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FRANKLIN INST RESEARCH LABS ROCKVILLE MD SCIENCE INFO--ETC F/G 6/18
BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION. VOLUME I, NUMB--ETC (U)
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BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION


A Digest of Current Literature and a
Forum of Communication

A QUARTERLY PUBLICATION
PRODUCED FOR
U.S. ARMY RESEARCH OFFICE

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THE FRANKLIN INSTITUTE
RESEARCH LABORATORIES
SCIENCE INFORMATION SERVICES

VOLUME I

NUMBER 3

DECEMBER 1974

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) The Franklin Institute Research Laboratories	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
	2b. GROUP

6. REPORT TITLE
Biological Effects of Electromagnetic Radiation. Volume I, Number 3.

4. DESCRIPTIVE NOTES (Type of report and, inclusive dates)
A Digest of Current Literature and a Forum of Communication

5. AUTHOR(S) (First name, middle initial, last name)
10. Bruce H. Kleinstein 12. 58p.

11. REPORT DATE
December 1974

7a. TOTAL NO. OF PAGES
53

7b. NO. OF REFS
202

8. CONTRACT OR GRANT NO.
U.S. Army Grant No. DAHCO4-74-G-0132

9a. ORIGINATOR'S REPORT NUMBER(S)
Volume 1, Number 3

b. PROJECT NO.
c.
d.

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Distribution unlimited

9. Quarterly publication, Jul 73 - Dec 74

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Co-sponsored by: Walter Reed Army Inst of Res
Bureau of Radiological Health, FDA, ONR,
BUMED, Air Force School of Aerospace Medicine

13. ABSTRACT
The Biological Effects of Electromagnetic Radiation serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radio-frequency radiation) are compiled, condensed, and disseminated on a regular basis. BEEMR 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.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Literature continuous wave extremely high frequency extremely low frequency electromagnetic radiation microwave non-ionizing radiation electric fields magnetic fields high frequency						

BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION

A Digest of Current Literature and a
Forum of Communication

Preparation of This Digest Supported by
U.S. Army Research Office - Durham
Under Grant No. DAHCO4-74-G-0132



VOLUME I

NUMBER 3

DECEMBER 1974

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by
THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
Science Information Services
Biomedical Section
Bruce H. Kleinstein, Ph.D., Technical Editor

ACCESSION for	
NTIS	White Section <input checked="" type="checkbox"/>
DDC	Buff Section <input type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
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DISTRIBUTION/AVAILABILITY CODES	
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PREFACE

Biological Effects of Electromagnetic Radiation is a publication researched and prepared by the Franklin Institute Research Laboratories, Science Information Services Department, under a grant from the U. S. Army Research Office. The grant is co-sponsored by the Bureau of Radiological Health, Food and Drug Administration; Office of Naval Research; U. S. Navy Bureau of Medicine and Surgery; U. S. Air Force School of Aerospace Medicine; and the Walter Reed Army Institute of Research. The U. S. Environmental Protection Agency is cooperating in this project.

Biological Effects of Electromagnetic Radiation 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 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 Electromagnetic Radiation is published quarterly. Volume I, 1974, consists of three issues, which cover the scientific literature published from July, 1973 through December, 1974. The first several issues also cover past work of importance. The quarterly issues of Volume II, 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. Articles carried over because of space limitations and materials for which full text is not available will be included as citations. When available, a special report section, technical note, book review, or topical retrospective literature survey will be included.

ABBREVIATIONS AND ACRONYMS

Biological Effects Electromagnetic
Radiation 1(3), December 1974

A - ampere (also amp)	LF - low frequency
ac - alternating current	LH - luteinizing hormone
ACTH - adrenocorticotrophic hormone	m, m ² - meter, square meter
AF - Air Force	mc - megacycle
AMP - adenosine monophosphate	MF - medium frequency
ANSI - American National Standards Institute	mg - milligram
ATP - adenosine triphosphate	mho - unit of measurement of conductivity
bpm - beats per minute	MHz - megahertz
BRH - Bureau of Radiological Health	MIC - microwave integrated circuit
c - cyclic	min - minute
C - Centigrade	ml - milliliter
CL - Current Literature	mm - millimeter
cm, cm ² - centimeter, square centimeter	mmho - millimho
CNS - central nervous system	mR - milliRoentgen
cps - cycles per second	mW - milliwatt
CR - Current Research	Mw - megawatt
CRT - cathode ray tube	MW - microwave
CW - continuous wave	mV - millivolt
dB - decibel	NaCl - sodium chloride
dc - direct current	NADH - reduced nicotinamide-adenine dinucleotide
DNA - deoxyribonucleic acid	NBS - National Bureau of Standards
DOD - Department of Defense	NIH - National Institutes of Health
dopa - dihydroxyphenylalanine	NIR - non-ionizing radiation
ECG - electrocardiogram	nm - nanometer
EEG - electroencephalogram	NMR - nuclear magnetic resonance
E-field - electric field strength (V/m)	NSF - National Science Foundation
EHF - extremely high frequency	NTIS - National Technical Information Service
ELF - extremely low frequency	ONR - Office of Naval Research
EM - electromagnetic	P - pulsed
EMC - electromagnetic compatibility	PEMF - pulsed electromagnetic field
EMF - electromagnetic field	PHA - phytohemagglutinin
EMI - electromagnetic interference	PHS - Public Health Service
EMP - electromagnetic pulse	p-p - pulsed power
EMR - electromagnetic radiation	pps - pulse per second
EPA - Environmental Protection Agency	PRR - pulse repetition rate
ERP - effective radiated power	R - Roentgen
ESF - electrostatic fields	rad - radiation absorbed dose
f - frequency	RBC - red blood cell
F - Farad	RC - resistance-capacitance
FDA - Food and Drug Administration	RF - radiofrequency
FM - frequency modulation	RMF - rotating magnetic field
FSH - follicle stimulating hormone	rms - root mean square
g - gram	RNA - ribonucleic acid
GABA - gamma-aminobutyric acid	rpm - revolutions per minute
GH - growth hormone	s.c. - subcutaneous
GHZ - gigahertz	sec - second
GMP - guanosine monophosphate	SHF - super high frequency
Hb - hemoglobin	TEM - transverse electromagnetic mode
HEW, DHEW - Dept. of Health, Education and Welfare	TSH - thyroid stimulating hormone
HF - high frequency	UHF - ultra high frequency
HFC - high frequency current	USAFSAM - U.S. Air Force School of Aviation Medicine
Hg - hectogram	USDA - U.S. Dept. of Agriculture
hr - hour	UV - ultraviolet
HZ - hertz	V - volt
IEEE - Institute of Electronic and Electrical Engineers	VA - Veterans Administration
IMPI - International Microwave Power Institute	VLF - very low frequency
i.p. - intraperitoneal	W - watt
ISM - assigned industrial, scientific and medical frequencies	Wb - unit of measurement of magnetic flux
i.v. - intravenous	WBC - white blood cell
J - joule	WG - waveguide
kg - kilogram	WHO - World Health Organization
kHz - kilohertz	
km - kilometer	
kV - kilovolt	
kW - kilowatt	
l - liter	
LD - lethal power density	
LED - light-emitting diode	

Symbols

ε - dielectric constant
λ - wavelength
μ - micro
σ - specific conductance
Ω - ohm

NEWS ITEMS

BIOLOGICAL EFFECTS OF LOW LEVEL RADIO WAVES MAY BE UNDERESTIMATED

A report released by the Office of Telecommunications Policy (OTP), in June of this year, suggests that low intensity microwave radiation over long periods may have greater effects on the nervous system and growth processes than originally thought. Part of a long-term study under the impetus of the Electromagnetic Radiation Management Advisory Council (ERMAC), the report indicates "that effects may occur, in the nervous system and behavior, normal developmental and growth processes, and possibly in some metabolic and biochemical parameters, at lower levels of radio wave radiations than anticipated in the past." The report emphasizes these are preliminary observations not yet scientifically validated. OTP will ask Congress for \$15.2 million, a doubling of its 1974 budget, to continue the studies, with emphasis on chronic exposure over extended periods of time. [*Microwaves*, July, 1974, 13(7), p.21]

TWO PERSONAL MICROWAVE MONITORS ARE DEVELOPED

Two small, personal monitors to protect against excessive exposure to microwave energy have been developed. A unit consisting of an antenna, detector, level sensor, keyed oscillator and speaker which may be easily carried in a coat pocket or attached to a belt has been developed by the California Institute for Technology (*NASA Tech Brief*, B74-10097, August 1974). A second monitoring device developed at the University of Newcastle-upon-Tyne in England makes use of the absorption of rf power in germanium films (see CL 0284, page 34, in this issue.) As the radiation is absorbed, the film temperature increases and its resistance changes.

The antenna of the pocket-sized monitor may be a single equiangular spiral or a set of orthogonal slot dipoles. The signal detector is a simple diode in a small package; the level sensor a standard integrated circuit. Potentiometers set the trip level of sensitivity and the level at which the equivalent microwave input would represent a safety hazard. A gated astable multivibrator is a dual-gate integrated circuit, which is wired as an astable multivibrator to furnish the warning tone. The multivibrator is gated on by the output of the level sensor; tone output is amplified and drives a small speaker. Requests for information about this device may be directed to: Technical Utilization Office, NASA Pasadena Office, 4800 Oak Grove Drive, Pasadena, California 91103.

By depositing germanium on a heated glass surface, germanium films 3 μm thick with a conductivity of $1.75 \times 10^3 \Omega/\text{m}$ have been obtained for the English exposure monitor. This type of germanium sensor can reliably monitor power levels from $1 \text{ mW}/\text{cm}^2$ to $1 \text{ W}/\text{cm}^2$. Light-emitting diodes driven by the outputs of a decade counter display the exposure level.

The device may be switched on or activated automatically when a danger level is reached. An integrated exposure-level indicator is used to show the accumulated radiation over a week.

NBS AUTOMATES MICROWAVE POWER MEASUREMENT

The National Bureau of Standards, Boulder, Colorado, has announced an automated system which calibrates bolometer units (waveguide and coaxial connector types) in the power level range from 1 to 10 mW. The NBS system employs a commercial automatic network analyzer (ANA), and can calibrate a bolometer unit at any frequency from 2 to 12.4 gigahertz (GHz, one billion cycles per second). Costs for calibration covering 20 frequencies in one of the bands 2-4, 4-8 and 8-12.4 GHz has been reduced from \$400 to \$35 per frequency point. The device calibrates a precision working-standard bolometer unit as a function of frequency by using a microcalorimeter as its primary standard for microwave power measurements. At each frequency the effective efficiency of the bolometer unit being calibrated is obtained in terms of the effective efficiency of a working-standard bolometer unit. As of now, this data is certified only at fixed frequencies of the manual calibration systems. NBS intends to specify the accuracy of the system at intermediate points soon. For further information contact: E. L. Komarek, Electromagnetics Division, NBS, Boulder, Colo. 80302. [*Dimensions/NBS*, 58(8):184, Aug., 1974]

IMPI REPORTS. . .

The April *International Microwave Power Institute Newsletter* [2(2):3-5] reported the new Canadian regulations for microwave ovens. Briefly, they call for safety features such as indicators for on/off, interlock failure, maximum or minimum power application; lock and key starting when the microwave generating capacity is 25 kilowatts or more; leakage-proof doors; covering that prevents insertion through any portal while power source is in operation; doors that cannot be opened while source is on, and vice versa; and user and service controls that do not produce leakage when on maximum. Visible and permanent labeling is required for manufacturing specifications and standards, as are various warning signs. Regulations and requirements for leakage limits, detection and indication for both microwave and x-ray emissions are set forth; a standard warning sign specified; and life-time adherence to functioning standards required for whole system and replacement components.

In June [2(3):34-36], IMPI drew attention to the Division of Compliance's revised guidelines for reports by microwave oven manufacturers. The reports

NEWS ITEMS

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are used by the Division for evaluation of the radiation safety of product lines. Copies of the guidelines are available from the Consumer-Industrial Products Branch, Division of Compliance, Bureau of Radiological Health, 5600 Fishers Lane, Rockville, Maryland 20852.

In a final disposition of the Consumers' Union petition to amend the U. S. microwave oven performance standards, the Food and Drug Administration has proposed that two separate warning labels be permanently attached to microwave ovens, viewable during use and servicing. One would warn of door leakage, the other of proper service procedures and precautions.

This issue also announced that the Division of Electronic Product's new high performance microwave power density calibration facility is now operational. The basic components of the system are an anechoic chamber, high-power microwave transmitter and antennae, National Bureau of Standards-calibrated power meter, closed circuit TV with a high-power telephoto lens, and a non-metallic remotely controlled cart for precise positioning of the instrument to be calibrated. Another facility, developed by the Division of Biological Effects, is an environmentally controlled waveguide irradiation facility. The chamber is designed to insure reproducibility of experiments by controlling temperature, relative humidity, and airflow.

IMPI is making its first call for papers for the 10th Annual Microwave Power Symposium to be held at the University of Waterloo, Waterloo, Ontario, Canada, on May 27-30, 1975. Original and review papers are being solicited in non-communication areas of microwave power such as biological effects, medical applications, and equipment safety and interference. Deadline for submission of a 40-word abstract and 500-word summary is January 15, 1975. Abstracts should be sent to: J. R. White, Gerling Moore, Inc., 1054 E. Meadow Circle, Palo Alto, Calif. 94303.

MEETINGS & CONFERENCES

**** SCIENTIFIC SESSION OF THE DIVISION OF GENERAL PHYSICS AND ASTRONOMY USSR ACADEMY OF SCIENCES

Date: January 17-18, 1973
Place: P. N. Lebedev Physics Institute, Moscow
Sponsor: USSR Academy of Sciences

Selected Bibliography of Papers Presented:

INFLUENCE OF MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON BIOLOGICAL OBJECTS. N. D. Devyatkov (no affil.). (See CL 0263)

CERTAIN METHODOLOGICAL PROBLEMS AND RESULTS OF EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF MICROWAVES ON MICROORGANISMS AND ANIMALS. E. B. Bazanova (no affil.), A. K. Bryukhova, R. L. Vilenskaya, E. A. Gel'vich, M. B. Golland, N. S. Landau, V. M. Mel'nikova, N. P. Mikaélyan, G. M. Okhokhonina, L. A. Sevast'yanova, A. Z. Smolyanskaya, and N. N. Sycheva (Gen. Ed.: N. D. Devyatkov). (See CL 0264)

A STUDY OF THE EFFECTS OF MILLIMETER-BAND MICROWAVES ON THE BONE MARROW OF MICE. L. A. Sevast'yanova (no affil.) and R. L. Vilenskaya. (See CL 0265)

EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON THE FUNCTIONAL ACTIVITY OF CERTAIN GENETIC ELEMENTS OF BACTERIAL CELLS. Z. A. Smolyanskaya (no affil.) and R. L. Vilenskaya. (See CL 0266)

EFFECTS OF MILLIMETER-BAND RADIO WAVES ON CERTAIN PROPERTIES OF BACTERIA. V. F. Konrat'eva (no affil.), E. N. Chistyakova, I. R. Shmakova, N. B. Ivanova and A. A. Treskunov. (See CL 0267)

EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC WAVES ON CERTAIN ASPECTS OF PROTEIN METABOLISM IN BACTERIA. S. E. Manóilov (no affil.), E. C. Chistyakova, V. F. Kondrat'eva, and M. A. Strelkova. (See CL 0268)

REACTIONS OF LIVING ORGANISMS TO EXPOSURE TO MILLIMETER-BAND ELECTROMAGNETIC WAVES. N. P. Zalyubovskaya. (See CL 0269)

EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC WAVES ON THE CELL AND CERTAIN STRUCTURAL ELEMENTS OF THE CELL. R. I. Kiselev (no affil.) and N. P. Zalyubovskaya. (See CL 0270)

OUTLOOK FOR STUDY OF THE MECHANISMS OF THE NON-THERMAL EFFECTS OF MILLIMETER- AND SUBMILLIMETER-BAND ELECTROMAGNETIC RADIATION ON BIOLOGICALLY ALIVE COMPOUNDS. V. I. Gaíduk (no affil.), Yu. I. Khurgin and V. A. Kudryashova. (See CL 0271)

REMARKS ON TWO POSSIBLE MECHANISMS OF THE EFFECTS OF MICROWAVES ON HEMOGLOBIN. D. S. Chernavskii (no affil.). (See CL 0272)

**** 45th ANNUAL SCIENTIFIC MEETING, AEROSPACE MEDICAL ASSOCIATION

Date: May 6-9, 1974
Place: Washington, D. C.
Sponsor: Aerospace Medical Association
Requests for Information: Dr. M. H. Goodwin, Exec. Vice Pres., Aerospace Medical Assn., Washington National Airport, Washington, D. C. 20001

Selected Bibliography of Papers Presented:

OVERVIEW OF AEROSPACE MEDICAL IMPLICATIONS OF NON-IONIZING RADIATION. J. E. Pickering (Radiobiol. Div., USAFSAM, Brooks AFB, Tex.).

