyzed for growth hormone, cortisol, and thyroxine levels to investigate those neuroendocrine parameters that respond readily to adverse environmental stimuli. In addition to providing a time-course of any prompt changes in the secretion of the above hormones during microwave exposure, the use of chronic indwelling catheters made it possible to study the same animal repeatedly under exposed or sham-exposed conditions to evaluate the reversibility of any prompt changes observed. Results of exposures to 20 mW/cm² incident power density will be discussed.

5864 ACTIVITY-RELATED ALTERATIONS IN GLUCOSE CONSUMPTION AT AUDITORY NUCLEI OF THE RAT DURING EXPOSURE TO MICROWAVE RADIATION: AUTORADIOGRAPHIC EVIDENCE USING [¹⁴C] 2-DEOXY-D-GLUCOSE (MEETING ABSTRACT). (Eng.) Wilson, B. S.; Zook, J. M.; Joines, W. T.; Casseday, J. H. (Center Technology Applications, Res. Triangle Inst., Research Triangle Park, NC 27709). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 8; 1978. (0 ref)

Alterations in the patterns of activity-related glucose consumption in the rat brain were measured during exposures to continuous wave (CW) and pulsed microwave fields by autoradiographic survey of [¹⁴C] 2-deoxy-D-glucose ([¹⁴C] 2DG) utilization in neural tissue. Patterns of [¹⁴C] 2DG utilization at the levels of the inferior colliculus and medial geniculate body of rats showed that exposure to pulsed microwave fields can elicit a metabolic response in the auditory system by some mechanism other than conduction of sound through the middle ear. This result confirmed the efficacy of the [¹⁴C] 2DG method for demonstration of a known effect at microwave fields on brain activity. Patterns of [¹⁴C] 2DG utilization in the brain also revealed a previously unknown effect of CW microwave fields on the activity of the auditory system. This latter effect was evident at power densities of 2.5 mW/cm² and 10 mW/cm². Effects of microwave fields on brain activity outside the auditory system were not found for various conditions of exposure to pulsed and CW microwave fields at average power densities equal to or below 10 mW/cm².

5865 EFFECTS OF RF ENERGY ON THE EEG OF RABBIT (MEETING ABSTRACT). (Eng.) Takashima, S.; Onaral, B.; Schwan, H. P. (Dept. Bioengineering D2, Univ. Pennsylvania, Philadelphia, PA 19104). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by International Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 9; 1978. (0 ref)

The effects of radio frequency (RF) fields (1-30 MHz) modulated at 14 and 60 Hz on the electroencephalogram (EEG) of rabbits using time domain as well as frequency domain analyses were investigated. Unprocessed EEG signals were unsuitable for detecting effects of RF. Autocorrelograms are adequate only for qualitative studies. Therefore, analyses of EEG signals before and after exposure are based on the use of power spectra. A pair of stainless steel electrodes were chronically implanted and used for the recording of EEGs. Animal heads were exposed to modulated RF at the level of 2-3 kV/m using a pair of matched aluminum plates. Although acute exposures at these levels caused considerable changes in the power spectra, it may only be due to the effect of local fields produced by intracranial electrodes. To

avoid local fields, the intracranial electrodes were replaced with a pair of silver electrodes, which were placed on the surface of the skull. With these electrodes, rabbits were exposed chronically for 4-6 wk, 2 hr/day, at the level of 0.5 to 1 kV/m at 3-5 MHz modulated with 14 Hz. After these prolonged exposures, the power spectra were found to change considerably. Namely, power spectra of normal rabbit EEGs were characterized by several continuously changing components between 4-20 Hz without a singularly dominant component. After the exposure, this feature was replaced by spectra, which was characterized by a low frequency dominant component at 4-5 Hz. This change was not permanent and could be reverted to the normal spectra if enough time was given.

5866 HISTOPATHOLOGICAL CHANGES IN THE RABBIT LENS DURING DEVELOPMENT OF MICROWAVE CATARACT (MEETING ABSTRACT). (Eng.) Carpenter, R. L. (Bureau Radiological Health, Northeastern Radiological Lab., 109 Holton St., Winchester, MA 01890). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 11; 1978. (0 refs)

Histopathologic changes occurring during development of microwave cataracts in the eyes of 51 rabbits were studied in lenses removed and preserved at intervals ranging from 12 hr to 123 days after cataractogenic exposure to continuous wave 2.45 GHz microwaves. During the first 2 days postexposure, lens fibers in the posterior subcapsular cortex became hydropic; many were swollen or contained numerous microscopic vesicles. By 3 days, some of the epithelial cells at the lens equator became distended to form "balloon cells"; they appeared to represent an abortive attempt of the cell to accomplish its normal process of differentiation. Also, in this region, the orderly arrangement of nuclei to form a "lens bow" became altered and shifted in a posterior direction. At 4 days, equatorial epithelial cells underwent mitotic division and migrated posteriorly under the capsule. This cellular proliferation and migration had previously been identified with the response of the lens to ionizing radiation. By 3 to 5 days postexposure, there were many nucleate cells and fibers in the posterior cortex, as well as cysts and vesicles containing debris of protein precipitates from degenerated fibers. No mitotic activity was observed after day 6 postexposure, but the degenerative changes continued. Lenses preserved at postexposure intervals of 2 to 5 wk exhibited balloon cells, degenerate fibers, cysts, vesicles, and displaced epithelial cells. These histopathologic changes, which were evident at 123 days, were responsible for the opacities observed by ophthalmoscopic or slit-lamp examination. No significant differences were identified in the thickness of the posterior capsule in both the exposed and nonexposed lenses.

- 5867 THERMAL CATARACT FORMATION IN RABBITS (MEETING ABSTRACT). (Eng.) Kramar, P. O.; Harris, C.; Guy, A. W. (Univ. Washington Medical Sch., Univ. Washington, Seattle, WA 98195). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by International Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 12; 1978. (0 ref)

Circulating hot water was used to produce cataracts in ten albino rabbits by maintaining their retrolental temperatures between 43 C and 45 C. The lens changes were similar to those described following acute microwave and infra-red exposure.

- 5868 MICROWAVE IRRADIATION OF GUINEA PIGS AT 2.45 GHz (MEETING ABSTRACT). (Eng.) Ferri, E. S.; Foti, M. E. G. (Dept. Health, Education, and Welfare, Bureau Radiological Health, 109 Holton St., Winchester, MA 01890). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 13; 1978. (13 refs)

The possible role of ascorbic acid in microwave cataractogenesis was investigated employing three groups of guinea pigs. One group of guinea pigs was maintained on a normal vitamin C diet, another on a vitamin-deficient diet supplemented with vitamin C drops administered orally, and a third on only the vitamin deficient diet. Analyses of the ascorbate in the aqueous, vitreous, and lens of these animals, both microwave exposed and unexposed, showed differing patterns of increasing and decreasing concentrations when compared either to normal values or to previous similar studies with rabbits. Following single 2.45 GHz continuous wave exposure, no lenticular opacities or other visible ocular changes were detected under slit lamp examination. Subcutaneous burns were observed around the head area, with the location dependent on the method of exposure. Locomotor changes were noticeable suggesting possible central nervous system injury.

- 5869 INCIDENCE OF SISTER CHROMATID EXCHANGE IN BONE MARROW CELLS OF THE MOUSE FOLLOWING MICROWAVE EXPOSURE (MEETING ABSTRACT). (Eng.) McRee, D. I.; Livingston, G. K.; MacNichols, G. (Environmental Biophysics, NIEHS, Research Triangle Park, NC 27709). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): pp. 15-16; 1978.