U.S. AND EASTERN STANDARDS FOR EXPOSURE TO ELECTROMAGNETIC RADIATION. P. Tyler (Navy Dept., Washington, D. C.).

INTERACTIONS OF MAN AND ANIMALS WITH RADIO-FREQUENCY FIELDS. J. W. Frazer (Radiobiol. Div., USAFSAM, Brooks AFB, Tex.).

RESULTS OF HUMAN EXPOSURE TO NON-IONIZING RADIATION. D. E. Beischer (Naval Aerospace Med. Res. Lab., Pensacola, Fla.).

OCULAR STATUS OF PERSONNEL OCCUPATIONALLY EXPOSED TO MICROWAVES. B. Appleton (Walter Reed Army Med. Ctr., Washington, D. C.).

SPECIAL PROBLEMS OF GENERAL PUBLIC EXPOSURE TO RF RADIATION. J. C. Mitchell (Radiobiol. Div., USAFSAM, Brooks AFB, Tex.).

METABOLIC AND THERMOREGULATORY RESPONSES TO MICROWAVE RADIATION IN YOUNG MALE RATS. W. M. Houk (Naval Aerospace Med. Res. Lab., Pensacola, Fla.). (See CL 0208)

EXPOSURE OF MAN TO MAGNETIC FIELDS ALTERNATING AT EXTREMELY LOW FREQUENCY. J. D. Grissett (Naval Aerospace Med. Res. Lab., Pensacola, Fla.).

**** 10th ANNUAL MICROWAVE POWER SYMPOSIUM, INTERNATIONAL MICROWAVE POWER INSTITUTE

Date: May 27-30, 1975
Place: University of Waterloo, Waterloo, Ontario, Canada
Sponsor: International Microwave Power Institute
Requests for Information: IMPI, Box 1556, Edmonton, Alberta, Canada.

MEETINGS

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1974 USNC/URSI-IEEE MEETING

Date: October 14-17, 1974

Place: Boulder, Colorado

Sponsor: The U.S. National Committee (USNC) of the International Union of Radio Science (URSI) in cooperation with the Inst. of Electrical and Electronics Engineers (IEEE).

Requests for Information: R. Y. Dow, Natl. Academy of Science, 2101 Constitution Ave., Washington, D. C. 20418

Selected Bibliography of Papers Presented:

ELECTROMAGNETIC FIELDS IN A HOMOGENEOUS MODEL OF MAN. P. W. Barber (Dept. Electr. Bioeng., Univ. Utah, Salt Lake City). (See CL 0300)

ELECTROMAGNETIC FIELD MEASUREMENTS FOR BIOEFFECTS EXPERIMENTS AND THE CONTROL OF POTENTIAL HAZARDS. R. R. Bowman (Natl. Bur. Stands., Boulder, Colo.). (See CL 301)

MEASUREMENT OF POWER ABSORBED IN THE TISSUES OF MAN AND ANIMALS EXPOSED TO ELECTROMAGNETIC FIELDS. A. W. Guy (Univ. Washington, Seattle). (See CL 0302)

LONG WAVELENGTH ANALYSIS OF PLANEWAVE ELECTROMAGNETIC POWER ABSORPTION OF A PROLATE SPHEROIDAL TISSUE BODY. C. H. Durney (Dept. Electr. Bioeng., Univ. Utah, Salt Lake City), C. C. Johnson and H. Massoudi. (See CL 0322)

**** HEALTH PHYSICS SOCIETY, 8TH MIDYEAR TOPICAL SYMPOSIUM

Date: October 21-24, 1974

Place: Knoxville, Tennessee

Sponsor: Health Physics Society

Requests for Information: J. C. Hart, Route 1, Box 287A, Lenoir City, Tennessee 37771

Selected Bibliography of Papers Presented:

USE OF AN AUTOMATED POPULATION DATA BASE IN POPULATION EXPOSURE CALCULATIONS. T. W. Athey (U.S. Environ. Prot. Agency, Electromagnetic Rad. Anal. Br., 9100 Brookville Rd., Silver Springs, Md.).

BIOMEDICAL EVALUATION OF LOW FREQUENCY (LONG WAVE) ELECTROMAGNETIC RADIATION ASSOCIATED WITH ELECTRIC POWER TRANSMISSION. R. S. Pogrud (Sch. Pub. Hlth., Univ. Illinois, PO Box 6998, Chicago).

CURRENT LITERATURE

- 0179 VITREO-RETINAL INJURIES DUE TO MICROWAVE RADIATION. (E.) Alani, S. (no affil.). *Acta Ophthalmol (Kbh)* 51(5):742-743, 1973.

Eye examinations were performed on 15 radar transmitter workers before, and during or immediately after their summer vacations. Before the vacations, 10 of the 15 workers showed scotomas bilaterally in the visual fields and two showed unilateral scotomas. After the vacations, only one worker showed bilateral scotomas and another had a unilateral scotoma. In two patients the slit lamp revealed very fine, whitish, irregular filaments immediately behind the lens, showing arborization with nodes and thickening in a vertical direction. Very fine punctate retinal or choroidal scars, whitish-yellow in color, were seen in the central parts of the fundus in two men, and a third showed a small cystic degeneration in the macular region, simulating a macular hole without affecting visual acuity. None of the workers complained of eye symptoms and all appeared in excellent physical condition. However, eight had a high erythrocyte sedimentation rate, five gave a positive antistreptolysin titer, and eight a positive antistaphylococcal titer. (No references)

- 0180 RADIO FREQUENCY FIELDS: A NEW ECOLOGICAL FACTOR. (E.) Bigu del Blanco, J. (Dept. Anat., Queen's Univ., Kingston, Canada), C. Romero-Sierra and J. A. Tanner. *Proc. IEEE 1973 Electromagnetic Compatibility Symp.*, June 1973, p. 54-59.

The role of radio frequency (RF) fields as a new ecological factor is justified by the well-established interaction of RF radiation with living systems and the continuous increase in the RF radiation background due to the proliferation of RF devices. Experiments on the interaction of RF radiation with biological systems were performed from the audiofrequency region (few Hz to about 20 kHz) to microwave (MW) region (up to 19 GHz). The following phenomena were observed: collapse of birds in moderate MW fields; changes in egg production of chickens in low intensity MW fields; changes in EEG patterns under MW radiation; effects of MW on plant vegetation; demyelination of peripheral nerves in high frequency fields; changes in the diffusion rate of aqueous electrolyte solutions through membranes under MW radiation; effects of MW fields on the rate of flow and mass flux of liquids flowing along small diameter tubes; converse piezoelectric effect in bird feathers in and beyond the audiofrequency region; and characteristics of bird feathers as dielectric aerials in the MW region. In biosystems, some RF effects were very sensitive to radiation threshold (dose rate) whereas other effects were very sensitive to radiation exposure (integral dose). This suggests the possibility of using living systems as RF radiation monitors and integration radiation dosimeters. Results of measuring natural MW emission from living systems indicate the potential capability of MW radiometry in the problem of bio-information transfer. Alternative approaches to RF exposure standards are reviewed. (41 references)

- 0181 BIOLOGICAL EFFECTS DIVISION: RESULTS OF A MICROWAVE STUDY. (E.) Galloway, W. D. (Div. Biol. Effects, Bur. Radiol. Hlth., Rockville, Md.). *IMPI Newsletter* 2(2):31, 1974.

Behavioral effects associated with microwave irradiation were explored. Such effects as a "general irritability syndrome," a decreased sensitivity of sensory systems and interference with learned behavior have been assumed to result from absorption of MW power in the CNS. In testing this assumption, a monkey's head was irradiated to determine if behavioral changes occur in a dose-related fashion. Prior to the irradiation 5 monkeys were trained to perform prescribed tasks. Two behavioral experiments were used to evaluate effects on discriminative performance and acquired learning. In a discriminative performance experiment, the task was to respond to a particular stimulus, a light, and not to respond to another stimulus, a different color light. In a behavior acquisition experiment, the monkey was to determine in what order three levers should be pressed in order to produce a reward. This order was changed each day. Once the tasks had been learned, the monkey was placed in an experimental chamber irradiated with 2450 MHz CW MWs. Two minute exposures were administered at total dose rates of 5, 10, 20 and 25 watts. Following irradiation, which produced either skin burns or convulsions, the monkey's performance of the previously learned task was tested. No behavioral deficits were indicated. (No references)

- 0182 1969 ANNUAL REPORT TO THE CONGRESS ON THE ADMINISTRATION OF THE RADIATION CONTROL FOR HEALTH AND SAFETY ACT OF 1969 PUBLIC LAW 90-602. (E.) Bur. Radiol. Hlth. Report No. OBD 70-3, April 1, 1970, 100 p.

This report covers 1969 DHEW activities in administering the Radiation Control for Health and Safety Act relating to x-rays, ultraviolet, visible light, infrared, microwaves, radiofrequency radiation, laser radiation, infrasonic, sonic, ultrasonic vibrations, and magnetic fields. Subject areas of the report are appraisals of the incidence of biological injury and effects, including genetic effects, of exposure to electronic product radiation; Federal radiation control standards; the degree of observance of such standards; priority problems in administration of the Act; research activities and technological progress achieved during 1969; completed or pending judicial actions; dissemination of technical and consumer-oriented information; and cooperation between Government and industry and other interested parties. Appendix material includes technical reports published by the Bureau of Radiological Health, 1969; short-term courses in radiological health presented in 1969; a log of staff visits to agencies, organizations, and industries; and membership of the Technical Electronic Product Radiation Safety Standards Committee. A report to the Congress on Bureau studies on electronic product radiation control and a list of study reports are included as Attachments. (20 references)

CURRENT LITERATURE

Biological Effects Electromagnetic
Radiation 1(3), December 1974

0183 THE EFFECTS OF RADIO-FREQUENCY ENERGY ON
Corynebacterium diphtheriae AND Clostridium
welchii TOXINS. (E.) Schmidt, P. (U.S. Army Med.
Res. Lab., Fort Knox, Ky.). *US Army Med. Res. Lab.
Report No. 603, March 31, 1964, 24p.*

Changes in toxicity and antigenicity of exotoxins after exposure to continuous microwave irradiation at 158 megacycles/sec were investigated. *Clostridium welchii* toxin (type A) was not affected by radiofrequency exposure, as determined by human serum opacity studies and i.v. lethality studies on Swiss mice. A guinea pig skin-reaction assay indicated a slight reduction in the toxicity of *Corynebacterium diphtheriae* toxin, rather than the 10-fold decrease in skin toxicity observed by other workers. A small decrease in toxicity of *C. diphtheriae* was also suggested by assays involving intracerebral inoculation of Swiss mice and i.p. inoculation of chicks. No change in antitoxin combining capacity or antigenicity was demonstrated by flocculation tests, nor were any gross qualitative changes in antigenic character detected by immunodiffusion. The efficacy of the available assay procedures is questioned. (24 references)

0184 MICROWAVE POWER DENSITY MEASUREMENTS IN THE
PRESENCE OF BIOLOGICAL SPECIMENS OF SIZE
COMPARABLE TO THE FREE-SPACE WAVELENGTH OF THE IMPOSED
RADIATION. (E.) Bigu del Blanco, J. (Dept. Anat.,
Queen's U., Kingston, Canada) and C. Romero-Sierra.
*Control Systems Lab. Report, Ottawa, Canada
LTR-CS-128, NRC, May 1974, 34 p.*

To emphasize the limited validity of free-space power density as a biological and behavioral exponent of microwave (MW) radiation effects, power density measurements at X-band frequencies were conducted in the absence and presence of biological specimens (animals and plant vegetation). Color thermography (infrared scanning) partly permitted evaluation of energy deposition in living tissue. In all cases diffraction and scattering of the electromagnetic wave took place in the presence of a specimen. These effects, together with the presence of a movable platform in the anechoic chamber and of the MW probe, resulted in multipath field formation and therefore in unpredictable hot and cold spots and in the irregular power density contour lines observed. The data show that direct measurement is the only reasonable way to obtain information on power density levels in the presence of biosystems. MW dosimetry should consider (1) more realistic electromagnetic field/bio-system configurations; (2) the magnetic field associated with the microwave field; (3) measurement of electric and magnetic field vectors; (4) the potential capability of noninvasive techniques such as MW radiometry; and (5) improved tissue implantation dosimetry techniques. (17 references)

0185 RF RESPONSE OF RADIATION SURVEY INSTRUMENTS.
(E.) Bradley, F. J. (New York State Dept.
Labor, Div. Ind. Hyg., New York, N.Y.) and A. H.

Jones. *Electronic Product Radiation and the Health
Physicist*, NTIS: PB-197 772. Oct. 1970, p. 173-181.

A survey of the radiofrequency (RF) response of radiation survey meters indicated that the following instruments and frequencies should be used with caution around RF equipment because of a steady response mimicking ionization radiation: end-type GM type Model 2650, 100 and 400 MHz; "Juno" ionization type, 200, 300, 400, and 600 MHz. In a TV repair shop survey, a scintillation type survey meter was used to locate sources of ionizing radiation around TV sets and an RF shielded ionizing type detector to obtain readings in mR/hr. Of 108 color sets checked, 1.9% or two sets were leaking radiation above 0.5 mR/hr; 2.8% were leaking some radiation but below the acceptable standard; and 95.3% were at background. (1 reference)

0186 MICROWAVE OVEN REPAIR: HAZARD EVALUATION.
(E.) Eden, W. M. (Florida Dept. Hlth. Rehabil. Services, Jacksonville). *Electronic Product
Radiation and the Health Physicist*, NTIS: PB-195 772.
Oct. 1970, p. 159-172.

Persons attempting to repair microwave ovens are subject to acute damage from sudden, high levels of exposure. Power density measurements around microwave ovens, with outer cabinet panels removed, indicated potential exposures in excess of currently accepted radiation protection guides for radiofrequency (e.g., 1-10 mW/cm² for incidental or occasional exposures). Repairs are attempted by microwave oven owners, radar technicians, electronics servicers, electrical appliance repairmen, restaurant equipment suppliers' service personnel, and food vending firms. Only a few manufacturers are represented by authorized repair firms. Corrective measurements should include adequate training regarding microwave hazards, utilization of microwave detection equipment, protective clothing, and eye protection. Personnel monitoring for radiofrequency and periodic eye examinations for microwave oven repairmen would provide indications of exposure levels. Shielding and warning labels for microwave tubes would provide further hazard reduction. (14 references)

0187 THE DIPOLE/SLOT RADIATION PATTERN AND ITS
USE IN UNDERSTANDING MICROWAVE LEAKAGE AND
SURVEY TECHNIQUES. (E.) Coats, G. I. (Northeastern
Radiol. Hlth. Lab., Winchester, Mass.), C. B. Nelson
and R. G. Underwood. *Electronic Product Radiation
and the Health Physicist* NTIS: PB-195 772, Oct.
1970, p. 141-158.

The theory of the dipole/slot radiation pattern is examined and its application to MW monitoring instruments and techniques is discussed. Comparison is made with ionizing radiation since the same survey techniques are applicable to both types of radiation. The major differences are that MW radiation is coherent and measurements are complicated by resonance,

interferences, and elastic reflections. To estimate the biological hazard of thermal heating of tissues by MWs on the order of 2450 MHz, the most suitable quantity to measure is power density, which, like the rate of heat development, is proportional to the square of the electric field. A crossed dipole survey meter, designed for MW oven measurements and calibrated for 2450 MHz or 915 MHz, reads power density directly and with multiple probes provides a range from 0.01-200 mW/cm². A spherical bolometer with adjustable impedance might provide the basis for development of a detector electrically similar to human tissue of interest; i.e., the lens of the eye. The meter is independent of polarization and frequency from 400 MHz to 40 GHz. (8 references)

- 0188 EFFECTS OF EXPOSURE TO MICROWAVES: PROBLEMS AND PERSPECTIVES. (E.) Michaelson, S. M. (Sch. Med. Dent., Univ. Rochester, N.Y.). *Exp. Hlth. Perspectives* 8:133-156, 1974.

Available literature on the biological effects of microwave exposure is categorized according to biophysical principles (absorption, reflection, scattering, heat sources, and molecular and cellular biology); biomedical manifestations in experimental animals; and clinical response of man. Data are presented on microwave bioeffects on the eyes, reproductive organs, and central nervous system. Extensive experimental and clinical investigations are required to determine the presence of these reported effects in man. Despite numerous investigations, there is no conclusive evidence of subtle, long-term, or cumulative effects of microwave exposure. Good laboratories with proper microwave sources, exposure and dosimetry facilities, and animal facilities are needed to assess microwave hazards. An interdisciplinary approach involving physical and biophysical scientists is another imperative. Discrepancies between U.S. and Eastern European microwave exposure standards are noted and attributed to differences in instrumentation and philosophy. (143 references)

- 0189 A COMPARISON OF MICROWAVE DETECTION INSTRUMENTS. (E.) Moore, R. L. (Bur. Radiol. Hlth., Rockville, Md.), S. W. Smith, R. L. Cloke, and D. G. Brown. *Electronic Product Radiation and the Health Physicist* NTIS: PB-195 772, Oct. 1970, p. 423-430.

Commercial MW detection instruments utilizing thermocouple sensing elements, thermistors set in a bridge circuit, and a helix antenna with a diode detector circuit were compared at 2450 MHz using a plane EM wave. The comparison covered sensitivity, readable range, ease of measurement, reliability and repairability, and stability. Test results show that the thermocouple device is best suited to measure leakage close to a slot source such as a MW oven at a frequency of 2450 MHz. (5 references)

- 0190 CENTRAL NERVOUS SYSTEM EFFECTS AS MEASURED BY REACTION TIME IN SQUIRREL MONKEYS EXPOSED FOR SHORT PERIODS TO EXTREMELY LOW-FREQUENCY MAGNETIC FIELDS. (E.) Grissett, J. D. (Naval Aerospace Med. Res. Lab., Pensacola, Fla.) and J. de Lorge. *Naval Aerospace Med. Res. Lab. Report* No. 1137, Aug. 1971, 13p.

Possible acute instantaneous CNS effects of exposure to extremely low frequency EM radiation were investigated by reaction-time measurements taken on three squirrel monkeys for 37 daily sessions. No significant changes in these measurements were observed between control sessions and sessions in which the animals were exposed to 3 gauss at 45 Hz or to a field of 3 gauss at 7 Hz. Two other indexes of performance, reinforcement ratio and efficiency ratio, were also unchanged. The small number of subjects does not permit a firm conclusion; however, the evidence indicates that the magnetic field does not produce a CNS response measurable by the techniques employed. (7 references)

- 0191 RADIATION INCIDENTS REGISTRY REPORT 1970. (E.) Mills, L. F. (Bur. Radiol. Hlth., Rockville, Md.) and P. Segal. *Natl. Tech. Inf. Service*, U. S. Dept. Commerce, PB 198078, December 1970, 56p.

The Radiation Incidents Registry, established by the Bureau of Radiological Health, has after 1 yr of operation provided data on 209 reported incidents resulting from exposure to ionizing and non-ionizing radiation and ultrasonic waves. These incidents include potential and overt biological injuries to 276 persons. Of the persons included in the Registry, 59% were exposed to ionizing radiation and 41% to non-ionizing radiation. Approximately 210 persons were reportedly exposed to electronic product radiation prior to October 18, 1968, while 66 have been reportedly exposed since that date. Of the persons for whom age data were available, 57 were between the ages of 16 and 30, 55 between the ages of 31 and 40, and 36 over age 45. There were 200 males, 31 females, and 45 whose sex was not reported. Individuals were exposed in the following decreasing order by occupation: technicians in the fields of engineering, physical science, and miscellaneous professional services; persons employed in electrical equipment industries; hospital personnel; and students performing experimental work in educational institutions. Eye injury, skin damage, and various blood disorders were the most frequently reported effects due to electronic product radiation. Exposure to ultraviolet equipment used in laboratories and to ultraviolet radiation produced by arc welding equipment accounted for the majority of cases (26%) involving non-ionizing radiation. Another 10% of reported incidents were due to microwave-generating equipment and microwave radiation from ovens, radar, and one diathermy unit. (25 references)

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- 0192 THE EFFECTS OF FM AND TV BROADCAST STATIONS UPON CARDIAC PACEMAKERS. (E.) Vreeland, R. W. (Dept. Med. Surg., Univ. California, San Francisco), M. D. Shepherd and J. C. Hutchinson. *Proc. IEEE 1974 Electromagnetic Compatibility Symp.*, July 16-18, 1974, p. 1-8.

To predict the possible effects of a new transmitting tower on pacemaker performance at a medical center, *in vitro* pacemaker performance tests were conducted in the vicinity of local FM and TV transmitters. Three external demand pacemakers stopped in an area where the maximum average field intensity was 0.63 V/m. The other pacemakers (three external demand, two implantable, and one fixed rate) functioned normally in an area where the highest measured field intensity was 1 V/m. Only the old fixed rate functioned normally under all test conditions in an area where the highest measured field intensity was 2.8 V/m. The data indicate that the critical worst-case thresholds for pacemakers are between 1 and 2.8 V/m. A tentative standard requires that the maximum field intensity within the medical center's hospital not exceed 1 V/m as measured with an average reading detector or 1.5 V/m as measured with a peak reading detector of 0.54 sec time constant. (21 references)

- 0193 MICROWAVE HAZARDS SURVEILLANCE AND CONTROL. (E.) Thompson, R. L. (Environ. Hlth., Cape Kennedy Air Force Station, Fla.). *Electronic Product Radiation and the Health Physicist*, NTIS: PB-195 772. Oct. 1970, p. 463-464.

Of 200 Air Force radar workers included in a 6-yr eye examination program, 18.5% showed the first indication of microwave eye damage. Early eye damage, determined by slit-lamp examination, usually resulted in localized opacification of the posterior portion of the lens capsule. It sometimes had a honeycomb appearance. Annual reexamination of exposed workers has identified only one case of incipient cataracts. Ophthalmological examinations appear to provide a suitable method for determining early indications of microwave exposure. (1 reference)

- 0194 EFFECT OF LOW LEVEL-LOW INTENSITY ELECTRIC FIELDS ON EEG AND BEHAVIOR IN *Macaca nemestrina*. (E.) Gavalas, R. J. (Brain Res. Inst., Univ. California, Los Angeles), D. O. Walter, J. Hamer, and W. R. Adey. *Brain Res.* 18:491-501, 1970.

The effects of low-level, low-frequency electric fields on the behavior and EEG of monkeys were studied. Three monkeys were implanted with subcortical and cortical EEG electrodes and trained to press a panel on a fixed interval-limited hold schedule. The monkeys were rewarded for pressing the panel once every 5 sec within the 2.5-sec period during which it was possible. After the animals were performing well, they were tested under low-level electric fields (2.8 V p-p); the voltage was applied to two large metal plates 40 cm apart so that the monkey's head was completely within the field. Field frequencies were set at 5 or 10 c/sec within the range of typical EEG recording (0-33 c/sec). Four-hr daily tests of

fields-on were randomly interspersed with 4-hr runs with fields-off. Under the 7 c/sec fields, the monkeys showed a significantly faster interresponse time in five of six experiments. Mean differences between fields-on and fields-off were 0.4 sec or greater. The 10 c/sec fields did not produce a reliable effect on behavior. Analysis of EEG data showed a relative peak in power at field frequencies for the hippocampus in all three monkeys. Similar peaks were seen less consistently in the amygdala and the center median. (19 references)

- 0195 EQUIPMENT SURVEYS FOR RF RADIATION HAZARDS. (E.) Lamaster, F. S. (Grnd. Electron. Eng. Instl. Agency, Griffis AFB, Rome, N.Y.). *Electronic Product Radiation and the Health Physicist* NTIS: PB-195 772, Oct. 1970, p. 420-422.

Equipment surveys for RF hazards are a regular part of the USAF Radiation Hazards Prevention Program. The surveys include a preplanning phase in which hazards are located or identified by a prediction process. Measurement personnel check areas of high side or bottom lobe radiation, reflection areas, and the RF blanking in radar and other equipment with scanning antennas. Other key areas of concern are the accuracy of existing radiation drawings; the site standard operation procedure file; and the radiation warning sign development. Investigation in these areas may result in the need for additional measurements and recommendations for changed procedures regarding site hazard control. (2 references)

- 0196 A REVIEW OF INTERNATIONAL MICROWAVE EXPOSURE GUIDES. (E.) Swanson, J. R. (Int. Labor Off., Occup. Safety Hlth. Branch, Geneva, Switzerland), V. E. Rose, and C. H. Powell. *Electronic Product Radiation and the Health Physicist* NTIS: PB-195 772, Oct. 1970, p. 95-110.

A review of MW exposure criteria used in the United States and other western countries in the past 10 yrs indicates a general acceptance of the power density exposure level of 10 mW/cm². The USSR and Poland specify permissible levels one thousand times lower at 10 μW/cm², while Czechoslovakia has a proposed sliding scale allowing 25 μW/cm² for an average working day exposure. In general, these differences arise from the acceptance of data showing nonthermal functional changes from MW radiation exposure of animals and humans. The first standards developed in the United States considered the 10 mW/cm² value to be a maximum permissible levels which should not be exceeded. These standards considered only the power density level. The two latest exposure criteria developed in the United States incorporate exposure time and permit exposures to power densities in excess of 10 mW/cm² for a limited duration. This concept has been accepted by France for military guidelines. Czechoslovakia has also accepted this newer concept by proposing a sliding scale of allowable radiation intensity while retaining a much lower allowable daily exposure level as the starting point. In applying the concept of

a time-weight exposure, the health specialist must consider how far the dose-time relationship can be extrapolated. Future standards should reflect environmental stress as well as other factors found to affect the biological response to MWs. (22 references)

- 0197 THE EFFECT OF THE UHF FIELD ON PATHOGENIC MICROORGANISMS. (Rus.) Reider, B. Sh. (Engels Inst. Trade, Leningrad, USSR). L. R. Afanasieva, and E. F. Antonova. *Vopr. Pitan.* 32: 77-78, 1973.

At present, UHF whole-product heating techniques are increasingly used in the food processing industries. Studies were made to investigate the effect of 2375 MHz radiation on dough microflora in sponge-cake baking, including colibacillus, coagulase-positive staphylococcus, salmonella and proteeae. The pathogenic microorganisms were introduced into the dough in the form of a 24-hr culture suspension. The dough was then mixed and baked in the Volzhanka type UHF oven. The results indicate that a 2-min oven baking at 60% and 100% of the generator's power output disposes of all salmonella and staphylococcus. The total number of bacteria in 1 g of product does not exceed 20-30 colonies. Examination of 10 g of the baked cake did not show any colibacillus. (No references)

- 0198 GAMMA-AMINOBUTYRIC ACID METABOLISM IN RATS FOLLOWING MICROWAVE EXPOSURE. (E.) Zeman, G. H. (Armed Forces Radiobiol. Res. Inst., Bethesda, Md.), R. L. Chaput, Z. R. Glaser, and L. C. Gershman. *AFRRRI TN73-5*, July 1973, 12p. NTIS: AD769299.

Gamma-aminobutyric acid (GABA) metabolism was studied in male Sprague-Dawley rats chronically exposed to 2.86 GHz microwaves at an incident power level of 10 mW/cm² or acutely exposed to incident power levels of 40 or 80 mW/cm². No changes occurred in whole-brain GABA levels or L-glutamic decarboxylase activity following these exposures. These results suggest that an altered GABA metabolism is not involved in reported responses of the nervous system to microwave exposure. (11 references)

- 0199 PROTECTION AGAINST MICROWAVE OVEN RADIATION LEAKAGE. (E.) Wheeler, R. H. (Am. Med. Assoc., Chicago, Ill.). *JAMA* 228(10):1296-1297, 1974.

Federal standards now limit the allowable radiation leakage of new MW ovens to 1 mW/cm², measured at 5 cm (2 in) from the oven door; this limit may be allowed to rise as much as 5 mW/cm² over the life of the appliance. The regulation also specifies that electrical interlocks be provided to shut down the power sources when the door is open or the door seal broken. Thus, depending on the successful enforcement of these standards, there appears to be little risk from ovens that are used in accordance with

the manufacturer's instructions. Where accessory shielding (e.g., a metal mesh) is impractical, the best protection is afforded by extending the physical separation of the body from the oven. For ovens manufactured before the new limit was set (Oct. 1971), it is advisable to stay an arm's length away from the door when the oven is operating. (No references)

- 0200 MICROWAVE CATARACTS - A CASE REPORT REEVALUATED. (E.) Hirsch, F. G. (Lovelace Fdn. Med. Ed. Res., Albuquerque, N.M.), *Electronic Product Radiation and the Health Physicist*. NTIS: PB-195 772. Oct. 1970, p. 111-140.

A 32-year-old man who had operated a microwave radio-frequency power source for a year developed blurred vision after three days in which his head was in close proximity to the near field zone of the horn antenna for about 24 hr. Due to the placement of the horn, the left side of his head had received the greater exposure. Examination revealed moderately advanced bilateral cataracts, chorioretinitis in the left eye, and numerous opacities in the vitreous humor of the left eye. The left lens was completely cataractous at the time of its removal 18 months later. The retinal and vitreous lesions stabilized with the passage of time and treatment with corticosteroids. The cataract in the right eye has remained stable for over 15 yr. The radiofrequency power source was a C-band megatron connected by waveguides to a standard S-band horn antenna. Oscillator output was between 5000-4000 MHz/sec, corresponding to a wavelength between 6.0-7.5 cm. Peak power output was 500 W. Peak power density in a plane at the rim of the horn was 0.9 W/cm², while the effective area of the horn was 550 cm². Based on these parameters the patient absorbed from 0.65-0.75 W/cm² of radiant energy, which is sufficient for the development of a cataract. (8 references)

- 0201 COMPREHENSIVE REPORT OF WORK ACCOMPLISHED FROM 1958 TO 1965 (FINAL REPORT). (E.) Michaelson, S. M. (Sch. Med. Dent., Univ. Rochester, N.Y.), R. A. E. Thomson and J. V. Rowland. *Univ. Rochester Report No. 49-810*, Contract No. AF (30-602)-2921. NTIS: AD 824 242. Sept. 1967, 138p.