Sister chromatid exchange (SCE) was utilized to investigate potential mutagenic bioeffects of

microwave (2,450 MHz) fields by comparing the incidence of SCE in bone marrow cells of 12 exposed mice, 12 sham controls, and 12 standard controls following a 28-day treatment period. Animals were exposed from above using an absorber-lined horn antenna under which 12 styrofoam cages were oriented in a circular geometry so that uniform exposure could be achieved for each mouse. The entire exposure setup was placed inside an environmental chamber lined with absorber and maintained at 22 C and 55% relative humidity. The daily treatment regimen consisted of two 4-hr-exposure periods between which 1 hr was provided at midday when the animals were fed and watered while the horn antenna was turned off. The incident power density, as measured with an isotropic probe, inside the styrofoam cages ranged from 18 to 20 mW/cm². At a level of 20 mW/cm² the specific absorption rate was calculated to be 15.4 mW/g. Colonic temperature during exposure at 20 mW/cm² increased within 10 min and ranged between 0.7 and 1.0 C above the initial value throughout the 4 hr of exposure. Measurement of SCE frequency was performed by differential labelling of sister chromatids with the base analog 5-bromo-deoxyuridine (BrdU) and subsequent staining of chromosome preparations with Hoechst 33258 and Giemsa. All 36 animals were injected with 10⁻² M BrdU at intervals of 45 min over an 8-hr period. At 19.5 hr after the first injection, colchicine was administered intraperitoneally to arrest cells in metaphase. After 90 min bone marrow cells were harvested from both femurs using standard cytogenetic procedures. Air dried slides were stained with the Fluorescent Plus Giemsa method to visualize SCE's. Slides were randomized, coded, and are now being scored. After scoring more than 300 cells, the incidence of SCE's in the exposed group is not significantly different from the unexposed controls. The value is approximately 3.0 exchanges per cell.

- 5870 SURVIVAL STUDIES OF MAMMALIAN CELLS EXPOSED TO RADIOFREQUENCY WAVES AT ELEVATED TEMPERATURES (MEETING ABSTRACT). (Eng.) Li, G. C.; van Kersen, I.; White, K. A.; Hahn, G. M. (Dept. Radiology, Stanford Univ. Sch. Medicine, Stanford, CA 94305). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 17; 1978. (0 refs)

A new variable frequency cavity applicator system was developed so that cultured mammalian cells could be exposed to radio frequency waves under controlled temperatures to investigate the thermal and possible nonthermal effect of radio frequency waves on cellular inactivation. Monolayers of Chinese hamster cells of ovarian origin (HA-1) were exposed for 30 min to 900 MHz radio frequency waves at various absorbed power densities up to 135 W/cm³ and temperature range 27-45 C. Cellular survival was measured by the cloning assay. Pre-

liminary results showed that at a maximum power density of 135 W/cm² absorbed by the medium, no cytotoxicity was observed between 27-37 C after 30 min of irradiation. At temperature range 40-43 C, no excessive cell killing above that induced by the elevated temperature can be demonstrated. Above 43 C, a non-thermal component of radio frequency waves may contribute to cellular cytotoxicity. Survival studies extended to lower frequencies (~433 MHz) and/or pulsed radio frequency waves are currently underway.

5871 8.6 GHz ELECTROMAGNETIC RADIATION EFFECT ON *ESCHERICHIA COLI* REPAIR DEFICIENT MUTANT UNDER CONTROLLED TEMPERATURE (MEETING ABSTRACT). (Eng.) Dutta, S. K.; Hossain, M. A. (Dept. Botany, Howard Univ., Washington, DC 20059). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 18; 1978 (0 refs)

The effects of pulsed microwave fields on the growth of the bacterium *Escherichia coli* strains *Pol A*⁺ (normal) and *Pol A*⁻ (repair deficient) were explored. Experiments were performed under controlled temperature (37 ± 0.1 C) in a waveguide exposure system using 8.6 GHz pulsed microwaves, which had a pulse width of 1 μsec and a pulse repetition rate of 1 kHz. The average specific absorption rate of the sample was 12 W/kg. The investigations were conducted to determine whether microwaves stimulate or retard growth of *E. coli* strains *Pol A*⁺ and *Pol A*⁻, and to determine if microwaves cause similar effects in these strains when the cells were not allowed to grow. In answer to the first question, exposure of the *E. coli Pol A*⁺ strain for 7 hr did not stimulate growth as compared with non-exposed (sham) treatment. However, the data indicated microwave induced growth of *E. coli Pol A*⁻ strain (.05 < p < 0.1). To answer the second question, the strains of *E. coli* were exposed in nongrowth medium (0.9% saline) up to 7 hr. No change was observed in the subsequent growth of normal or repair-deficient bacteria.

5872 EFFECTS OF 2450 MHz MICROWAVES ON MOUSE TESTICULAR CYTOLOGY (MEETING ABSTRACT). (Eng.) Cairnie, A. B.; Harding, R. K.; Leach, K. E.; Prud'homme-Lalonde, L. E. (Radiation Biology Section, Defence Res. Establishment, Ottawa, Ontario K1A 0Z4, Canada). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 19; 1978. (0 refs)

A total of 180 male F1 mice (B6C3 strain) were exposed in an anechoic chamber to 2,450-MHz continuous wave microwaves for 1, 2, 4, 8, or 20 hr, or for 16 hr/

day for 1, 2, 4, or 7 days. Mice housed singly in polypropylene cages were exposed in a multi-unit cage array located within the 1.8 m diameter zone. Measured changes in a blank position of power density following inclusion in the array of cages, bedding, feed, mice, and small water reservoirs were not greater than 1 dB from the free space measurement. Power density incident on each animal depended on its position-angle relative to the central axis of the horn. Measured values varied from 50 to 25 mW/cm². End points studied included: cell survival (as indicated by dye exclusion by a dispersed testis cell preparation) measured immediately following exposure (except in the case of 1- and 2-hr exposures when it was measured 4 hr after the start of exposure); sperm counts and scoring of abnormally shaped mature sperm, assayed immediately and 2 wk after exposure; testis histology, describing changes in cell development and maturation, assayed at zero time and 2 wk post-exposure. Comparisons with anechoic chamber control animals indicate significant (p < 0.05) increases in the percentage of cells that failed to exclude dye. These differences were seen in groups exposed for 8 hr and for the 2 x 16 hr and 7 x 16 hr series. Sperm counts were also significantly reduced (p < 0.05) 2 wk following a 2-hr exposure, as well as immediately following a 16-hr exposure for a 4 x 16 hr exposure series. The results will be compared with earlier data on the exposure of the hind end of mice in a waveguide or in a heated water-bath.

5873 RADIOFREQUENCY RADIATION AND ENZYME KINETICS (MEETING ABSTRACT). (Eng.) Albanese, R. A.; Cohoon, D. K. (Biometrics Div., Dept. Air Force, USAF Sch. Aerospace Medicine, Brooks Air Force Base, TX 78235). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 20; 1978. (0 refs)

The possible influence of electromagnetic fields on enzyme kinetics are discussed through mathematic analysis of the interaction of a field with an enzyme. Numeric predictions of different mathematic models are compared, and the predictions are related to available experimental data.

5874 EVALUATION OF LYMPHOCYTE FUNCTION IN MICE EXPOSED REPEATEDLY TO 2450 MHz (CW) MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Smialowicz, R. J.; Riddle, M. M.; Brugnotti, P. L.; Ward, T. R.; Kinn, J. B. (U.S. Environmental Protection Agency, Health Effects Res. Lab., Research Triangle Park, NC 27711). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): pp. 27; 1978. (0 refs)

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Mice repeatedly exposed to 2,450 MHz continuous wave (CW) microwaves were investigated for effects on hematology and lymphocyte function. Groups of mice (BALB/c females) were exposed under far-field conditions in a temperature- and humidity-controlled environment to 2,450 MHz CW microwaves. An equal number of sham-exposed animals served as controls. Exposures were performed at power densities ranging from 5 to 30 mW/cm² for periods of 15 or 30 min daily for from 4 to 23 consecutive days. Specific absorption rates ranged from 2 to 13 mW/g depending on the incident power density employed. Rectal temperatures were taken before and immediately following exposure during the course of several experiments. Hematologic parameters were compared between control and irradiated groups. Lymphocyte function was assessed by the *in vitro* blastogenic response of splenic lymphocytes as measured by ³H-thymidine incorporation following stimulation with T- or B-lymphocyte mitogens. Determination of the fraction of T- and B-lymphocyte subpopulations in spleens was made using techniques that identify specific lymphocyte surface markers. Only slight changes in rectal temperatures were observed in mice exposed at the higher power densities employed. Results of exposure of mice to 2,450 MHz microwaves and the effect of such exposures on the hematologic and immunologic parameters examined in these mice will be presented.