The exact nature of the biological effects of microwaves is not completely understood. Evidence indicates that microwave energy can act as a stressor agent, and has an effect on regulatory and integrative body mechanisms with resultant alteration in homeokinesis. Animals exposed to microwaves at specific frequencies and flux densities experience thermal stress. Duration of exposure, environmental temperature, and drugs that effect the central nervous system (CNS) and temperature regulation influence the response of animals. High ambient temperature exaggerates the thermal response, while exposure in a cold environment prolongs the time interval for an increase in body temperature. The subtle nature of some microwave effects such

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as modification of response to x-irradiation and effect on bone marrow and thyroid function require careful evaluation. Soviet reports allude to asthenic reactions, CNS, cardiovascular, and thyroid changes from radar exposure. The described effects are for the most part inseparable from responses which could result from thermal stress. It is recommended that all microwave workers undergo a thorough pre-employment and periodic medical examination. Persons with cardiovascular problems or lenticular defects should be considered as risks. Because of indication of bone marrow and thyroid sensitivity to microwaves, hematologic and thyroid function studies should be incorporated in the medical examination. An increase in the present maximum permissible exposure level of 10 mW/cm² could introduce risks that might be readily recognized. (191 references)

0202 ARE YOUR WORKERS EXPOSED TO NON-IONIZING RADIANT ENERGY? (E.) Michaelson, S. M. Sch. Med. Dent., Univ. Rochester, N.Y.). *Ind. Med. Surg.* 42(9):9-11, 1974.

The last 24 years have seen a marked development and increased utilization of equipment and devices that emit non-ionizing radiant energies. These include ultraviolet, infrared, visible light, microwaves, and radiofrequency waves that are classified as electromagnetic waves. Electromagnetic energies at certain frequencies, power levels, and exposure durations can produce biological effects or injury, depending on multiple physical and biological variables. Various protection guides and standards for these radiations are summarized. They are for the most part based on the concept of maximum permissible exposure and threshold for reversible or irreversible damage to critical biological structures. Occupations potentially associated with ultraviolet radiation exposures are listed and infrared radiation threshold doses for minimum ocular damage are given. (No references)

0203 THE IMPACT OF THE ELECTRONIC PRODUCT RADIATION CONTROL PROGRAM (P. L. 90-602). (E.) Britain, R. G. (Bur. Radiol. Hlth., Rockville, Md.) and D. J. McConeghy. *Electronic Product Radiation and the Health Physicist* NTIS: PB-195 772, Oct. 1970, p. 40-50.

The Radiation Control for Health and Safety Act of 1968 (Public Law 90-602) authorizes the Bureau of Radiological Health to develop and administer performance standards for electronic products capable of emitting ionizing, non-ionizing EM radiation, particulate radiation, or sonic, infrasonic, and ultrasonic waves which result from the operation of an electronic circuit in a product. Examples of electronic products to be controlled are microwave ovens, color television, x-ray machines, and particle accelerators and lasers. The evolution of two performance standards is described: one for television receivers which is now in effect, and the second for MW ovens which

will appear in the Federal Register in the next several months. The television receiver standard specifies an 0.5 mR/hr limit, the lowest level practical at this time. The standard will be reviewed as technology improves and the radiation limits will be reduced accordingly. The problem of evolving a MW oven standard is reviewed at length. (No references)

0204 BIOLOGICAL DOSIMETRY OF 2450 MHZ MICROWAVE IRRADIATION WITH MICE. (E.) King, N. W. (Battelle, Richland, Wash.), E. L. Hunt and R. D. Phillips. *Proc. Microwave Power Symp., IMPI*, May 29-31, 1974.

Mice of the C57BL/6J strain in two sizes, and of the SJL/J strain in one size were exposed to 2450 MHz microwave irradiation in a multimodal cavity. Latency to massive clonic convulsion was measured. As with an earlier study using several sizes of Wistar rats, convulsion latency was more closely associated with absorbed power per gram of animal than with net power to the cavity. At lower irradiation levels, where absorbed dose was 80 mW/g or less, and convulsive latencies were more than five minutes, the mouse data diverged from the rat data, the mice taking longer to convulse. The mouse's greater surface-to-volume ratio gives it a cooling advantage over the rat during longer periods of irradiation. (No references)

0205 CALORIMETRIC CALIBRATION METHOD FOR A COMMERCIAL POWER MONITOR FOR USE WITH HIGH POWER MICROWAVE GENERATORS. (E.) Herman, W. A. (Bur. Radiological Hlth., Rockville, Md.), D. W. Peak, D. L. Conover, and L. W. Strong. *DHEW Publication No. (FDA) 73-8010, BRH/DEP 73-1*, Sept. 1972, 23p.

A power monitor used with a high-power (2.5 kW) microwave generator operable in the 2450-MHz industrial-scientific-medical (ISM) band was calibrated by a calorimetric method. Several measurements of the forward and reflected power were made at two positions one-quarter of a guide wavelength apart on the waveguide assembly connecting the generator and the load. The normalized average of the two determinations of the forward and reflected power yielded calibration factor values that were independent of the voltage standing wave ratio of the load and the directivity of the coupler which monitored the forward and reflected power. A linear equation was empirically derived to specify the power delivered to the load as a function of the forward and reflected power meter indications. When the equation was used to predict the power delivered to the load, the total 2σ uncertainty limit (including the uncertainty limit of calorimetric measurement of delivered power values) was ± 0.40 dB. The method described requires only equipment generally available to researchers interested in the biological effects of MW radiation. (4 references)

- 0206 LATEST DEVELOPMENTS IN UHF-THERAPY DOSIMETRY PROCEDURES. (E.) Skurikhina, L. A. (All-Union Sci. Res. Inst. Med. Instr. Eng., Moscow, USSR) and O. V. Shereshevskiy. *Med. Tekh* (5):10-15, 1973. Translated by Joint Publications Research Service, Arlington, Va., JPRS 60754, December 1973.

A method and a device are described for continuous measurement of high-frequency power absorbed by a patient during ultrahigh-frequency (UHF) therapy. The readings of the metering device give the magnitude of power being absorbed directly by the patient, and its scale can be graduated in watts. Clinical investigations with the device yielded the actual magnitudes of power absorbed by a patient in a number of typical UHF-therapy procedures. A close correlation was found between a patient's heat-sensing ability and the magnitude of power density, which made it possible to determine the required values for a broad range of UHF-therapy procedures. Results of the clinical investigations provide the basis for the transition to objective dosage metering in accordance with the magnitude of absorbed power. (4 references)

- 0207 POSSIBLE EFFECTS OF ELECTROMAGNETIC RADIATIONS. (E.) Bond, V. P. (Brookhaven Natl. Lab., Upton, N.Y.) and E. P. Cronkite. *Naval Research*, 27(7):20-21, July, 1974.

Essential to the Navy's communications systems are electromagnetic radiations (EMR) of a wide spectrum of frequencies or wave lengths. Because of possible deleterious biological effects of EMR, a primary exposure limit of 10 mW/cm² has been established in the U.S.; the USSR recommended exposure limit is considerably less than this. The authors reviewed the Navy's research programs designed to determine what, if any, effects on man may occur as a result of EMR. Five intramural facilities were visited and the programs of a number of university and other laboratories reviewed. Definite effects of microwaves at higher power densities (of the order of 100 mW/cm²) have been observed, and are considered to be secondary to the heating of tissues. Characteristic opacifications of the lens of the eye, and the alignment of some microorganisms in electrical fields have been reported. At the longer wavelengths there is no significant heating of tissues. Some "athermal" effects of microwaves and radiations of lower frequencies, including ELF, have been reported. A series of concentrated and well-controlled studies, particularly of low-power densities, is recommended. (No references)

- 0208 METABOLIC AND THERMOREGULATORY RESPONSES TO MICROWAVE RADIATION IN YOUNG MALE RATS. (E.) Houk, W. M. (Naval Aerospace Med. Res. Lab., Bethesda, Md.) and S. M. Michaelson. *Proc 45th Scientific Meeting, Aerospace Medical Association*, May 9, 1974.

To assess the magnitude and pathophysiological im-

plications of thermoregulatory neuroendocrine and metabolic changes secondary to microwave exposure, 400 8-week old male Long-Evans rats were illuminated by whole-body irradiation techniques using 2450 MHz (CW) microwaves. During and after 150-minute irradiation (at 9, 18, and 36 mW/cm² exposures) rats were removed from chambers, colonic temperature taken within 60 secs., weighed, decapitated and exsanguinated. Compared to sham-exposed groups for each time point during the irradiation period, 9 mW/cm² exposure caused a distinct temperature rise that was maintained through exposure ($p \leq 0.05$). The 18 mW/cm² exposure induced a significant whole-body temperature rise compared with sham-exposed group ($p \leq 0.001$) and the 9 mW/cm² group ($p \leq 0.05$) except at 120 minutes, where no statistically significant difference between the 9 and 18 mW/cm² groups was evident ($p > 0.10$). A statistically significant temperature rise was induced and maintained the entire exposure period by 36 mW/cm² ($p \leq 0.001$). All groups returned to pre-exposure levels of temperature within 60 minutes after irradiation. At 36 mW/cm² rat serum GH dropped with 60 minutes of irradiation and pulsatile GH release no longer occurred. Within one-half hour after radiation mean serum GH rose to very high levels in all exposure groups. Though not statistically significant ($p > 0.10$) the trend was obvious even at 9 mW/cm². Serum triglyceride responses were not markedly affected at 36 mW/cm² incident energy. The levels dropped following the pattern observed for serum GH but tended to recover in the post-exposure period. Serum glucoses demonstrated no significant changes throughout the exposure and post-exposure period. The compatibility of these rat serum GH results with those of general stress reactions, and the sensitivity of serum GH levels to subjective influences, are discussed. (No references)

- 0209 MICROWAVE HAZARD MEASUREMENTS NEAR VARIOUS AIRCRAFT RADARS. (E.) Tell, R. A. (U.S. Environ. Prot. Agcy., Silver Spring, Md.) and J. C. Nelson. *Radiation Data and Reports*, 15(4):161-179, April 1974.

In order to determine the potential for exposure of individuals when in the vicinity of aircraft radar units when aircraft are on the ground, the Electromagnetic Radiation Analysis Branch monitored four radar units that were typical of radars used by commercial aircraft. Two of the units were surveyed at a radar simulation laboratory and the other units were surveyed while in their operating positions in aircraft. The survey determined that the radar beams from navigational and weather radar units in commercial aircraft rotate in either a sector-scanned or 360 degree rotation at approximately 15 r/min. The radar beams emanated from the aircraft above 6 feet from the ground. It was determined that power density exposures of 10 mW/cm² can occur from 8 to 18 feet from the antenna of an aircraft radar unit. No radiation levels in excess of 0.2 mW/cm² existed in the aircraft cockpits. (6 references)

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0210 CALCULATED FIELD INTENSITIES NEAR A HIGH
POWER UHF BROADCAST INSTALLATION. (E.)

Tell, R. A. (U.S. Environ. Prot. Agcy., Silver Spring, Md.) and J. C. Nelson. *Radiation Data and Reports*, 15(7):401-410, July 1974.

A UHF transmitter site in the Washington, D.C. area, which is used cooperatively by two UHF television stations, was chosen for calculations of effective radiated power (ERP), field strength, and power density. Using the specifications for the two broadcasting stations, field strengths and power densities were calculated and presented graphically. The calculated power densities for this broadcasting installation showed that the exposure values fall very sharply as the distance from the tower increases to about 1 mile. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 $\mu\text{W}/\text{cm}^2$ occurring at 0.5, 3.3, and 4.5 miles. As the height above ground at the receiving point is increased, the exposure value generally increases. Based on the calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86,000 people reside in an area within which the estimated exposure is 1 $\mu\text{W}/\text{cm}^2$ or more. (19 references)

0211 RF PULSE SPECTRAL MEASUREMENTS IN THE
VICINITY OF SEVERAL AIR TRAFFIC CONTROL

RADARS. (E.) Tell, R. A. (U.S. Environ. Prot. Agcy., Silver Spring, Md.) and J. C. Nelson. *U.S. Environ. Protection Agency, Off. of Rad. Programs, Md.*, May 1974.

The purpose of this study was to determine the response characteristics of a microwave scanning spectrum analyzer in the presence of a relatively intense and complex electromagnetic environment. Measurements of ambient field intensities were made in the vicinity of three different ground radars used in air-traffic-control operations. Maximum peak field strengths of 960 V/m were measured about 1000 feet from the radar site. Characteristic radar spectrum signatures were recorded by photographing visual displays on the analyzer CRT. (11 references)

0212 PRENATAL EXPOSURE TO AN EXTREMELY LOW FREQUENCY,
LOW INTENSITY ROTATING MAGNETIC FIELD AND IN-
CREASES IN THYROID AND TESTICLE WEIGHT IN RATS. (E.)

Ossenkopp, K. P. (Dept. Psychol., Univ. Manitoba, Canada). *Dev. Psychobiol.* 5(3):275-285, 1972.

Extremely low frequency (ELF) electromagnetic fields and waves (0.1-40 Hz) which occur daily in the environment, are associated with lightning discharges, atmospheric lability, solar eruptions, and geomagnetic micropulsations. In 3 experiments, adult rats that had been exposed to a 0.5-3 or 3-15 gauss ELF (0.5 Hz) rotating magnetic field (RMF) during various periods of gestation, had significantly heavier thy-

roid and testicle weights than controls. The difference in these measures was a function of the field intensity and duration of exposure. Rats exposed prenatally to a sham-RMF (no magnets) did not differ from controls in the above measures. No significant differences were found between the thymus weights, adrenal weights, blood sugar, or circulating blood eosinophil levels of RMF-exposed and control rats. The implications of the thyroid and testicle changes are discussed in terms of the physiological and physicochemical effects of ELF electromagnetic phenomena. (31 references)

0213 THERMAL REGULATION IN LONG-EVANS RATS EXPOSED
TO 2450 MHz MICROWAVE RADIATION. (E.) Houk,

W. M. (Dept. Radiol. Biol. Biophys., Univ. Rochester, N. Y.), S. M. Michaelson and A. Longacre, Jr. *Proc. Am. Physiol. Soc.*, Aug. 24, 1973.

Colonic temperature was measured in 400 unrestrained young male Long-Evans rats which had been exposed to various power levels (9, 18, 36 mW/cm^2) of 2450 MHz (CW) far field microwave irradiation, and maintained under constant environmental conditions. Equilibration times of up to three hours were required in the experimental enclosure, to avoid masking the temperature elevations induced by this unique volume heating agent. Temperature responses appear to be related to power density (exposure) and duration of exposure. Microwave illumination at these power densities causes an increase in colonic temperature in a manner analogous to a fever. However, the problems encountered when altering external environmental conditions, using radiant heat, or injecting pyrogens to analyze the effects of increased body temperature were avoided. A simple model of a microwave irradiated rat and rat carcass is presented, and its use in studying thermal regulation is discussed. (No references)

0214 CARDIAC PACEMAKER ELECTROMAGNETIC INTERFERENCE
(3050 MHz). (E.) Hurt, W. D. (USAF Sch. Aero-
space Med., Brooks AFB, Tex.). *Aerospace Med. Div. Report*
No. SAM-TR-72-36, NTIS: AD-757 930, Dec. 1972, 20p.

Tests were performed to determine the effect of 3050 MHz radiofrequency radiation on cardiac pacemakers. Five pacemaker models were implanted in large dogs, and electrocardiographs of each animal were continuously monitored during exposure to continuous wave, sine wave half-wave rectified, or square-wave modulated signals. Most of the pacemakers exhibited some electromagnetic radiation interference under certain test conditions. The most sensitive unit cut off at 100 volts/meter at pulse repetition frequencies less than 35 pulses/sec, while one pacemaker was unaffected throughout the tests. (1 reference)

- 0215 A MICROWAVE DECOUPLED ELECTRODE FOR THE ELECTROENCEPHALOGRAM. (E.) Larsen, L. E. (Baylor Coll. Med., Houston, Tex.), R. A. Moore and J. Acevedo. *IEEE Trans. Microwave Theory Tech.* MTT-22(10):884-886, Oct. 1974.