5875 ALTERATION OF IN VIVO LYMPHOCYTE MIGRATION BY WHOLE-BODY MICROWAVE HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Liburdy, R. P. (Radiation Sciences Div., USAF Sch. Aerospace Medicine, Brooks AFB, TX 78235). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 28; 1978. (0 refs)

Lymphocyte migration was significantly altered in mice experiencing acute microwave hyperthermia. Spleen lymphocytes or thymus cells were obtained from naive Balb/c or C57Bl/6 mice, labeled with ⁵¹Cr, and introduced intravenously (iv) into autologous recipients. Animals were then exposed to a 2.6-GHz field (25 mW/cm², 19 specific absorption rate (SAR), 1.5 C increase in core temperature) for 15 min. Lymphocyte migration patterns were determined 24-hr postexposure. No change in lymphocyte traffic was observed in nonthermogenic microwave-exposed mice (5 mW/cm², 3.8 SAR). Significantly, plasma corticosteroid levels in thermogenic-exposed mice were three-fold elevated over sham-irradiated controls: 158 ± 18 ng/ml (n=10), compared with 46 ± 6 ng/ml (n=10). Administration of hydrocortisone sodium succinate at 4 mg/kg iv resulted in alteration of splenocyte and thymocyte migration qualitatively similar to that observed following thermogenic microwave treatment. These results suggest that whole-body microwave hyperthermia leads to alterations in lymphocyte migration that is associated with steroid release due to thermal stress.

5876 FETAL RAT DEVELOPMENT IN RESPONSE TO MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Chernovetz, M. E.; Levinson, D. M.; Justesen, D. R. (Dept. Psychology, Univ. Tulsa, Tulsa, OK 74104). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 29; 1978. (0 refs)

Primigravid Holtzman rats were exposed to a 2,450 MHz microwave field at averaged energy doses of either 13.59 mW/g or 27.65 mW/g. A total of 48 rats were exposed at one of the two levels in a multimode cavity on one of four gestational days (8, 10, 12, 14). A total of 24 additional rats received either sham exposure or served as passive cage controls on the same four gestational days. Fetuses were removed by cesarean section on day 18 of gestation and assessed for evidence of gross structural abnormality, hemorrhagic signs, and fetal mass. No evidence of structural abnormality as a result of microwave exposure was observed. Fetal development assessed by fetal mass demonstrated a significant effect of the exposure, but the degree as well as the direction of the effect was dependent upon the interaction of the day of gestation and the level of energy dosing. Higher levels of exposure (approximately 26 mW/g) occurring on day 8 or 10 of gestation resulted in decreased fetal mass, while similar dosing on day 12 or 14 resulted in increased fetal mass. In contrast, fetal mass decreased for animals receiving approximately 14 mW/g on days 12 and 14. Additional correlational analyses provided evidence that the higher dose of microwave energy accounted for the largest proportion of variation.

5877 ADAPTATION TO MICROWAVE EXPOSURE AS A FUNCTION OF POWER DENSITY AND AMBIENT TEMPERATURES IN THE RAT (MEETING ABSTRACT). (Eng.) Johnson, R. B.; Mizumori, S.; Lovely, R. H.; Guy, A. W. (Dept. Rehabilitation Medicine, Univ. Washington, Seattle, WA 98195). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 30; 1978. (0 refs)

Three similar studies were conducted; in each, eight rats were exposed for 10 hr/night for 10 nights to 918 MHz, continuous wave, circularly polarized guided waves. Sham-exposed control groups were run for each study. Power density and ambient room temperature were varied such that exposure conditions were: (1) 10 mW/cm² at 70 F, (2) 10 mW/cm² at 80 F, and (3) 20 mW/cm² at 70 F. All three exposed groups showed decrements in daily body weight gain compared with their controls as an initial response (days 1-2) to microwave exposure. Rats exposed to 10 mW/cm² at 70 and 80 F exhibited comparable initial decrements. However, by day 10 rats at 70 F did not demonstrate any body weight decrement compared with controls,

although rats at 80 F evidenced a dramatic body weight loss compared with their own pre-exposure baselines. On the other hand, rats exposed to 20 mW/cm² at 70 F, although exhibiting a larger initial decrement in weight gain, showed only a moderate body weight decrement compared with controls. These data indicate that a rat's adaption to 20 mW/cm² can be more successful than its adaption to an 80 F environment.

5878 INDUCTION OF TERATOGENIC EFFECTS IN RATS BY 27.12 MHz RF RADIATION (MEETING ABSTRACT). (Eng.) Conover, D. L.; Lary, J. M.; Foley, E. D. (Dept. Health, Education, & Welfare, Public Health Service, Center for Disease Control, Nat'l. Inst. Occupational Safety & Health, Physical Agents Branch, 4676 Columbia Parkway, Cincinnati, OH 45226). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 31; 1978. (0 refs)

The National Institute for Occupational Safety and Health conducted surveys to measure occupational exposure levels of radio frequency (RF) fields. At least 75% of the sources examined exceeded the current guidelines set by the American National Standards Institute. All sources surveyed were operated by women, some of whom were pregnant. A pilot study is underway to determine exposure conditions for production of RF teratogenic effects in rats at the frequency (27.12 MHz) at which most of these industrial sources operate. Three-month-old Sprague-Dawley rats were housed and mated under standard laboratory conditions. Pregnant females were exposed in an RF near-field synthesizer operating in the dominant magnetic field mode 27.12 MHz at a magnetic field strength of approximately 43 A/m. Experimental animals were exposed without anesthesia for 20 to 30 min on gestation days 9, 11, or 13. Control animals were housed and mated under identical conditions but not exposed. All animals were sacrificed on gestation day 20 (21-day gestation period), and their fetuses examined by standard teratology procedures. The exposed animals had a specific absorption rate of 15 to 35 mW/g, depending upon total exposure time. Fetuses of the 21 females initially exposed had a high incidence of gross external and visceral malformations. Malformations were predominant in rats exposed for 30 min on gestation day 9 and in rats exposed for 25 to 30 min on gestation day 13. The primary defects noted were exencephaly, meningoencephalocele, severe facial aplasia, micrognathia, agnathia, microphthalmia, anophthalmia, and various heart, kidney, and liver anomalies.

5879 BEHAVIORAL AND PHYSIOLOGICAL EFFECTS OF CHRONIC LOW LEVEL 2450 MHz MICROWAVE RADIATION IN RATS (MEETING ABSTRACT). (Eng.) D'Andrea, J. A.; Gandhi, O. P.; Astle, L.; Durney,

C. H.; Lords, J. L.; Johnson, C. C. (Univ. Utah, Salt Lake City, UT 84112). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 33; 1978. (0 refs)

To investigate the behavioral and physiologic effects of low level microwave radiation, twenty Long Evans male rats are being exposed to 2,450 MHz continuous wave microwaves at an average power density of 5 mW/cm² for a period of 16 wk. Exposures are being given 8 hr/day, 5 days/wk. In each of the exposure chambers, ten animals are exposed 36 degrees apart along the circumference of a circle of 90 cm radius (distance for far field plane wave exposure is on the order of 2.5 λ or 31 cm). This allows an inter-animal spacing of 4.6 wavelengths, reducing any mutual coupling effects. During the night, 15 of the rats are given access to running wheels and also periodically tested in a second activity measure throughout the experiment. The remaining five rats are trained to lever press for food pellet reward after each daily 8-hr exposure period. Daily recordings of behavioral performance, body weight, and food and water intake are being taken for the 20 exposed and 20 sham-exposed control animals. Blood and urine samples have been taken during a 4-wk baseline behavioral training period and will be taken during wk 1, 5, 9, 13, and 16 of the exposure period. Hematologic, serum chemistry, and urine indices will be assessed. In addition, an assessment of electroencephalogram activity (differential spectrolanalysis) will be made after the exposure sequence is complete. The results and significance with previous findings of 16-wk exposures to 915 MHz are discussed.