In studying the time course of microwave radiation in an unanesthetized animal, one of the measurable electro-physiological responses of the CNS, the EEG figures prominently. The recording of the EEG in an amplitude-modulated microwave field presents two related but distinct problems when conventional electrodes are employed. The electrode and its associated conductors extract power from the incident radiation, resulting in increased local power deposition which confounds dosimetric arguments and imposes local thermalization; the electrode tissue interface is a nonlinear system that demodulates amplitude-modulated signals with the results that the demodulate is additively mixed with the EEG. The problems were studied in a series of bench tests with conventional and thin-film microwave integrated circuit (MIC) electrodes. The latter are decoupled from the magnetic component of the field by virtue of radically reduced dimensions of the thin-loop component of its geometry, and suppression of dipole (i.e., electric field interaction) currents by use of integrated Nichrome series resistance. The result is that the demodulation artifact is undetectable in the ensemble averaged-power spectrum from the *in vitro* electrode up to an S-band incident-power density of 100 mW/cm². Thermalization was studied in a dielectric brain phantom with high-resistance monofilament leads to the MIC with a result that 0.6 C heating is attributable to the electrode with prolonged exposure to a 50-mW/cm² field. (No references)

- 0216 POLARIZATION AND FREQUENCY EFFECTS ON WHOLE ANIMAL ABSORPTION OF RF ENERGY. (E.) Gandhi, O. P. (Dept. Electr. Eng., Univ. Utah, Salt Lake City). *Proc of IEEE*, 62(8):1171-1175, Aug. 1974.

A parallel-plate waveguide is used to determine wide-band RF (285 to 4000 MHz) absorption characteristics of 96- to 390-g Wistar rats, 25-g mice and brain-phantom prolate spheroidal bodies of several aspect (a/b) ratios to 5.75 (the value taken for humans). The results compare well to those of free space irradiation. From the absorption characteristics of 25-g mice and prolate spheroidal bodies for three orientations $\hat{E} \parallel \hat{a}$, $\hat{H} \parallel \hat{a}$, and $\hat{k} \parallel \hat{a}$ (where \hat{a} is along the major length) a strong orientational effect is observed. Alternative experiments using plane waves at 1700 MHz to heat saline-filled prolate spheroidal bodies of fixed aspect ratio 5.75 but changing overall dimensions, corroborate the main features of the WG results. From the excellent correlation between the two sets of values the viability of using parallel-plane WG as a simple method of determining broad-band absorption characteristics of biological systems is indicated. The RF power deposition is found to

vary significantly with orientation and frequency. RF absorption, larger by an order of magnitude or more than for other configurations, may occur at resonance for $\hat{E} \parallel \hat{a}$ orientation, which should be taken into account in microwave biological effects research. (4 references)

- 0217 COMPARATIVE EFFECTIVENESS OF 39- AND 2450-MHz ELECTRIC FIELDS FOR CONTROL OF RICE WEEVILS IN WHEAT. (E.) Nelson, S. O. (Agric. Res. Serv., USDA, Lincoln, Neb.) and L. E. Stetson, J. *Econ. Entom.* 67(5):592-595, Oct. 1974.

A comparison of 39-MHz and 2450-MHz radiofrequency (RF) electrical treatments to control adult *Sitophilus oryzae* (L.) in hard red winter wheat revealed that the 39-MHz treatment was much more effective than treatment at 2450 MHz. Complete insect mortality was achieved by 39-MHz treatments that raised grain temperatures to 40 C; whereas, grain temperatures of ca. 80 C were required for complete mortality in 2450-MHz treatments. Insect mortalities from 39-MHz exposures were much greater 1 day after treatment than were those from 2450-MHz exposures producing comparable grain temperatures. The degree of injury and delayed mortality resulting from 39-MHz exposures also was much more severe than that resulting from 2450-MHz exposures. The results confirmed predictions, based on measurements of dielectric properties of adult rice weevils and wheat, that 39-MHz treatments should provide a much better opportunity for selectively heating the insects than would treatments at 2450 MHz. (11 references)

- 0218 NUMERICAL ANALYSIS OF ELECTROMAGNETIC FIELDS IN BIOLOGICAL TISSUE. (E.) Wu, T. K. (Dept. Electr. Eng., Univ. Mississippi, University) and L. L. Tsai. *Proc. IEEE* 62(8):1167-1169, Aug. 1974.

The feasibility of using integral equation techniques to predict EM fields in biological tissues is demonstrated by analyzing the scattering from arbitrary cylinders composed of lossy dielectric materials. For the circular cylinder case, good agreement is obtained between moment method solutions and exact solutions. To show the applicability to arbitrary geometries, an elliptical cylinder is also considered. (6 references)

- 0219 LETHAL EFFECTS OF 3000 MHz RADIATION ON THE RAT. (E.) Schrot, J. (Dept. Microwave Res., Walter Reed Army Inst. Res., Washington, D.C.) and T. D. Hawkins. *Radiat. Res.* 59:504-512, 1974.

Rats were exposed for short durations (30, 60, 120, and 240 sec) to electromagnetic irradiation at a frequency of 3000 MHz. At each duration of exposure percent mortality increased with increases in inci-

dent energy density (power density X duration). The incident energy density required to kill 50% (LD₅₀) increased monotonically with increasing exposure durations. Lethal power density (LD₅₀) was a decreasing monotonic function of exposure duration. In addition, body weight was found to be a factor in determining mortality. (5 references)

0220 PACEMAKER PERFORMANCE IN THE VICINITY OF FM AND TV TRANSMITTERS. (E.) Vreeland, R. W. (Res. Dev. Lab., Univ. California, San Francisco) and M. D. Shepherd. *Proc. 26th ACEMB*, Sept. 30-Oct. 4, 1973.

Nine pacemakers were tested at a mountain top transmitter site. They included six external demand pacemakers, one of the bipolar implantable demand type, one monopolar implantable demand pacemaker and one monopolar implantable fixed rate unit. Various pacemaker terminations including several standard catheters as well as transmission lines and dipole antennas were studied. Pacemaker performance was clearly a function of the type of termination. Eight of the nine pacemakers were affected. Six of them stopped pacing. The strongest signals at the mountain top were 0.71 and 1.3 volts per meter from two TV stations and 0.47, 0.56, 0.84 and 2.8 volts per meter from FM transmitters. (2 references)

0221 OPERANT BEHAVIOR OF RHESUS MONKEYS IN THE PRESENCE OF EXTREMELY LOW FREQUENCY-LOW INTENSITY MAGNETIC AND ELECTRIC FIELDS: EXPERIMENT 1. (E.) de Lorge, J. (Naval Aerospace Res. Lab., Pensacola, Fla.) *Naval Aerospace Med. Res. Lab. Report No. 1155*, Nov. 1972, 18p.

In an exploratory study of the biological effects of extremely low-frequency magnetic and electric fields of low intensity, two rhesus monkeys were trained on three tasks with food or water as reinforcement: Fixed Interval, Reaction Time, and Match-to-Sample. Following 39 training sessions, the animals were given 26 experimental sessions in the presence of a magnetic field of 10 gauss at 75 Hz, or the magnetic field combined with an electric field of 4 V/m at 75 Hz. Although behavioral changes occurred, no significant changes could be related to the electromagnetic fields. Instead, most changes in performance were a consequence of continuous experimental sessions and elapsed time, or of equipment problems. These results provide supportive evidence that these specific EM fields have no general behavioral influence on nonhuman primates. (20 references)

0222 OPERANT BEHAVIOR OF RHESUS MONKEYS IN THE PRESENCE OF EXTREMELY LOW FREQUENCY-LOW INTENSITY MAGNETIC AND ELECTRIC FIELDS: EXPERIMENT 2. (E.) de Lorge, J. (Naval Aerospace Med. Res. Lab., Pensacola, Fla.) *Naval Aerospace Med. Res. Lab. Report No. 1179*, March 1973, 25p.

Consonant with the U.S. Navy's exploration of the biological effects of extremely low-frequency EM radiation, two rhesus monkeys were exposed to 10-gauss 45-Hz and 10-Hz fields. Low-intensity electric fields occurred simultaneously. No effects of the 45-Hz fields on immediate memory, operant responding, reaction time, or activity were observed. Statistically significant effects were produced by 10-Hz fields, but not in both animals nor in a replication of the experiment. The study failed to provide unequivocal evidence that extremely low-frequency magnetic and electric fields affect behavior, although weak support for effects on 10-Hz fields on general motor activity was afforded. (18 references)

0223 OPERANT BEHAVIOR OF RHESUS MONKEYS IN THE PRESENCE OF EXTREMELY LOW FREQUENCY-LOW INTENSITY MAGNETIC AND ELECTRIC FIELDS: EXPERIMENT 3. (E.) de Lorge, J. (Naval Aerospace Med. Res. Lab., Pensacola, Fla.) *Naval Aerospace Med. Res. Lab. Report No. 1196*, Nov. 1973, 14p.

A magnetic field of 10^{-3} with its associated electric field alternating at 60 Hz and 10 Hz had no discernible effect on operant response-rate, reaction time, match-to-sample behavior, or general motor activity of 2 female rhesus monkeys. No abnormalities in hematological samples or general physical condition were observed at the conclusion of the experiment. The results agree with those obtained in previous experiments on male rhesus monkeys. (20 references)

0224 STUDIES OF THE BIOMEDICAL EFFECTS OF MICROWAVE RADIATION: PAST, PRESENT AND FUTURE. (E.) Glaser, Z. R. (Bur. Med. Surg., Dept. Navy, Washington, D.C.) *Proc. Microwave Power Symp., IMPI*, May 29-31, 1974.

An introduction is given to the study of the biological effects of non-ionizing electromagnetic radiation at radio and microwave frequencies, and the historical perspective is outlined. Studies (including philosophy) conducted during the "Tri-Service Era" (1957-1960), and those described at the Richmond, Virginia (1969), and New York Academy of Sciences meetings (1974) are compared. Biological "effects" reported in the literature prior to 1971 are described, as are current RF/microwave biological studies and experimental problems. Human exposure "standards"; future research needs; and the beneficial effects, uses, and applications of RF/microwave radiation are also discussed. (No references)

0225 CENTRAL MECHANISM OF ACTION OF ELECTROMAGNETIC FIELDS. (E.) Sudakov, K. V. (no affil.) and G. D. Antimony. *USP Fiziol Nauk* (2):101-135, 1973. Translated by Joint Publications Research Service JPRS 60711, Dec., 1973.

The published literature on the biological effects of electromagnetic fields (EMF) is reviewed. The

different aspects considered are the role of natural EMF in the evolutionary processes and their influence on animals and man, participation of EMF in the activity of the central nervous system, sensing of EMF by living organisms, effect of EMF on human and animal behavior, and current concepts of the neurophysiological mechanisms of action of EMF. Data from the authors' own experiments show that EMF acts selectively on limbic structures. Brief exposure of rats to 39 MHz at low intensities (30-100 V/min) stimulated convulsive activity in the limbic structures (mostly in the hippocampus). With increased duration of exposure, the activity spread to other limbic structures and to the cortex. Subsequently, generalized slow-wave activity occurred; and, finally, with exposure of 1 1/2 to 2 hr, a state resembling catalepsy developed. The results suggest disruption of the protective functional system by EMF. (216 references)

- 0226 EEG CONCOMITANTS OF EXPOSURE TO OSCILLATING ENVIRONMENTAL ELECTRIC FIELDS. (E.) Adey, W. R. (Brain Res. Inst., Univ. California, Los Angeles). *Final Report to ARPA, DOD, Research Contract, U. S. Army DADA-17-67-C-7124, Sept. 30, 1970.*

Experiments were conducted to determine the effect of low-level (2.8 volts p-p), low-frequency (7 and 10 Hz) fields on EEG and behavior in *Macaca nemestrina*. Behavioral results for 4-hr exposures showed that the three test monkeys responded slightly faster to the 7 Hz fields. The 10 Hz field did not show a reliable effect. Analysis of the EEG data revealed relative peaks in power at the frequency of the field (7 or 10 Hz) for certain brain structures. These peaks appeared most reliably in the hippocampus and less consistently in the amygdala and center median. The most marked EEG changes occurred in samples of predominantly incorrect responses taken near the end of the 4-hr exposure; a review of the responses showed that they tended to the responses which were too fast rather than too slow. In two monkeys, analysis of peak quotients showed that there was a greater peak in power at the frequency of the field for fast than for slow responses for four of five responsible brain structures. These results suggested that the observed behavioral effect was mediated by a change in the electrical field activity of the brain (especially the hippocampus) at the frequency of the imposed 7 Hz field. No systematic behavior effect was observed in 2-hr exposure tests, while the results of 24-hr exposure showed great variability in behavioral performance. Monkeys were not awakened from sleep by the presence of 7 Hz fields, nor was there any gross distortion in their EEG patterns. External electromagnetic fields of low intensity (1 μ V, 1-100 mV p-p) and low frequency (4-24 Hz) caused no changes in waveform or latency of a visually evoked response in three cats. (4 references)

- 0227 CATARACTS FOLLOWING USE OF MICROWAVE OVEN. (E.) Zaret, M. M. (Bellevue Hosp. Ctr., New York, N. Y.). *NY State J. Med.* 74(11):2032-2049, 1974.

A 51-yr-old woman was examined to determine the etiology of her cataracts which were not of a hereditary or senile type. The previous year the patient had undergone cataract extraction for the right eye after examination revealed that extensive posterior subcapsular opacities were present in both lens but were more advanced in the right eye. Symptoms of early cataract had appeared almost 3 yr earlier, 3 yr after the woman had a microwave oven installed in her home. The current examination indicated aphakia of the right eye and an advanced capsular cataract in the right eye which involved the posterior region of the capsule more than the anterior. At the posterior surface, many regions of the contiguous cortex were also opacified, giving rise to multiple areas with a honeycombed appearance. Before the appearance of early cataract, the patient had used the microwave oven for about 500 hr, opening its door approximately 5000 times. Subsequently, until the oven was found to be leaking microwave radiation (2 mW/cm² during operation and 40 mW/cm² with the door open), she used the oven for about 350 hr and opened the door about 3500 times. The distinctive capsulopathy, the latency period, and the pattern of opacification were concluded to be typical of microwave cataracts. This conclusion is disputed in 5 appended letters of comment and supported in 1. In his response to these comments, the author argues against the concept that all microwave effects are thermal and maintains that this case meets the criteria for a delayed microwave cataract. (5 references)

- 0228 LONG-TERM PROGRAMME IN ENVIRONMENTAL POLLUTION CONTROL IN EUROPE: HEALTH HAZARDS FROM EXPOSURE TO MICROWAVES. (E.) Evaluation Group, *World Health Organisation Report*, WHO Regional Office for Europe, Copenhagen, 1974, 14p.

The Evaluation Group convened by the WHO Regional Office for Europe has recommended a number of measures to determine and reduce the risk to public health from microwave radiation (300 GHz-300 MHz). The recommendations include an interdisciplinary symposium on the physical and biologic aspects of microwave radiation; standardization of nomenclature; a literature survey of biologic effects; interaction between physical, engineering, and biologic scientists; development and standardization of dosimetry and measuring instruments; evaluation of ambient electromagnetic fields; establishment of criteria for epidemiologic studies; personal exposure and product performance standards; evaluation of the compatibility between microwave radiation and medical electronic equipment; evaluation of the risk from diathermy; and training programs for health physicists and public health personnel. (No references)

0229 REVIEW OF A PROGRAM TO ASSESS THE EFFECTS
ON MAN FROM EXPOSURE TO MICROWAVES. (E.)

Michaelson, S. M. (Sch. Med. Dent., Univ. Rochester, N. Y.), *J. Microwave Power* 9(2):147-161, 1974.

An analysis is given of the papers presented at the International Symposium on Biologic Effects and Health Hazards of Microwave Radiation, Warsaw, October 15-18, 1973. Of the 38 papers, 9 were related to the physiopathology of the central nervous and neuroendocrine systems, 8 to epidemiological surveys, and 7 to energy/absorption measurement techniques. Other subjects included cellular and molecular biophysics (4), ocular effects (3), thermal regulation (3), mammalian development (1), combined effects (1), and applications (2). Symposium participants recommended that microwave intensities be classified in three broad categories: (a) above 10 mW/cm², at which potentially hazardous thermal effects occur; (b) below 1 mW/cm², where thermal effects are improbable; and an intermediate range of weak but noticeable thermal effects. The need of further research was stressed for cumulative effects, delayed effects, differential sensitivity, and effects related to cellular transformations. Based in part on the symposium papers, an Evaluation Group convened by the WHO Regional Office for Europe formulated a program to reduce the public health risk from microwave radiation. The program covers the exchange of information, standardization of nomenclature, interaction between physical, engineering, and biologic scientists, evaluation of ambient electromagnetic fields, compatibility between microwave radiation and medical electronic equipment, the significance of diathermy, protection standards and guides, and training programs for the evaluation of microwave and radiofrequency radiation. (No references)

0230 EXPOSURE OF MAN TO MAGNETIC FIELDS ALTER-
NATING AT EXTREMELY LOW FREQUENCY. (E.)

Beischer, D. E. (Naval Aerosp. Med. Res. Lab., Pensacola, Fla.) J. D. Grissett and R. E. Mitchell. *Naval Aerosp. Med. Res. Lab.*, NAMRL-1180, July, 1973.

Ten subjects were confined for periods up to 7 days and during this time were exposed to a low-intensity magnetic field (10^{-4} Wb/m² at 45 Hz) for periods up to 24 hours. Five subjects were confined but were not exposed. A large battery of physiological and psychophysiological tests were given throughout the confinement period. No effects were seen that could be definitely linked with the magnetic field. The only changes that could be correlated with the time course of exposure to the ELF magnetic field were in serum triglycerides of blood samples drawn 14 hours after the evening meal. In 9 of the 10 exposed subjects, serum triglycerides reached a maximum value 24 to 48 hours after the ELF field exposure. Similar trends were not seen in any of the 5 control subjects. For the corresponding period chylomicrons were negligible for all subjects while cholesterol levels were stable and within the nor-

mal range; therefore, the serum triglycerides were in the form of very low density lipoproteins. The number of subjects is too small, however, to exclude statistically other factors such as psychophysiological reactions to forced changes in personal living habits, modified activity, restricted diet, and confinement. A final conclusion must await further experiments and the establishment of a relationship between field strength and physiological effects, as well as establishment of a threshold for the effects. (28 references)

0231 CHANGES IN THE FUNCTIONAL STATE OF THE
BODIES OF WORKERS SERVICING HIGH-FREQUENCY
CURRENT GENERATORS. (Rus.) Stefanov, B. (Hygien.
Epidem. Inst., Varna, Bulgaria) and S. Solakova.
Gig. Tr. Prof. Zabol. (7):44-45, 1973.

Studies were made of 45 male workers, 22-43 yrs of age, exposed to 33 HFC generators of 60-300 KHz, 10-125 kW. The workers were divided into 3 groups depending on the length of exposure: 1 yr, 1-5 yrs, and over 5 yrs. The average daily exposure was 4-5 hr. Twelve nonexposed subjects served as controls. Exposed workers generally complained of asthenia, poor memory, and excessive perspiration. Group 3 had higher irritability, somnolence, poor eyesight, hyperhidrosis, and cardiac pains. Workers in the induction zone had tremor, red dermography, hyperhidrosis and acrocyanosis. Disturbance of the vasomotor and thermoregulating functions as result of exposure to EM fields was also observed. Findings indicate a weaker vascular tonus of 12 mm in systole and 11 mm in diastola. Group 3 exhibited the greatest incidence of asymmetry and hypotonia--33.3% and 41.7%, resp. Pulse rate in exposed workers was higher by 10 per min; cholinesterase function of the blood was inversely proportional to the length of service: 2.9 units in Group 2, 2.6 in Group 3, and 3.1 in controls. Results indicate that workers servicing HFC generators have functional changes in the vegetative nervous system correlated to their length of work. (15 references)

0232 POSSIBLE USE OF MICROWAVES IN THE MANAGE-
MENT OF LUNG DISEASE. (E.) Susskind, C.
(Dept. Electr. Eng. Computer Sci., Univ. California,
Berkeley). *Proc IEEE* 61(5):673-674, 1973.

Microwave techniques may be adaptable to the detection and mapping of excessive fluid accumulation in the interstitial regions of the lung. Adaption of microwave devices for fluid detection is contingent on development of a methodology that would normalize the effects of variations in skin, fat, and muscle layer thickness, the effect of the curvature of the torso, and those of body size and position in the field. Once the difficulties of normalization are overcome, systematic investigation should quickly yield optimum power levels and wavelengths. The relative merits of continuous wave versus pulsed sources should also be investigated;

because thermal effects depend on average power densities, pulsed operation at a suitable duty cycle may permit more efficient operation without hazard to the subject than the continuous wave regime. Radar and scanning-electron-microscope techniques could be applied to the mapping of fluids abnormally present in the lung area. (9 references)

0233 PHYSIOLOGICAL CHANGES IN ADULT RATS
 EXPOSED TO AN ELF ROTATING MAGNETIC FIELD.

(E.) Persinger, M. A. (Dept. Psychol., Laurentian Univ., Sudbury, Canada), G. B. Glavin and K. P. Ossenkopp. *Int J Biometeor* 16(2):163-172, 1972.

Male Holtzman rats between 80 and 150 days of age were exposed either to a 0.5 to 3 gauss or a 3 to 30 gauss extremely low frequency (ELF) (0.5 Hz) rotating magnetic field (RMF) for 5, 10, or 26 days. Among the animals aged at least 115 days, the RMF exposed group consumed more water than an unexposed control group; this difference was significant among the animals exposed to the RMF for 10 or 26 days. The ELF-RMF-exposed rats also showed a progressive decrease in relative thyroid weight with increased body weight up to 10 days of exposure and an increase in testicular weight up to 26 days of exposure. Nonsignificant differences were found between the groups in terms of circulating blood eosinophil count and relative adrenal weight. None of these changes were noted in the 80-day-old rats. The ELF-RMF field may have initiated correlative changes in physiology and behavior by altering the characteristics of the colloid contained in the thyroid follicles of the exposed rats. (26 references)

0234 BEHAVIORAL CHANGES IN ADULT RATS EXPOSED
 TO ELF MAGNETIC FIELDS. (E.) Persinger,

M. A. (Dept. Psychol., Laurentian Univ., Sudbury, Canada), M. A. Persinger, K. P. Ossenkopp and G. B. Glavin. *Int J Biometeor* 16(2):155-162, 1972.

Male Sprague-Dawley, Holtzman, and Wistar rats between 30 and 100 days of age were exposed to an extremely low frequency (ELF) (0.5 Hz), 3-50 gauss rotating magnetic field (RMF) for 21 to 30 days. The subsequent ambulatory behavior of the exposed rats in an open field was significantly increased. In another experiment, the animals were exposed to a different RMF apparatus (3-30 gauss) and tested in a different open field apparatus for a longer period of time. Again, the RMF-exposed group was significantly more active than the control group. The effect showed a high degree of consistency. (14 references)

0235 MATURATION AND OPEN-FIELD BEHAVIOR IN RATS
 EXPOSED PRENATALLY TO AN ELF LOW-INTENSITY
 ROTATING MAGNETIC FIELD. (E.) Ossenkopp, K. P. (Univ.
Manitoba, Canada). *Psychol. Rep.* 30:371-374, 1972.

Rats that had been exposed continuously during their prenatal development to a 3 to 12 gauss, 0.5

Hz rotating magnetic field (RMF) were significantly retarded, in comparison to control group, in time of eye opening ($p < .01$) and time of teeth eruption ($p < .01$), but did not differ significantly in maturation of startle response. The RMF-exposed animals traversed significantly fewer squares than their controls in an open-field situation ($p < .01$), but defecated ($p < .05$) and urinated ($p < .01$) significantly more often, and entered the center circle in the open field significantly less often ($p < .01$). There was no significant difference in the number of rearing responses for the two groups. These results are consistent with the hypothesis that extremely low frequency (ELF) waves alter the ion-milieu near synaptic clefts in such a manner that action potentials result and that the ELF effect is greatest where the synapse density is highest and where the summation of action potentials is likely to take place. (13 references)

0236 THE BASIC BIOLOGICAL DATA TRANSMISSION
 AND CONTROL SYSTEM INFLUENCED BY ELECTRICAL
 FORCES. (E.) Becker, R. O. (VA Hosp., Syracuse,
N. Y.). *Ann NY Acad Sci* 238:236-241, 1974.

All the reported effects of electrical and magnetic forces are on nerve functions or on activities, such as growth and repair, that are under some degree of neuronal control. Most of these effects are on biological functions that are under precise control by mechanisms which elude description by solution biochemistry. Apparently a basic property of living material is responsible for initiating, directing, and controlling responses to trauma and is sensitive to alterations in the electromagnetic parameters of the environment. The presence of two data transmission and control systems in most present-day animals may explain reported electromagnetic phenomena. The one system is a sophisticated, action potential digital-type system, while the other is a more basic primitive analog-type system that antedated the former. The analog system, which resides primarily in the supportive or perineural cells of the nervous system, deals with notification of trauma and the detection of alterations in the environmental electromagnetic field. The general level of activity of the digital action potential system is controlled by direct-current fields in the central and peripheral nervous systems. The overall level of activity of the neural action potential system is set by the perineural system. The influences of low-level electromagnetic parameters on biological systems and parallel phenomena indicate the possibility of an underlying biological control system of considerable import. (36 references)

0237 MICROWAVE AND ULTRASONIC THERAPY OF TAPE-
 TRETINAL DEGENERATION OF THE RETINA.

(Rus.) Lutsker, L. S. (Gelmgolts Moscow Sci. Res. Inst. Eye Diseases, USSR) and S. M. Nurieva. *Vest. Oftolmol.* 5:69-71, 1973.

Studies were made of both consecutive and combined microwave and ultrasonic treatment of retina degeneration of 126 eyes in 65 patients aged 7-60, of whom 53 had retinitis pigmentosa, 9 had Stargardt's disease, and 3 Best's disease. Microwave therapy included 20 daily sessions of 10-15 min at 20 W, distance 9 cm, emitter diameter 9 cm. Ultrasonic therapy included 20 daily sessions of 5 min at 800 KHz, power density 0.3 W/cm². Nearly all the patients received vasodilative therapy of nicotinic acid administered by injections or electrophoretically. Mean average visual acuity before the treatment was 0.25, after treatment 0.33. Combined therapy proved to be more effective (increase of mean average visual acuity of 0.13) than each method used separately (increase of 0.07 for microwave, and 0.06 for ultrasonic treatment). The combined treatment is recommended for managing tapetoretinal degeneration of the retina. (12 references)

0238 BIOLOGICAL EFFECTS OF NON-IONIZING RADIATION: AN OUTLINE OF FUNDAMENTAL LAWS. (E.) Romero-Sierra, C. (Dept. Anat., Queen's Univ., Kingston, Canada) and J. A. Tanner. *Ann NY Acad Sci* 238:263-272, 1974.

Exposure of the sciatic nerve of the rat to a continuous-wave electromagnetic field at 27 MHz for 5-30 min produced demyelination and hypermyelination, changes in the collagen content, and varying degrees of axonal and Schwann cell damage. Demyelination ranged from a minimal alteration of myelin lamellar array to the complete denudation of axons. The effect was directly proportional to exposure time and inversely related to distance. Collagen content increased after a brief exposure and collagen-like fibrils protruded from Schwann cell cytoplasm into the endoneural space. In other experiments, rats with a 1-15-cm wound below the scapulae were treated with saline, 15-min exposure to 27 MHz, histamine (1.0 mg/ml), or histamine and a 27-MHz field. The cosmetic appearance of wounds treated with an electromagnetic field and histamine was superior to that of the other three treatment groups, and fewer white blood cells were present in the incisional gap of rats receiving this treatment. These findings show that electromagnetic fields imposed on a living system modify the electromagnetic interaction that exists between glial and neuronal cells inside a nervous structure. To predict the consequences of any interaction, all parameters that characterize the electromagnetic field, the environment, and the subject radiated must be quantified and integrated. (30 references)

0239 USE OF A BACTERIOPHAGE SYSTEM FOR INVESTIGATING THE BIOLOGICAL EFFECTS OF LOW INTENSITY PULSED MICROWAVE RADIATION. (E.) Walker, C. M. (Surg. Med. Res. Inst., Univ. Alberta, Edmonton, Canada), K. G. McWhireter and W. A. G. Voss. *J Microwave Power* 9(3):221-229, 1974.

The influence of 2450 MHz microwave radiation, pulsed at 8 KHz, on the number of infections of *Escherichia coli* B by phage T4r_{II} was examined. Low level radiation at a power density between 1 and 10 mW/cm² was used, the biological samples being irradiated in S-band waveguide. The results indicate that this pattern of radiation does not have a statistically significant effect on the number of infections. (30 references)

0240 A PILOT STUDY OF THE INTERACTION OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS WITH BRAIN ORGANELLES. (E.) Riesen, W. H. (IIT Res. Inst., Chicago, Ill.), C. Aranyi, J. L. Kyle, A. R. Valentino and D. A. Miller. Contract N00039-71-C-0111, Proj. E6185, Tech. Memo. #3, Aug. 1971, 27p.

Two types of subcellular particles (mitochondria and nerve ending particles) were exposed in vitro to extremely low frequency (ELF) non-ionizing and magnetic fields. An appropriate biochemical function was monitored simultaneously for both exposed and unexposed particles. Exposure to a 60-Hz, 100-gauss magnetic field, at 10 C for up to 110 min, had no demonstrable effect on isolated brain mitochondria from young adult male guinea pigs. Isolated brain synaptosomes from weanling or aged Sprague-Dawley rats were exposed to a 60-Hz field at 50-100 gauss at 37, 25, 10, and 0 C for 30 min. Uptake of ³H-norepinephrine was measurably depressed only under the 0 C condition. No trends were suggested by the data from weanling or aged rats. Exposure of guinea pig brain and liver mitochondria to an electric field of 6.3 V/m at 60 Hz for 60 min at 4 C had no demonstrable effect on oxidative phosphorylation. Exposure of brain mitochondria to an electric field of 155 V/m for 15 min had no effect, but after 40 min resulted in complete loss of respiratory control and total uncoupling of oxidative phosphorylation. (9 references)

0241 OCULAR HEATING DURING DENTAL DIATHERMY TREATMENT. (E.) Tell, R. A. (Off. Res. Monitoring, Environ. Prot. Agency, Rockville, Md.) and J. B. Kinn. *J. Oral Surg.* 30:284-287, 1972.

A dielectrically equivalent phantom human head was given a typical diathermy treatment of the jaw. Irradiation was performed with a diathermy unit operating at 2450 MHz and capable of delivering 100 W of power to the applicator. Temperature measurements were made to assess the degree of microwave hazard to the eye. The results show that treatments as long as 8 min can produce temperature elevations of 1.6-2.4 C in the midpoint of the eye on the treated side. Extra caution against radiation of the orbital region should be exercised during any facial diathermy treatment technique. (9 references)

- 0242 HEALTH SURVEILLANCE OF PERSONNEL OCCUPATIONALLY EXPOSED TO MICROWAVES. I. THEORETICAL CONSIDERATIONS AND PRACTICAL ASPECTS. (E.) Czerski, P. (Dept. Sanit. Inspection, Ministry Hlth. Social Welfare, Warsaw, Poland), M. Siekierzynski and A. Gidyński. *Aerospace Med* 45(10):1137-1142, 1974.