5880 ALTERATION OF BEHAVIORAL AND BIOCHEMICAL PARAMETERS DURING AND CONSEQUENT TO 500 mW/cm² CHRONIC 2450 MHz MICROWAVE EXPOSURE (MEETING ABSTRACT). (Eng.) Lovely, R. H.; Guy, A. W.; Johnson, R. B.; Mathews, M. (Dept. Rehabilitation Medicine, Univ. Washington, Seattle, WA 98195). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 34; 1978. (0 refs)

To replicate Soviet microwave research findings, rats were exposed 7 hr/day for 3 mo to 500 mW/cm² 2,450-MHz, continuous wave microwaves in individual anechoic chambers. Monthly assessments of urinary ketosteroids failed to reveal any differences between exposed and control animals. Blood cholinesterase and sulfa-hydral (glutathione) activity revealed initial decrements in the exposed animals relative to sham-exposed control rats followed subsequently by no differences between groups. At the end of the 3-mo exposure protocol, significant differences in Na⁺, K⁺, CO₂ and ion gap were re-

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vealed. Behavioral testing of shock sensitivity monthly and terminal tests of open field activity and shuttlebox avoidance responding suggested significant differences between groups. These behavioral and biochemical effects disappeared after a 1-mo recovery period. These findings agree in part with some Soviet findings and clearly suggest a need for further low-level microwave chronic exposure protocols.

- 5881 FAILURE OF RATS TO ESCAPE FROM AN INTENSE 918-MHZ MICROWAVE FIELD (MEETING ABSTRACT). (Eng.) Carroll, D.; Levinson, D. M. (Univ. Missouri, Kansas City, MO 64128). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 35; 1978. (0 refs)

In two independent studies, experimentally naive, adult rats of the Long-Evans' strain were observed for evidence of escape behavior in the 918-MHz field of a multi-mode cavity. A false base of the cavity was a white sheet of plastic with a visually well-demarcated "safer" area (25%) along one wall. Animals were individually dosed at 27 mW/g (root-mean-square whole-body average of 120-Hz sinusoidally modulated field) during each of a succession of 2-min trials, at 2-min intertrial intervals. In the first study, after baseline measures were made independently by two observers, each of ten rats could abruptly reduce the dose-rate to 67%, then to 50%, then to 33%, and then to 1% by entering the "safer" area. In the second study, also with 10 experimentally naive rats, entry into the "safer" area resulted in a 99% reduction of the 27-mW/g dose rate. Although a pilot study revealed that a 2-min exposure at 34 mW/g was lethal, none of the 20 rats formally studied exhibited reliable evidence of escape or avoidance behaviors even after 50 trials under each condition of testing. While there were pronounced physiologic signs of heat stress--salivation, hyperventilation, and immobilization--the animals appeared to lack the impetus of painful stimulation.

- 5882 SHUTTLEBOX SIDE PREFERENCE AS MEDIATED BY PULSED MICROWAVE AND CONVENTIONAL AUDITORY CUES (MEETING ABSTRACT). (Eng.) Hjeresen, D. L.; Doctor, S. R.; Sheldon, R. L. (Biology Dept., Engineering Physics Dept., Battelle, Pacific Northwest Labs., Richland, WA 99352). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 36; 1978. (0 refs)

Previous research has indicated that rats, able to occupy either shielded or unshielded regions in a pulsed microwave beam, spend more time in the

shielded region; rats exposed without this choice show significantly higher activity levels than unexposed controls. Experiments were conducted to determine if audition of pulsed microwaves could be a mediating factor in either response. Rats were exposed in an anechoic chamber to the far field of a pulsed microwave beam (2.88 GHz, 100 pulses/sec, 2.3 μ sec pulse width, 10 mW/cm² average power density, 100 μ J/cm²/pulse). In one experiment a 37.5-kHz tone was substituted for microwave exposure in one of nine test sessions; in the second experiment, microwave audition was masked in some of the test sessions using 20-100 kHz noise. The results indicate that while microwave audition may be responsible for shielded region preference, it has little or no influence on activity level.

- 5883 DISRUPTION OF BEHAVIOR IN MAMMALS OF THREE DIFFERENT SIZES EXPOSED TO MICROWAVES: EXTRAPOLATION TO LARGER MAMMALS (MEETING ABSTRACT). (Eng.) De Lorge, J. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 37; 1978. (0 refs)

In three separate studies, rats, squirrel monkeys, and rhesus monkeys were exposed to 2.45 GHz microwaves (100% amplitude modulated at 120 Hz) under far field conditions in anechoic chambers. Incident fields at power densities from 0-75 mW/cm² were measured in the absence of the animal. All animals were performing on operant schedules for food reinforcement during the microwave exposures. Rats worked unrestrained in a response chamber of Styrofoam, while monkeys worked restrained in Styrofoam chairs. Rectal temperature was measured continuously during exposures of the monkeys and measured immediately after exposures in rats. Exposure sessions lasted 60 min and were repeated on a daily basis. Stable performance on the operant schedules was disrupted in all three animals at power densities positively correlated with the body mass of the animals. The behavior of rats was perturbed at lower power densities while that of the rhesus was perturbed at higher power densities. The behavior of the squirrel monkeys was disrupted at the middle level of power densities. When the averages of these power densities (23, 45, and 67 mW/cm²) were plotted as a function of body mass (0.3, 0.7, and 5 kg) a semilog relationship became evident. Extrapolation allowed prediction of the power densities needed to disrupt ongoing operant behavior in larger animals, such as, man. Also, the power densities associated with behavioral disruption approximate those power densities that produce an increase in rectal temperatures of at least 1 C (above control levels) in the corresponding animals. It is concluded that under the environmental conditions of these studies a well-controlled behavior is not disrupted in most mammals by microwaves until extra body heat exceeds the level that an animal is capable of dissipating within the exposure duration.

- 5884 **CONDITIONED TASTE AVERSION IN RATS EXPOSED TO 2450 MHz CW MICROWAVES (MEETING ABSTRACT).** (Eng.) Williams, W. (Medical Center, Univ. Rochester, Rochester, NY). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 38; 1978. (0 refs)

The ability of 2,450 MHz continuous wave microwaves to induce an aversive response to saccharin was investigated in rats subjected to incident power densities of 10-65 mW/cm² for 10 min, 20 mW/cm² for 2 hr, and 65 mW/cm² continuously for 1 hr. Sham-exposed controls were tested simultaneously. Core body temperatures were measured using a rectal probe before and after microwave exposure. Only those animals exposed continuously at 65 mW/cm² for 1 hr responded with significantly reduced saccharin intake. The aversive response correlated with a rise of core body temperature to 39.8 C or higher. One group, previously unresponsive to microwave exposure, was injected intraperitoneally with apomorphine-hydrochloride, an emetic drug known to induce taste aversion to saccharin. These animals subsequently responded with a strong aversion to the saccharin solution and demonstrated a lowered core body temperature, unmistakable signs of illness and general malaise. These side effects were absent following exposure to microwaves. While taste aversions following administration of apomorphine are considered to be the result of gastrointestinal disturbances, such disturbance did not appear to be the primary cause for microwave-induced aversion. It appeared that exposure to certain levels of microwave fields induced a stress that was hyperthermic in nature. When core body temperature was raised to 40 C or higher for 1 hr or more, the physiologic and behavioral temperature regulating mechanisms of the animal become sufficiently stressed to produce the observed taste aversion.