Medical data for 841 men (aged 20-45 yr) occupationally exposed to microwaves were analyzed for incidence of causes of inability to continue work. The population was divided into two groups: one consisting of 507 men exposed to mean power densities above 2 W/m^2 ; the second of 334 men exposed to power densities below 2 W/m^2 . Each group was further subdivided according to age or duration of work. Causes of inability to continue work were classified as ophthalmologic contraindications, severe functional disturbances, and other causes including endocrinologic disorders, blood and blood-forming system disorders, traumas, and disorders of the digestive tract. The difference in microwave exposure levels of the two groups did not influence the incidence of disorders considered contraindications for continued exposure. No significant correlation between causes of inability to continue work and level or duration of microwave exposure was demonstrated. In the second group, there was a significant correlation with age. Comparison of low- and high-level exposure groups may be helpful in perfecting the method of health surveillance of microwave workers. (15 references)

- 0243 HEALTH SURVEILLANCE OF PERSONNEL OCCUPATIONALLY EXPOSED TO MICROWAVES. II. FUNCTIONAL DISTURBANCES. (E.) Siekierzynski, M. (Military Med. Acad., Warsaw, Poland), P. Czerski, H. Milczarek, A. Gidyński, C. Czarnecki, E. Dziuk, and W. Jedrzejczak. *Aerospace Med* 45(10):1143-1145, 1974.

The incidence of functional disturbances (neurotic syndrome, gastro-intestinal tract disturbances, cardio-circulatory disturbances with abnormal ECG) was analyzed in 841 males aged 20 to 45 years, occupationally exposed to microwaves for various periods of time. The whole population was subdivided into two groups differing only in respect to microwave exposure--low; i.e., below 0.2 mW/cm^2 and high; i.e., between 0.2 mW/cm^2 and 6 mW/cm^2 . No dependence of the incidence of functional disturbances on the exposure level or duration of occupational exposure (years) could be demonstrated. (4 references)

- 0244 HEALTH SURVEILLANCE OF PERSONNEL OCCUPATIONALLY EXPOSED TO MICROWAVES. III. LENS TRANSLUCENCY. (E.) Siekierzynski, M. (Military Med. Acad., Warsaw, Poland), P. Czerski, A. Gidyński, S. Zydecki, C. Czarnecki, E. Dziuk and W. Jedrzejczak. *Aerospace Med* 45(10):1146-1148, 1974.

The incidence of lenticular opacities was examined in 841 workers (aged 20-45 yr) exposed to microwave mean power densities from $2-60 \text{ W/m}^2$ (507 individuals) or below 2 W/m^2 (334 individuals). The incidence of opacities was compared between both these groups, subdivided according to age or duration of occupational exposure. Lens opacities were not dependent on microwave exposure level or on duration of exposure. A clear-cut dependence on age was demonstrated. (8 references)

- 0245 THE EFFECTS OF PULSED ELECTROMAGNETIC ENERGY ON PERIPHERAL NERVE REGENERATION. (E.) Wilson, D. H. (Gen. Infirm., Leeds, England), P. Jagedeesh, P. P. Newman and D. G. F. Harriman. *Ann NY Acad Sci* 238:575-585, 1974.

The median ulnar nerve in the left forelimb of a series of pairs of Wistar rats was divided and sutured under a general anesthetic. Subsequently, 1 rat from each pair was exposed 15 min/day to pulsed electromagnetic radiation (975-W emission for 65 μsec at 27.12 megacycles). Clinical observations showed that the wounds in the treated animals healed in 4 days, whereas wounds in the controls required 7 days. Treated rats began to use their left forelimb after 10 days; the untreated rats required 3 weeks to reach this same stage of recovery. Nerve conduction studies at 12 days showed a modified biphasic response to an 0.5-V stimulus in the treated nerve but none in the untreated one. At 30 days, a biphasic action potential was demonstrated in the treated animals after a stimulus of 1.0 V; and at 45 days, the nerve conduction tracing was indistinguishable from that of a normal nerve. Nerve conduction in untreated rats did not return before 60 days. Histologic preparations revealed that at 30 days, the nerve in the treated animal had progressed further toward recovery than had the nerve of an untreated animal at 60 days. Nerve dissection was relatively simple in treated animals but was difficult in untreated rats due to considerable scarring and fibrous tissue around the nerve suture site. Problems of applying these findings to the treatment of patients include the daily dosage of pulsed electromagnetic energy involved and the possibility that damage to surrounding tissue may complicate the treatment. (1 reference)

- 0246 DIFFERENTIAL BIOLOGIC EFFECTS OF PULSED AND CONTINUOUS ELECTROMAGNETIC FIELDS AND MECHANISMS OF EFFECT. (E.) Frey, A. H. (Randomline, Inc., Huntingdon Valley, Pa.). *Ann NY Acad Sci* 238:273-279, 1974.

Specific examples of electrical fields and tissue interactions are given. Human subjects perceived "sounds" when illuminated with pulsed, but not with continuous, electromagnetic energy at 0.3-3 GHz,

the portion of the electromagnetic spectrum at which electromagnetic energy passes into and through the head. The effect was related to peak power; average power was relatively unimportant. In the cat brain, responses were evoked with pulse-modulated ultrahigh-frequency energy (1.2-1525 GHz). The threshold power required to elicit activity was $30 \mu\text{W}/\text{cm}^2$ average and $60 \text{mW}/\text{cm}^2$ peak. Variation in power density had a distinct effect on the evoked activity. In another experiment, heart beat increased significantly when the heart was illuminated 200 millisecond after the P wave, about the time the QRS complex occurred (in ECG). Arrhythmias occurred in 1/2 the cases and were associated with radiofrequency illumination. Electrical fields at low levels could influence neural conformational changes that are significant in information transfer and storage in the nervous system. Other possible hypotheses are concerned with field-induced forces on the neural junction and its effects; the apparent ability of tissue to act as a wax electret; and the possibility of microthermal effects. Previous investigators have suggested that radiofrequency energy can produce localized temperature gradients that cause thermoosmotic and thermoelectric after-effects. Further study of electrical field interactions with tissue should add to the understanding of growth processes and repair. (29 references)

- 0247 RADIATION LEAKAGE CONTROL OF INDUSTRIAL MICROWAVE POWER DEVICES. (E.) Elder, R. L. (Bur. Radiol. Hlth., Rockville, Md.), J. A. Eure and J. W. Nicolls. *J Microwave Power* 9(2):51-61, 1974.

The current responsibilities and activities of the Bureau of Radiological Health in carrying out the requirements of the Radiation Control for Health and Safety Act of 1968 are reviewed, especially in relation to industrial uses of microwave power. Power levels of industrial microwave units range from 1.0-200 kW and average 25 kW/unit compared to ranges of up to 2.0 kW for commercial ovens and 0.5-1.0 kW for household ovens. Although the industrial operator of microwave equipment constitutes a very small fraction of the total population exposed or potentially exposed to radiation leakage, the duration of his exposure can be on the order of hours. Based on a survey conducted at manufacturers' facilities, the Bureau has recommended a number of safety features to ensure that microwave leakage does not exceed design limits. Another investigation has resulted in recommendations for improving the operating safety of 15 conveyerized, industrial microwave processes operating at 915 or 2450 MHz. Means for accurate power density measurements at other wavelengths are not available. Performance standards which have been promulgated include those for microwave ovens, television receivers, demonstration cold-cathode gas-discharge tubes, and diagnostic x-ray systems. Responsibilities of the manufacturer under the Radiation Control for Health and

Safety Act include submission of initial reports on new electronic products, reports of model changes, annual reports, and reports of accidental radiation occurrences. Close cooperation between the Bureau of Radiological Health and state and local agencies should ensure the proper maintenance and use of industrial electronic products. (23 references)

- 0248 GENERATION OF ACOUSTIC SIGNALS BY PULSED MICROWAVE ENERGY. (E.) Sharp, J. C. (Walter Reed Army Inst. Res., Washington, D. C.), H. M. Grove and O. P. Gandhi. *IEEE Trans Microwave Theory Tech.* MTT-22(5):583-584, May 1974.

An acoustic signal was produced when short microwave pulses were directed at a carbon-impregnated polyurethane absorber used to shield portions of an observer's head from radiofrequency radiation. When the distance from the absorber to an acoustically coupled sound meter was 1.43 m, the sound arrived approximately 4.68 millisecond after application of triggered pulses 14 μsec long. The net transmitted power was determined to be 4500 W/pulse, yielding a calculated power density of $7.5-15 \text{kW}/\text{m}^2$ for a working distance between 0.3-0.6 m. The quality and amplitude of the acoustic signal did not differ when the carrier frequency was changed from 1200 through 1600 and 2450 MHz. Several types of absorber produced audible sounds as did loosely crumpled aluminum foil. The threshold power/pulse for audibility, under less than ideal conditions, was 275 W peak for an estimated peak power density from $0.46-0.92 \text{kW}/\text{m}^2$. The phenomenon may be due to the fact that radiation pressure exerted on surfaces causes changes in the magnitude and/or orientation of impinging electric and magnetic fields. Other transduction mechanisms may be operating when humans "sense" microwave pulses. Bone has piezoelectric properties and the difference of potential resulting from bone deformation has been measured; if the radiation pressure or electrostrictive forces are sufficient in the irradiated cranium to engender such a potential difference, there could be an electrically mediated sensation. Direct acoustic excitation of the auditory organ may occur via bone conduction of such a vibration or the basilar membrane may directly couple with the microwave energy. (4 references)

- 0249 MICROWAVE CATARACTS. (E.) Appleton, B. (Walter Reed Army Med. Ctr., Washington, D. C.). *JAMA* 229(4):407-408, 1974.

Over a 5-yr period detailed lens examinations were performed on personnel with the greatest likelihood of exposure to microwaves at military bases. Age- and sex-matched personnel with minimal exposure served as controls. Biomicroscopically physical signs that are considered to be components or pre-

cursors of cataract occurred equally in both groups. It was therefore concluded that no lens damage was caused by occupational exposure to microwave energy. None of 7 persons with presumed acute exposure to microwave energy sustained any physical evidence of superficial burn production, nor was there any evidence of eye damage; the ocular status of all individuals examined was consistent with their age. Some persons previously identified as having "early microwave cataract" or "early microwave lens effect" were also studied. Their visual acuity and the appearance of their lenses by slitlamp examination changed very little over the 5-yr survey period. This suggested that if microwave lens effects existed, they were nonprogressive, or that the physical signs previously identified as microwave lens effects were nonspecific changes with very little progression. In another study, 19 diathermy workers were compared with age- and sex-matched controls from the same hospital. Ocular examination showed no differences between the diathermy workers and the controls. The data indicate that (1) lens damage probably has not occurred in humans from cumulative exposure to low levels of microwave energy and (2) lens damage probably could not occur in a human from acute exposure without associated severe facial burns. (No references)

0250 ELECTROMAGNETIC RADIATION INTERFERENCE WITH CARDIAC PACEMAKERS. (E.) Ruggera, P. S. (Bur. Radiol. Hlth., Div. Electron. Prods., Rockville, Md.) and R. L. Elder. *Bureau of Radiological Health Publication* 71-15, April, 1971, 36p.

The Division of Electronic Products, Bureau of Radiological Health, has initiated a study to determine the relative danger presented to cardiac pacemaker patients by the microwave oven in comparison with other known sources of electromagnetic radiation. This report explains how pacemakers and microwave ovens function, describes the mechanism of electromagnetic interference, and outlines the status of Division of Electronic Products activities in this area. The microwave oven performance standards specify a maximum average leakage of 5 mW/cm² for the life of the product. At this rate of leakage, assuming a plane wave, power density 5 ft from the oven would be 5.4 μW/cm²; the electric field intensity in the air at the same distance would be 44 mV/cm. Assuming that 50% of this is absorbed by the body, 31 mV could be available to every cm of exposed circuitry. Comparing this to the 5- to 15-mV sensitivity of the pacemaker, the probability of interference cannot be dismissed. However, the oven is not the only or most dangerous source of interference. Any signal with a fast rise time, thus containing many high-frequency components, is capable of disrupting pacemaker function. (49 references)

0251 ELECTRIC FIELD EFFECTS IN SELECTED BIOLOGIC SYSTEMS. (E.) Marino, A. A. (VA Hosp., Syracuse, N. Y.), T. J. Berger, J. T. Mitchell, B. A. Duhacek and R. O. Becker. *Ann NY Acad Sci* 238:436-444, 1974.

Since low-level, trigger effects induced by electromagnetic fields do occur in mammalian systems, this study investigates the question of whether such effects are induced by electrostatic fields (ESFs). Male Sprague-Dawley rats were continuously exposed to ESFs for 30 days, to determine the biologic effects of the fields. In another experiment, female Swiss Ha/ICR mice were injected with Ehrlich ascites tumor cells and studied for the effect of ESFs on the ascites cell chromosome pattern after 14 days exposure. Secondary glaucoma developed in 16% of 56 Sprague-Dawley rats exposed to vertical ESFs (6-197 V/cm) but the effect was not seen in the 42 rats subjected to horizontal ESFs (3-98 V/cm) or in the 72 control rats. Significant differences in serum proteins occurred between rats exposed to the three highest vertical ESF fields (28, 56, and 197 V/cm) and controls. The ratio of albumin proteins to nonalbumin proteins increased for vertical ESFs of 197 and 28 V/cm and decreased for the vertical ESF of 56 V/cm. The percentage of abnormal chromosomes in Ehrlich ascites tumor cells increased 4-fold after 14-day exposure to ESFs at 8-160 V/cm. The average number of abnormalities/cell in experimental animals was more than twice that of controls. These results confirm the existence of ESF-induced trigger phenomena in biologic systems. (18 references)

0252 BENEFICIAL AND HARMFUL ACCELERATED GROWTH INDUCED BY THE ACTION OF NON-IONIZING RADIATION. (E.) Tanner, J. A. (Control Systems Lab., National Res. Council, Ottawa, Canada) and C. Romero-Sierra. *Ann NY Acad Sci* 238:171-175, 1974.

Both beneficial and noxious effects of microwaves were observed in experiments on birds and plants. Exposure of Leghorns to 7.06 GHz at field intensities up to 1000 μW/cm² increased egg production, but the death rate of the irradiated colony was almost double that of controls. In other experiments, the reactions of chickens with and without tail feathers were compared. After 1-20 sec irradiation at 9.29 GHz (burst frequency, 416 pulses/sec; pulse width, 2.35 μsec), chickens with feathers showed mounting signs of distress in the form of vocalization, defecation, and initiation of flight. Similar and much longer irradiation periods produced little or no reaction in defeathered birds. Experiments at 16 GHz revealed that the elicited response was frequency dependent. To determine the nature of the interaction with feathers, sections of the calms of chicken feathers were subjected to electrical excitation at 0.1-10 kHz. An axial twisting of the long fibrous molecules was induced, with

high cholesterol diet and was continued for 5 weeks. A large discrepancy in lipid levels between the experimental and control animals developed two weeks after the treatments were begun. Animals irradiated for 180 min/day, rather than 90 min, showed a greater and more prolonged lowering of cholesterol levels. Treated animals showed about 15% gross aortic lipid deposits, compared with about 30% for controls (6 controls; 6 experimental). The effects described may be due to an activation of lipid catabolism caused by the radiation treatments. (1 reference)

0253 PANCREATIC FUNCTION IN GASTROINTESTINAL DISEASES FOLLOWING ULTRA-HIGH FREQUENCY THERAPY. (Rus.) Korepanov, A. M. (Izhevsk Med. Inst., USSR). *Sov. Med.* (6):101-105, 1973.