- 5885 **AN ANALYSIS OF RADIOFREQUENCY AND MICROWAVE ABSORPTION DATA WITH CONSIDERATION OF THERMAL SAFETY STANDARDS (MEETING ABSTRACT).** (Eng.) Tell, R. A. (U.S. Environmental Protection Agency, Office of Radiation Programs, P.O. Box 15027, Las Vegas, NV 89114). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 41; 1978. (0 refs)

An analysis of existing radio frequency (RF) and microwave (MW) energy absorption data was performed to examine the frequency dependent phenomenon of biologic tissue heating. The analysis was restricted to thermal considerations and examined the exposure field intensities associated with the various levels of RF- and MW-induced thermal loading on both the body as a whole and on specific selec-

tively absorbing tissues in adult humans and infants. An underlying absorption factor of 1 W/kg, equivalent to the basal metabolic rate for the adult, averaged over total body mass, was used for comparative purposes. A method of specifying safety standard limits, based on the electromagnetic field energy density rather than the plane wave free-space equivalent power density, is presented. The analysis revealed a particularly important resonance frequency range, $10 \leq f \leq 1,000$ MHz, in which RF and MW absorption could lead to whole body thermal loads several times the whole body basal metabolic rate for exposures equal to the present safety standard in use in the United States. A discussion is developed for applications of this analysis to occupational environments and short duration exposure conditions. Some implications of this thermal analysis of RF and MW energy are discussed in terms of existing safety standards in use in the United States and the Soviet Union and in typically encountered exposures in the United States.

- 5886 **EFFECTS OF HIGH INTENSITY 60-Hz ELECTRIC FIELDS ON RATS (MEETING ABSTRACT).** (Eng.) Koltun, D. M.; Seto, J. M.; Weissfeld, D. M.; Seto, Y. J. (Electroscience & Biophysics Res. Lab., Tulane Univ., New Orleans, LA 70118). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 46; 1978. (0 refs)

A series of experiments was designed to investigate possible biologic effects on rats of continuous exposure to high intensity 60-Hz electric fields. A total of 32 male (16) and female (16) Sprague-Dawley rats were exposed to an unperturbed electric field strength of 20 kV/m. The rats were paired and allowed to breed in the field. An equal number of male and female rats was sham-exposed under identical conditions of housing and handling and served as controls. Upon the birth of a litter, males were separated from the mother and her young and placed in individual cages. Body weight and water consumption were monitored regularly. At the end of 3 mo, blood specimens were obtained via heart puncture from all male rats for serum chemistry and hematology studies. The animals were then sacrificed, and their organs examined for morphologic and histologic changes. Similar testing will be performed and reported on the first filial generation of rats born in the field.

- 5887 **EVOKED POTENTIAL STUDY OF RATS CHRONICALLY EXPOSED TO 60 Hz, 20 kV/m ELECTRIC FIELD (MEETING ABSTRACT).** (Eng.) Walker, C.; Weissfeld, D. M.; Koltun, D. M.; Seto, Y. J. (Electroscience and Biophysics Res. Lab., Tulane Univ., New Orleans, LA 70118). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power

Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 47; 1978. (0 refs)

As part of a series of experiments, 10 male Sprague-Dawley rats were exposed to a 20 kV/m, 60-Hz vertical electric field. After 4 mo of 24 hr exposure, their visual evoked responses (VERs) were measured and analyzed. The analyzed results were then compared with those of 10 sham-control rats. By superimposing the averaged evoked responses of each group it was found that the 2 averaged VERs differed only in their downward deflection at a latency of 40 msec. To determine whether such a difference is indicative of physiopathologic changes, a series of experiments is currently underway involving periodic measurements of the VER throughout the developmental stage of the second generation of rats. The results of these experiments are presented.

5888 EFFECTS OF 60 Hz ELECTRIC FIELDS ON THE BEHAVIOR OF RATS (MEETING ABSTRACT).

(Eng.) Hjeresen, D. L.; Chandon, J. H.; Phillips, R. D. (Biology Dept., Battelle, Pacific Northwest Lab., Richland, WA 99352). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 48; 1978. (0 refs)

The position and activity levels of 39 male Sprague-Dawley rats, confined to a visually symmetrical shuttlebox, were investigated. Following 23.5-hr sessions with field strengths of 0, 25, 50, 75, and 100 kV/m, no difference between groups was seen in activity levels, which followed a predictable diurnal pattern corresponding to the light cycle used (7 a.m. on, 7 p.m. off). Rats spent significantly ($p < 0.01$) more time shielded from fields of strengths 75 and 100 kV/m than did 0-kV/m controls, particularly during the light-on periods. During the same periods, however, rats showed a preference for the exposed portion of the box at field strengths of 25 and 50 kV/m.

5889 EFFECTS OF HIGH STRENGTH 60-Hz ELECTRIC FIELDS ON GENERAL AND REPRODUCTIVE ENDOCRINOLOGY OF MALE RATS. (MEETING ABSTRACT). (Eng.)

Free, M. J.; Smith, L. G.; Jaffee, R. A.; Kaune, W. T.; Phillips, R. D. (Biology Dept., Battelle, Pacific Northwest Lab., Richland, WA 99352). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 49; 1978. (0 refs)

Adult male rats were exposed (N=20) or sham-exposed (N=20) to 100 kV/m for 30 days in a system that eliminated secondary effects to examine the effects of electric fields on general and reproductive endocrinology. Plasma blood was assayed for testos-

terone, follicle stimulating hormone, luteinizing hormone, and thyroxine. Weights of body, thymus, thyroid, pituitary, adrenals, testes, seminal vesicles, coagulating glands, and epididymis were recorded, but no statistically significant differences between exposed and sham-exposed animals were found in any of these parameters. Additional exposed (N=10) and sham-exposed (N=8) rats were anesthetized and heparinized, and one testis was exposed and maintained at 33 C, while testicular vein blood samples (200 μ l) were taken. Plasma from these samples was assayed for androgens. Immediately following testicular vein sampling, 10 μ or 50 μ labeled microspheres were injected into the left ventricle, while a reference blood sample was withdrawn at a known rate from the femoral artery. After 3 min, both testicles, epididymis, and vasa deferens were excised, and tissues and reference blood were assayed for radioactivity. Blood flow to each organ, calculated by comparing intraorgan radioactivity with reference blood, did not differ between exposed and sham-exposed animals. Likewise, testosterone secretion rate and testicular vein concentrations of testosterone, dihydrotestosterone, 5 α androstan 3 α , 17 β -diol, 5 α -androstan-3 β , 17 β -diol and dehydroepiandrosterone were unaffected by the electric field. It was concluded that major systemic and reproductive hormones and blood flow to the reproductive tract of adult male rats are unaffected by 30 days exposure to 60-Hz electric fields (100 kV/m) when secondary effects are eliminated.

5890 THE EFFECTS OF CHRONIC EXPOSURE TO A 60-Hz ELECTRIC FIELD ON SYNAPTIC TRANSMISSION IN THE MAMMALIAN NERVOUS SYSTEM (MEETING ABSTRACT).

(Eng.) Jaffe, R. A.; Kaune, W. T.; Phillips, R. D. (Biology Dept., Battelle, Pacific Northwest Lab., Richland WA 99352). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 51; 1978. (0 refs)

The effects of chronic (30-day) exposure to a 60-Hz, 100 kV/m electric field on synaptic transmission were investigated in rats. Superior cervical sympathetic ganglia were removed from anesthetized rats placed in a temperature-controlled chamber, and continuously superfused with a modified mammalian Ringer's solution. Several parameters and tests were used to characterize synaptic transmission through the ganglion. These included amplitude, area, and configuration of the postsynaptic compound action potential; conduction velocity and synaptic delay; conditioning-test response; frequency response; post-tetanic response; and high-frequency-induced fatigue. To date, the results of all the neurophysiologic tests and measurements indicate that synaptic transmission is not significantly affected by chronic (30-day) exposure to a 60-Hz, high voltage electric field.

5891 ELECTROMAGNETIC MEDIATED HORMONAL EFFECTS: THEORETICAL CONSIDERATIONS AND EXPERIMENTATION (MEETING ABSTRACT). (Eng.) Hsieh, S.; Weissfield, D.; Koltun, D.; Lymangrover, J.; Seto, Y. (Electroscience and Biophysics Res. Lab., Tulane Univ., New Orleans, LA 70118). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 52; 1978. (0 refs)

A theoretic model for the study of electromagnetic mediated hormonal regulation is proposed. Analysis based on this model includes the effect of an external electromagnetic field on the diffusional process of some hormones. Perturbation of the secretion and the target site of the hormones is examined. Experiments were performed with adult male Sprague-Dawley rats. The rats, after living in a 60-Hz electric field of strength 20 kV/m for 3 mo, were examined for endocrine changes. Weights of the testes, pituitary, adrenal, and thyroid glands were measured and compared with those from an identical group of animals not exposed to the field. In addition, a set of experiments was designed to examine the integrity of the pituitary-adrenal axis by testing the ability of the adrenal cortex to respond to adrenocorticotrophic hormone stimulation. The results of this experimental work are compared with the theory.

5892 MONITORING OF ARTERIAL WALL MOVEMENTS BY MICROWAVE DOPPLER RADAR (MEETING ABSTRACT). (Eng.) Stuchly, S. S.; Goldbert, M.; Thansandote, A. (Univ. Ottawa, Faculty Science and Engineering, Electrical Engineering, Ottawa, Ontario, Canada). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada); p. 54; 1978. (0 refs)

A new technique for monitoring arterial wall movement by microwave Doppler radar is proposed. Preliminary experimental results, performed using a low power Doppler transceiver operating at a frequency of 10.525 GHz, indicate that the technique is feasible and in many respects seems to be complementary to ultrasonic techniques used in studies of arterial wall movements.

5893 USE OF MICROWAVE POWER IN NEONATAL CARDIAC SURGERY (MEETING ABSTRACT). (Eng.) Johnson, C. C.; Durney, C. H.; Wong, K. W.; Westenskow, D. R. (Dept. Bioengineering, Univ. Utah, Salt Lake City, UT 84112). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 55; 1978. (0 refs)

The use of 915 MHz power, applied directly to the heart, is described as an improved method for warming in neonatal cardiac surgery. Very rapid restoration of heart and blood pressure has been observed in animals. Restoration of mean blood pressure from 50 mm Hg, after 1 hr of arrest at 20 C, to 130 mm Hg in 18 min has been observed. Since the heart is warmed first and the circulatory capability is restored before warming peripheral tissue, it is suggested that microwave heating is preferred to conventional warming techniques. The design of the microwave hardware and results of animal experiments are presented.

5894 LOCAL MICROWAVE-INDUCED HYPERTHERMIA FOR CANCER THERAPY (MEETING ABSTRACT). (Eng.) Bowers, E. D.; Walsh, J. E.; Douple, E. B.; Strohhahn, J. W.; Gibson, R. (Thayer Sch. Engineering, Dartmouth Coll., Hanover, NH 03755). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 56; 1978. (0 refs)

Results of experiments that have investigated the delivery of heat directly into mouse tumors using a microwave antenna are reported. A quarter-wave length antenna, consisting of a rigid coaxial cable with an inner conductor and insulator exposed in length that corresponds to 1/4 of the wavelength in the medium, and less than 0.5 mm in diameter was employed. Operating in the GHz range, thermal distributions produced by this microwave system have been measured in saline solutions, bologna, and transplantable mouse tumors using thermistor probes and a fiberoptic thermometry system. It is proposed that this approach may overcome some of the problems associated with other systems, which use external radiation sources.

5895 HEATING PATTERNS OF A NEW MICROWAVE HYPERTHERMIA APPLICATOR (MEETING ABSTRACT). (Eng.) Sandhu, T. S.; Johnson, R. J.; Kantor, G.; Kowal, H. S. (Dept. Radiation Medicine, Roswell Park Memorial Inst., Buffalo, NY 14263). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 57; 1978. (0 refs)

Heating patterns produced in tissue equivalent materials by a new dielectric loaded waveguide applicator excited simultaneously in the TE₁₀ and TE₀₁ modes at a frequency of 915 MHz are compared with those of a similar applicator excited in the TE₁₀ mode alone. Studies were performed on phantom materials simulating the electromagnetic properties of various tissue types, and heating patterns were recorded using a thermograph camera. The results show that the applicator excited in the

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TE₁₀ mode alone produces an asymmetric heating pattern. This drawback is overcome in the new design. This feature is very important in clinical use of these applications in the evaluation of thermal enhancement of the therapeutic ratio of ionizing radiation in the treatment of cancer. Also, if needed, an asymmetric heating pattern of a desired shape can be obtained by changing the relative power input levels of the TE₁₀ and TE₀₁ modes.

5896 A NEW 915 MHz DIRECT CONTACT APPLICATOR WITH REDUCED LEAKAGE (MEETING ABSTRACT). (Eng.) Kantor, G.; Witters, D. M. (Div. Electronic Products, Bur. Radiological Health, FDA, 5600 Fishers Lane, Rockville, MD 20857). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 58; 1978. (0 refs)

A new commercially-developed direct contact applicator for microwave diathermy, operating at 915 MHz, was evaluated by investigating thermographic heating patterns in phantoms and associated leakage. The main features are a quadrangle circular waveguide to obtain circular polarization and a choke around the waveguide to minimize unwanted leakage. Two similar prototypes with outside diameters of 15 cm and 25 cm were developed. The smaller one has an annular choke, while the larger one has three such concentric chokes. The four forward ridges in each applicator were adjusted to optimize polarization. An axial ratio of about two in the far field was measured. Heating patterns on the exposed surface of muscle phantoms and inside fat-muscle phantoms are spatially similar for both designs. Muscle heating, in a plane parallel to the fat-muscle interface at a temperature of half the maximum temperature, covers an area of about 45 cm². The ratios of free space longitudinal and transverse components of the total electric field (squared) in front of the center of the apertures were obtained for each applicator. For the 15-cm aperture and the 25-cm aperture, the ratios are respectively 0.03 and 0.05. Effective heating (specific absorption rate [SAR] of 235 W/kg) required 55 W and 40 W of net power to be applied to the large and small applicators, respectively, while typically corresponding leakage level of less than 0.25 mW/cm² and 10 mW/cm² equivalent plane wave power density were observed for these two units.

5897 THE EFFECT OF LOCAL TUMOR HYPERTHERMIA ON THE GROWTH OF SOLID TUMORS IN MICE (MEETING ABSTRACT). (Eng.) Magin, R. L. (Lab. Chemical Pharmacology, DTP, DCT, National Cancer Inst., NIH, Bethesda, MD 20014). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 59; 1978. (0 refs)

A single treatment with local microwave (2,450 MHz) tumor hyperthermia (43 C, 60 min) retarded the growth of small solid mouse tumors but did not result in cures. The microwave power was automatically regulated to maintain the center of the tumor at a constant temperature. The steady state intratumor temperature, monitored by implanted thermocouples, was measured to be less than 2.0 C when the tumor was encapsulated with a bolus of muscle-equivalent dielectric phantom material. No significant whole body hyperthermia occurred during treatment. Eight different subcutaneously implanted mouse tumors (B16 melanoma, Lewis lung carcinoma, Glioma 26, Ovarian carcinoma M5076, Colon adenocarcinoma No. 38, adenocarcinoma No. 26, Barrett mammary adenocarcinoma, and Mammary adenocarcinoma Line 16C) were tested. Groups of eight mice with tumor volumes in the range 100-150 mm³ were selected for the control and local heat treatment groups. Both groups were anesthetized, and the treatment group subjected to 60 min of local tumor hyperthermia at 43 C. Tumor volumes and body weights were recorded twice weekly following treatment. A single local hyperthermia treatment reduced the size and retarded the growth of each of the treated tumors compared with the controls. A difference in the sensitivity of the different tumors to local hyperthermia treatment was observed. Short growth delays (1-5 days) and moderate size reduction (20-50%) were observed in five of the treated tumors, while longer growth delays, greater size reduction, and a few cures were seen in Colon adenocarcinoma 38 (13 days, 71%), Glioma 26 (7 days, 67%, 1 cure) and Ovary M5076 (9 days, 71%, 1 cure). Three sequential treatments of the Colon adenocarcinoma 38 at approximately 1-wk intervals increased the growth delay to 19 days, and the tumor size was significantly inhibited.

5898 RADIOFREQUENCY (0.5 & 3.3 MHz) CURRENT INDUCTION OF LOCALIZED HYPERTHERMIA IN TISSUES: SOME EXAMPLES (MEETING ABSTRACT). (Eng.) Cetas, T. C.; Connor, W. G.; Cooper, D. H.; Miller, R. C.; Roth, H. B. (Health Sciences Center, Univ. Arizona, Tucson, AZ 85724). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 60; 1978. (0 refs)

Physical aspects of clinical trials of localized hyperthermia are discussed. Heating is primarily by radio frequency (0.5 and 3.3 MHz) currents in direct resistive contact with the tissue to be heated. Various electrode geometries have been used effectively including interstitial needle electrodes, surface plate electrodes (usually water cooled), and central obturator electrodes for rectal and vaginal tumor heating. Water baths and microwaves (2.45 GHz) are used for heating shallow surface lesions. Thermographic studies with phantom, and occasionally, animal models are used in treatment planning. Temperature measurements during

human treatments are often limited by clinical constraints to one or two subcutaneous or intratumor probes. Thermographic monitoring of exposed surfaces of the heated field gives dosimetric data for the normal skin tissue and provides valuable, if only semiquantitative, information on the uniformity of the heating. The techniques discussed clearly represent early stages of development, but the clinical efficacy provides strong stimulus for continued efforts.

5899 FINITE-ELEMENT CALCULATIONS OF ELECTROMAGNETIC ABSORPTION BY BIOLOGICAL BODIES (MEETING ABSTRACT). (Eng.) Barber, P. W.; Johnson, C. C.; Yeh, C. (Dept. Bioengineering, Univ. Utah, Salt Lake City, UT 84112). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 63; 1978. (0 refs)

To better quantify the absorption characteristics of realistic inhomogeneous models of man and animals, the unimoment formulation of the finite-element method was used to make calculations. The unimoment approach surrounds the object under consideration by a sphere. The interior region is discretized into a mesh of triangular subregions. Relationships between the fields in the sub-regions are developed by the finite-element method and assembled into a system of linear equations that govern the entire interior region. The fields outside the sphere are expanded in the usual spherical harmonic wave functions. The interior and exterior problems are solved separately and later coupled on the spherical surface by enforcing continuity on the tangential electric and magnetic fields. The finite-element method is also used to calculate the total power absorption and power distribution in realistic models of mice and rats. The results show the dependence of the absorption characteristics on the size and location of internal inhomogeneities. Particular problems associated with applying the finite-element method to man model calculations are considered.

5900 HEAD RESONANCE: NUMERICAL SOLUTIONS AND EXPERIMENTAL RESULTS (MEETING ABSTRACT). (Eng.) Hagmann, J.; Gandhi, O. P.; D'Andrea, J. A.; Chatterjee, I. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 64; 1978. (0 refs)

New numeric results are presented for a 312-cell model of man, which differs from previous models in that 144 cells are used in the head region to provide greater detail regarding the distribution of energy deposition. Preliminary tests were con-

ducted with anesthetized 450 ± 30 g Long Evans rats at 2,450 MHz, and a value of head specific absorption rate (SAR), which is approximately 2.2 times the whole-body average was observed. Experimental data are presented for head resonance in the laboratory rat with both $\vec{E}||\vec{L}$ and $\vec{K}||\vec{L}$ orientations. The measurements of whole-body average SAR and the absorption cross section of the head for phantom models of man at frequencies near head resonance with both $\vec{E}||\vec{C}$ and $\vec{K}||\vec{C}$ orientations are presented and compared with numeric solutions.

5901 SURFACE INTEGRAL EQUATION SOLUTIONS FOR FIELDS IN BIOLOGICAL BODIES OF REVOLUTION (MEETING ABSTRACT). (Eng.) Wu, T. K. (Dept. Electrical Engineering, Univ. Mississippi, University, MS 38677). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 65; 1978 (0 refs)

Internal fields and power absorption in biologic bodies of revolution are evaluated using the surface integral equation method. The method yields moment method solution for the induced current densities on the body surface. The interior fields to the body are then evaluated via the reciprocity theorem and the measurement matrix concept. The bulk body power deposition is obtained by the integration of the surface Poynting vector. The method applies for a wide range of dielectric parameters in the resonance region.

5902 THERMOGRAPHIC COMPARISON OF TEMPERATURE PROBES USED IN MICROWAVE DOSIMETRY STUDIES (MEETING ABSTRACT). (Eng.) Olsen, R.; Hammer, W. (No affiliation given). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): pp. 66-67; 1978. (0 refs)

Temperature probes were compared for accuracy and for perturbation of the energy absorption pattern in a sphere of tissue equivalent material. A two-part styrofoam mold was filled with muscle phantom material. Double layer gauze was used to partition the hemispheres. The gauze was very light weight, and it allowed virtually continuous contact of the phantom material across the interface. The various temperature probes entered the spherical phantom along the partition plane with the measuring tip either at the center or at a measured depth. Two anechoic chambers were used in this study; at 1.7 GHz, overhead irradiation from a low-gain waveguide horn was used to illuminate the phantom. At 5.95 GHz, a wall-mounted standard gain horn (Narda) in a smaller chamber provided the radio frequency feed. In both instances, the phantom sphere was located in the far zone of the horn. Temperature probes used in this comparison in-

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cluded a typical rectal thermistor (YSI Type 401), a liquid crystal optical fiber device (Ramel Inc.), a fine wire thermocouple made of copper and constantan, a non-metallic thermocouple developed at NBS, and a four-lead device using high-resistance lead material. By recording the thermographic scan at 4-sec intervals, the surface cooling process was utilized to construct cooling curves for the various locations of observed temperature maxima on the scanned surface. With an individual probe tip inserted into the phantom during irradiation, the probe output was monitored and compared with the formerly deduced change in temperature. Immediately following the microwave exposure, the phantom was opened and scanned thermographically. The resulting image was then compared with the heating pattern obtained for the unperturbed sphere. Initial results of this study showed a very large perturbation for all metallic probes when oriented parallel with the electric field. The field distortion was much smaller yet still visible for probes with non-metallic (but conducting) leads.

5903 TRANSMISSION COEFFICIENT OF NEAR ZONE MICROWAVES INTO PLANAR BIOLOGICAL TISSUES: HORIZONTAL DIPOLES (MEETING ABSTRACT). (Eng.) Kamal, A. A.; Al Badwaihy, K.; Hashish, E. (Electronic Dept. Faculty of Engineering, Cairo Univ., Giza-Cairo, Egypt). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 68; 1978. (0 refs)

The transmission coefficient of near zone fields may have higher values than in the case of normally incident plane waves. An upper limit is computed for the coefficient of transmission of microwave fields into living tissues. The source is an elementary horizontal electric or magnetic dipole located in the free space region above the biologic half space.

5904 TEMPERATURE RISE IN TISSUE SPHERES INDUCED BY MICROWAVE RADIATION: A GREENS FUNCTION APPROACH (MEETING ABSTRACT). (Eng.) Kritikos, H. N.; Foster, K. R.; Schwan, H. P. (Dept. Electrical Engineering, Univ. Pennsylvania, Philadelphia, PA 19104). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 69; 1978. (0 refs)

To find the steady state temperature increases throughout living tissue, exposed to microwave radiation, a simple thermal model for tissue, including a scalar term representing blood flow in the head transport equation, and including the (physiologically complicated) transfer of heat from the tissue surface into space as an appropriate boundary condition was investigated. The Greens function solution for the heat transport equation is presented

for several cases; a "false color" computer display is used to present the results. For relatively low microwave frequencies (where the wavelength in the tissue is much less than the tissue diameter) the specific absorption rate (SAR) can be analytically expressed in terms of a multipole expansion. For the first three terms, the Greens function solution is analytically evaluated; the resulting steady state temperature profile clearly shows the electric and magnetic dipole heating contributions from the microwave field. For higher microwave frequencies, the Greens function solution must be evaluated numerically. In a four-layer tissue sphere of 5-cm radius exposed to a 1-GHz field, the SAR (from a previous study) shows a "hot spot" near the sphere's center. The calculated steady state temperature profile for this complicated heating pattern closely resembles the steady state temperature distribution produced by a uniform "hot spot" embedded in a much larger uniform volume of tissue. For values of blood flow appropriate for human brain tissue, the maximum calculated tissue temperature rise is about 0.6 C at an incident microwave intensity of 10 mW/cm². The thermal model and results are discussed in terms of the physiology of temperature regulation.

5905 IMPLICATIONS OF THE RADIOFREQUENCY RADIATION DOSIMETRY HANDBOOK (SECOND EDITION) (MEETING ABSTRACT). (Eng.) Allen, S. J.; Durney, C. H.; Johnson, C. C. (Radiation Sciences Div., USAF Sch. Aerospace Medicine, Brooks AFB, TX 78235). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 70; 1978. (0 refs)

The second edition of the *Radiofrequency Radiation (RFR) Dosimetry Handbook* includes predictions of specific absorption rate for frequencies from 10 MHz to 100 GHz utilizing human and experimental animal models. These data, which extend well above resonance, should prove valuable in establishing more meaningful experimental protocols and interpreting RFR bioeffects research in terms of predicted effects on man.

5906 NUMERICAL MODELING OF THREE-DIMENSIONAL ARBITRARILY-SHAPED HETEROGENEOUS BIOLOGICAL BODIES UNDER COMPLEX EXCITATIONS (MEETING ABSTRACT). (Eng.) Wang, J. J. H.; Cain, F. L.; Burdette, E. C. (Engineering Experiment Station, Georgia Inst. Technology, Atlanta, GA 30332). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 71; 1978. (0 refs)

A generalized numeric model or a composite, arbitrarily-shaped, heterogeneous three-dimensional biologic body under complex excitation has been

developed and validated. The model employs the method of moments to solve a pair of integral equations for the unknown equivalent volume electric and magnetic currents. Pulse functions are used as basis functions, and delta functions are used for testing. The excitation can be a plane wave, the near-field of an antenna, or that due to an enclosing coil. The biologic body must be electrically small and have ferromagnetic seeds to produce hyperthermia for the treatment of cancerous tumors. The computer program was validated, and numeric tests, such as, convergence and conservation of energy tests were also conducted. In the most demanding case of coil excitation and magnetic heating, gross agreements between measurements and calculations established two important aspects of the process. First, the effectiveness of magnetic heating to generate hyperthermia was verified by the heating patterns. Secondly, the adjustment of hyperthermia patterns by varying the frequency was achieved using ferrites with a magnetic loss tangent, which rapidly increased for frequencies from 5 to 20 MHz. Therefore, the feasibility of controlling magnetic heating between 5 and 20 MHz has been demonstrated in both analysis and experiments.

5907 NUMERICAL CALCULATION OF MICROWAVE ABSORPTION IN ARBITRARY GEOMETRY WITH APPLICATION TO A MODEL OF MAN (MEETING ABSTRACT). (Eng.) Neuder, S. (Bureau Radiological Health, HEW/FDA, Rockville, MD). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 72; 1978. (0 refs)

A recently developed numeric approximation technique for calculating induced electromagnetic fields and absorbed power density in multiregion, arbitrary, biologic systems has been applied to a model of the human body. The associated computer program, FEMS (A Fortran Program for Microwave Scattering - to be published), provides approximate solutions in irregularly-shaped lossy dielectric media. To formulate the FEMS equations, the reduced Maxwell's equations are written in the weak form. A homogeneous model of the human body, 175 cm high, was chosen, and exposed to a linearly polarized plane wave in the MHz frequency range. Isoparametric finite elements followed curved contours of the body model so that improved accuracy was achieved. Quantities calculated were the induced field and the distribution of absorbed power densities in the body during exposure at various frequencies. Preliminary results of these calculations were presented.

5908 THERMAL ANALYSIS OF HUMAN PHANTOM MODELS EXPOSED TO EMISSION FROM A MICROWAVE OVEN (MEETING ABSTRACT). (Eng.) Prucha, R. V.; Belsen, L. H. (General Electric Co., Appliance Park, Louisville, KY 40225). In: *Abstracts of Scientific*

Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 73; 1978. (0 refs)

A series of thermographic measurements were performed on full size phantom models exposed to energy from a microwave oven. Specific emphasis was directed toward determining the maximum specific absorption rate into the lower abdomen of a female phantom model and the head of a child phantom model. To understand the model variables, several different conditions were adjusted (i.e., single material model, multilayer model, and different parting plane material). A thermal time history of the models was also evaluated to better understand the effect of material properties, parting plane material, and exposure time. The results from these measurements were used as the basis for heat input and temperature rise calculations in thermal models of humans. Both worst case and typical case calculations based on movement patterns were made, and the results compared with those produced by other heating means, such as, changes in metabolic rate (deep heating) and exposure to normal sunlight (surface heating). Results also were compared with medical diathermy practice. These results show the conservative nature of the current microwave oven emission standards.

5909 AN EMPIRICAL FORMULA FOR CALCULATING THE SAR OF PROLATE SPHEROIDAL MODELS OF HUMANS AND ANIMALS IRRADIATED BY PLANE-WAVES (MEETING ABSTRACT). (Eng.) Durney, C. H.; Iskander, M. F.; Massoudi, H.; Johnson, C. C. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 74; 1978. (0 refs)

An empiric relation that allows the calculation of approximate values of the average specific absorption rate (SAR) over a broad frequency range for any prolate spheroid model is derived for E-polarized incident plane waves. The formula satisfied the f^2 SAR behavior at lower frequencies, the resonance characteristic at intermediate frequencies, the $1/f$ behavior past resonance, and the dielectric constant dependence at the geometric optics limits. An expression for the resonance frequency F_0 in terms of the dimensions of the model was also derived. The unknown coefficients in the empiric relations were determined by curve fitting all the data available in the second edition of the *Radiofrequency Radiation Dosimetry Handbook*. Since the empiric formula is a nonlinear function of these coefficients, the method of differential corrections together with Newton's iterative method were used. Numeric results obtained from the empiric relations for prolate spheroid models of a variety of sizes are presented graphically

and compared with available data calculated by other techniques. The results obtained from the empiric relations were generally very close to those calculated by other means, differing at most by about 15% in some models at some frequencies. For those models where neither the resonance frequency nor the SAR at resonance were previously known, the results from the empiric formulas were found to be in good agreement with those obtained using other empiric relations particularly developed for frequencies near resonance. This empiric formula is intended to complement the specific data available in the *Radiofrequency Radiation Dosimetry Handbook*.

5910 APPROXIMATE ANALYSIS OF PLANEWAVE IRRADIATION OF MAN NEAR A GROUND PLANE (MEETING ABSTRACT). (Eng.) Iskander, M. F.; Durney, C. H.; Massoudi, H.; Johnson, C. C. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). In: *Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada*. Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 75; 1978. (0 refs)

An approximate analysis for calculating the average specific absorption rate (SAR) of a model of man exposed near or on a ground plane is presented. The analysis involved two approaches, namely, the antenna approach, which utilized the equivalent circuit of a receiving antenna, and a combination of circuit theory and curve-fitting procedures. In the former, the antenna input impedance was obtained by calculating the internal impedance of a finite cylinder, while the field impedance was calculated by extrapolating available data for a cylindrical antenna. In both cases, the introduction of a separation between the man's feet and the earth (rubber sole or shoe) was taken into account by introducing a lossy capacitor in the equivalent circuit. Numeric results showed that the effect of the ground plane on the average SAR values was primarily important at lower frequencies, diminishing as the frequency increases. Furthermore, it was found that such an effect decreases rapidly with increasing gap width. For the worst case of a barefoot man placed at a distance from a wet earth, it was found that for separation distances of 7.5 cm or more, the SAR was the same as that for freespace irradiation. Results for both cases of lossy and lossless capacitive gaps are presented graphically.

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