Data on the effect produced by UHF-therapy administered in oligothermal doses on the external and internal secretory function of the pancreatic gland, both when it is dispensed in a single sitting and course-wise, are offered. The external secretory function was investigated in 207, internal secretory in 196, patients who suffered mainly from chronic cholangiohepatitis (318 cases). Single sittings were seen to cause an increased external secretion and activity of the blood enzymes (within the limits of normal fluctuations). With initial hypo- and hyperglycemia there was noted a tendency towards normalization of glycemia on an empty stomach. Course-wise treatment showed positive dynamics in many of the parameters under study. (3 references)

0254 THE EFFECT OF SLIGHT DROPS IN ELECTROMAGNETIC FIELDS ON THE BIOELECTRIC ACTIVITY OF THE HUMAN BRAIN. (Rus.) Mikhailova-Lukasheva, V. D. (Gerontology Section, Acad. Sci., Beloruss. SSR), A. V. Skripal, V. P. Melnikov, and V. P. Korotkii. *Dokl. Akad. Nauk BSSR* 17(7):672-674, 1973.

Studies were made to elucidate the effects of electromagnetic fields (EMF) on the information action functioning of the human brain. EEG measurements of the bioelectric activity of the sinciput were made in 7 subjects, aged 20-30, exposed for 25-30 sec to an EMF drop of the order of 10^{-14} W/sec and frequency spacing of 2.8-10 and 400 Hz of coherent radiation. Three subjects were exposed to the same frequency spacing and white noise drop of 50 Hz to 6 mHz. Preliminary data indicate that the reaction of the subjects to EMF action varies considerably. Substantial changes in bioelectric activity were observed in 6 subjects exposed to 400 Hz, and only in 4 exposed to 2-10 Hz. The most pronounced decrease of bioelectric activity was observed in β , α and δ rhythms. Distinct changes were observed in θ rhythms of the 3 subjects exposed to the action of white noise, with only minor responses in other rhythms. (8 references)

0255 PECULIARITIES IN METABOLISM OF SKELETAL MUSCLES IN RATS UNDER EFFECT OF PULSED ELECTROMAGNETIC FIELD OF LOW FREQUENCY. (Ukr.)

Kolodub, F. A. (Res. Inst. Labor Hyg. Prof. Diseases, Kharkov, USSR) and H. P. Evtushenko. *Ukr. Biokhim Zh.* 45(3):356-361, 1973.

The effects of pulsed electromagnetic fields (PEMF) on the supply of macroergic compounds to the skeletal muscles of rats was studied using low frequency (7kHz, 72 and 24 kA/m) radiation. Oxidative phosphorylation processes, carbohydrate metabolism, and the systems participating in the formation and removal of ammonia in muscle tissues were also examined. It was found that PEMF causes a decrease in ATP content and creatinephosphate, due to separation conjugation of oxidation with phosphorylation and glycolysis intensification. Increases were also observed in protein desamidization (a decrease in the content of protein nitrogen amide), desamidization of adenosine, adenylic (activation of adenosine- and adenylyatedesaminases) and glutaminic acids, with the absence of corresponding intensification of glutamine synthesis resulting from ATP deficit. A considerable increase in the content of ammonia in the skeletal muscles, reaching in some periods to 76.3%, also resulted. (23 references)

0256 ACTION OF ELECTROMAGNETIC WAVES AND OF MAGNETIC FIELDS ON LIPID CHANGES IN THE RABBIT CAUSED BY THE ADMINISTRATION OF A HIGH CHOLESTEROL DIET. (Fr.) Pautrizel, R. (UER Médicale, Bordeaux, France), A. Priore, M. Dallochio and R. Crockett. *C. R. Acad. Sci. [D] (Paris)* 274:488-491, 1972.

Forty-two male Fauves de Bourgogne rabbits were fed a diet containing about 1 g cholesterol/animal/day; 24 experimental animals also received daily exposure to electromagnetic waves and magnetic fields for 90 or 180 min. Blood samples were taken weekly from each animal and analyzed for lipid content; 30 animals were examined for the extent of lipid deposits on the aorta. Experimental animals were divided into 3 groups: (1) Blood sampling, irradiation, and high cholesterol diet began at the same time. Irradiation continued for 15 days. Blood samples taken 3 weeks after the beginning of the experiment were the first to show a significantly lower lipid content for the experimental than for the control animals. The difference in cholesterol levels was the most pronounced (6 controls; 6 experimental animals). (2) Radiation was given from 2 to 4 weeks. In all cases, the difference in lipid content between experimental and control animals became noticeable after the third week. The effect continued for 2 to 3 weeks after discontinuation of the treatment. Gross lipid deposits covered about 20% of the surface of the aorta for experimental animals, compared with about 50% for controls (6 controls; 12 experimental). (3) Radiation treatment was instituted 5 weeks after the clearly defined resonance characteristics. Based on measures of trajectory, frequency of escape responses, and feeding behavior, a 16 GHz pulsed-radiation field had an aversive effect on para-keets in flight. The effect was enhanced by steam and reduced by cold vapor. Other harmful effects of electromagnetic radiation were demyelination of nerve tissue in rats exposed to 9.29 GHz (burst frequency, 416 pulses/sec; pulse width, 2.35 μ sec)

and permanent wilting of most plants exposed to continuous-wave 10 GHz fields at a field intensity of 190 mW/cm². The results indicate that electromagnetic field intensity *per se* is a meaningless quantity without also defining the parameters that relate to the biological effects of the field. (9 references)

0257 THE EFFECT OF DECIMETER WAVES ON THE HYPHYSAL AND ADRENOCORTICAL FUNCTION IN RABBITS. (Rus.) Grigorieva, V. D. (Central Sci. Res. Inst. Hlth. Resorts Physiotherapy, Moscow USSR.), A. I. Zolnikova, S. Kh. Kubli, and L. I. Maksimova. *Vopr. Kurortolog.* (38):488-490, 1973.

The effects of 65 cm radiation (460 MHz) at subthermal (110 mW/cm²) and thermal (330 mW/cm²) doses on the back, in the area of D₁₀ - L₄ vertebrae including the adrenal glands, were studied in 70, 2.5 kg - 3 kg, rabbits. Six-minute daily exposures lasted for 12 days. The animals were divided into 6 groups. The first two were exposed to 110 mW/cm², the third to 330 mW/cm², the fourth was unexposed controls. In the fifth group, exposed to 110 mW/cm² a pathological condition was induced by s.c. injection of Freund adjuvant. The sixth group was also injected with adjuvant and used as unexposed controls. Exposure at 110 mW/cm² stimulated the hypophyseal and adrenocortical function; content of 11-hydroxycortico steroids in the blood rose by 93%, noradrenalin by 50%. Elevation of adrenalin and noradrenalin in the adrenal glands rose by 13% and 4-fold, resp. In hypothalamus noradrenalin and adrenals rose by 12% and 80%, respectively, and dopa rose 10 times. In the heart, noradrenalin rose 25%. The stimulating effect of the exposure persisted for 20 days. Exposure at 330 mW/cm² had an adverse effect on the hypophyseal and adrenocortical function. Findings indicate that Freund adjuvant injected s.c. (0.7-0.8 mg/kg) inhibits inflammations and results in far lesser injuries of the joints and viscera in the animals exposed to 110 mW/cm² power density than in the controls (Group 6). The latter had an acute inflammatory process. The results indicate that certain exposure levels in the decimeter range may be used as a preventive measure to protect the organism from adverse effects of some agents. (6 references)

0258 THE EFFECTS OF EXPOSURE TO THE UHF FIELD. (Rus.) Gembitskii, E. V. (no affil.). *Voен. Med. Zh.* (10):58-63, 1973.

Biophysical, physiological and clinical aspects of UHF effects are reviewed. The biophysical mechanism of microwave absorption is believed to involve the vibration of ions and water dipoles and resonance power absorption by cellular protein molecules. Studies of the nonthermal effects of the UHF exposure indicate that radiation of large animals at power density 1-3 mW/cm² results in central nervous system disorders, bradycardia, hypotension, and slight bio-

chemical and immunological changes. The mechanism of subcellular disorders caused by nonthermal radiation has not been elucidated. It may be assumed that direct heating of cellular microstructures is involved. Pathogenic UHF effects include functional changes in the cells, above all in the central nervous system and receptors; disorders of the reflexory-humoral regulation of the viscera and metabolism; and secondary changes in the viscera. Disorders caused by the UHF field may be acute and chronic. Prior literature describes no more than 10 cases of acute cataract (2-3 months) after exposure from several hundred mW/cm² to several W/cm². Chronic disorders are more frequent. Generally, patients begin to complain of asthenia, tremors in the hands and lids, hyperhidrosis and acrocyanosis, 2-5 years after occupational exposure. In severe cases various diencephalic disorders are observed. Treatment aims at restoring the central nervous functions. The use of valeriana, bromine, somnifacients, antihistaminic drugs and tranquilizers has been effective. Other methods include parenteral administration of vitamin B₁, injections of cortin and anabolic hormones. The USSR Ministry of Health has set the following maximum exposure times for UHF hazardous jobs: 8 hr at under 10 μW/cm², 2 hr at 100 μW/cm², 15-20 min at 1,000 μW/cm². (6 references)

0259 THERAPEUTIC EFFECT OF MICROWAVES ON CHRONIC NONSPECIFIC DISEASES OF THE RESPIRATORY TRACT IN CHILDREN. (Rus.) Stepanova, L. T. (Moscow Inst. Pediatr. Child Surgery, USSR). *Vopr. Kurortol. Lech. Fiz. Kult.* 38:143-147, 1973.

Studies to evaluate microwave therapy of chronic bronchial and pulmonary pathology in the active inflammatory period, and to elucidate the physiological reaction to microwave exposure, involved 95 children, aged 7-14 yrs. Sixty-five of the children had chronic pneumonia, and 30 bronchial asthma; 104 healthy children, aged 7-15, served as controls. The children with chronic pneumonia were divided into three groups: 13 with moderate pulmonary fibrosis without grave localized deformation of the bronchial trunk, 18 with anatomic changes in the bronchial trunk, and 34 with chronic pneumonia with diffuse bronchiopulmonary changes. Treatment consisted of ten 6-8 min daily exposures of the interscapular region at 2-6 W, depending on age. The treatment had a favorable effect on the pulmonary ventilation and gaseous exchange. The respiration rate in children with chronic pneumonia and bronchial asthma dropped from 118 to 109, and from 111 to 106, respectively. The alveolar-total ventilation ratio increased from 50 ± 1.2% to 56 ± 1.8% in Group 1, and from 45 ± 3.1% to 53 ± 2.1% in Group 2. Most of the children in Group 1 showed positive clinical and roentgenological changes. The treatment was least effective in Group 3 with irreversible bronchial and pulmonary changes. The results indicate that microwave treatment has a spasmolytic effect which is particularly manifested in children with bronchial asthma. (12 references)

0260 CHANGES IN TISSUE RESPIRATION AND OXIDATION-REDUCTION ENZYMES IN THE GASTROINTESTINAL ORGANS AFTER EXPOSURE TO ELECTROMAGNETIC FIELDS IN METER RANGE. (Rus.) Faitelberg-Blank, V. R. (Odessa Agricultural Inst., USSR) and E. V. Bykova, *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (37):426-432, 1972.

Oxygen uptake of the liver, mucosa of the stomach, and small and large intestines was measured in 143 albino rats to study the effects of inductothermy at 13.56 MHz, and UHF fields at 39 MHz, on tissue respiration and the activity of peroxidase and catalase. Anode current of 120-280 milliamps were used in inductothermy and UHF fields of 40-300 watts. Measurements were made immediately after exposure, and after 30 and 60 min. At UHF exposure of 40 W for 10 min, oxygen uptake in the liver and respiration in the small and large intestines tended to increase, while in the gastric mucosa it decreased from 6.7 to 5.6 μ l. Exposure at 80 W for 20 min. inhibited O₂ uptake in all the organs. Findings indicate that inductothermy and UHF fields affect tissue respiration and the activities of peroxidase and catalase. The changes correlate with the intensity of the field and duration of exposure. The intensity and direction of change obviously depend on the different patterns of energy absorption in the organs involved. Changes in the peroxidase and catalase activity in the gastrointestinal organs exposed to UHF radiation were as follows:

	Controls	Exposure Time/UHF Field (Minutes/Watts)			
		10/40	10/80	20/80	20/300
Liver					
Perox.	57.8	68.5	63.0	40.2	49.3
Catal.	15.7	16.8	10.9	17.8	17.8
Stomach					
Perox.	31.4	23.6	15.0	39.4	45.7
Catal.	10.0	6.4	4.9	7.4	5.6
Sma. Intest.					
Perox.	44.1	54.2	16.3	30.2	35.7
Catal.	11.6	8.7	4.8	6.7	6.1
Lrg. Intest.					
Perox.	18.1	18.3	18.0	10.0	13.3
Catal.	4.8	8.2	8.2	4.7	3.0

(22 references)

0261 THE EFFECT OF STIMULANTS OF THE CENTRAL NERVOUS SYSTEM AND ADRENAL GLAND HORMONES ON THE OUTCOME OF ACUTE INJURIES IN MICE EXPOSED TO UHF RADIATION. (Rus.) Koldaiev, V. M. (Vladivostok Med. Inst., USSR). *Biull. Eksp. Biol. Med.* 76:27-28, 1973.

Studies were made of the effects of stimulants of the central nervous system and adrenal gland hormones on the survival of animals exposed to UHF electromagnetic field. The experiment involved 175 male 20-30 g albino mice exposed for 16 min to UHF radiation ($\lambda=12.5$ cm) at power density of 62 ± 5 mW/cm². Pentylene-tetrazole (20 mg/kg) and strychnine nitrate (0.2 - 50 mg/kg) injected subcutaneously, and noradrenalin bitartrate (0.25 - 2.0 mg/kg) and hydrocortisone (0.5, 1.0, 2.0 mg/kg) injected intraperitoneally were administered immediately after the exposure. Controls were injected with 10 mg/kg of NaCl isotonic solution. The survival rate of the mice treated with 1.0 mg/kg hydrocortisone was twice that of the controls, and 1.5 times higher than animals treated with noradrenalin and strychnine. Pentylene-tetrazole was least effective. Findings indicate that an early administration of stimulants and hormones may have a favorable effect on the recuperative period. (1 reference)

0262 THE EFFECT OF SLIGHT DROPS IN ELECTROMAGNETIC FIELDS ON MAN. (Rus.) Mikhailova-Lukasheva, V. D. (Gerontology Section, Acad. Sci., Beloruss. SSR) A. V. Skripal, V. P. Melnikov, V. P. Korotkii, and L. V. Naimitenko. *Dokl. Akad. Nauk BSSR.* 16(12):1147-1149, 1972.

It is assumed that living organisms in their evolution have used electromagnetic fields to obtain information on the environmental changes as EMF are the most reliable information carriers of all alternative geophysical factors. Living organisms must therefore possess systems to enable them to respond to EMF which carry useful information only. According to prior experiments, the response to a certain range of EMF frequencies depends on the duration, form and frequency spacing of the pulses. Assuming that the receptor cells would have the greatest response when exposed to a signal similar to the rhythms of the excited receptor, viz 200-400 pulse/sec, the experiment studied the effect of optimum parameters of EMF pulses on animal behavior. The greatest response was evoked by exponential pulse fields of 2×10^{-4} sec. To investigate human reactions to weak EMF the subjects were exposed to 200-400 Hz, which corresponds to the rhythms of physiological processes ($f = 0.5-30$ Hz). Studies also involved "white noise" drop in the 50 Hz-6 MHz range. Testees were shielded from all outside light and noise interferences. Exposure time was 10-25 sec. The following physiological data were monitored: EEG, ECG, phonocardiogram, rheobasegram, plethysmogram, arterial pressure, and respiration. The data obtained showed certain physiological changes in humans and animals, reported in later papers (see, for instance, CL 0300, below). (3 references)

0263 INFLUENCE OF MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON BIOLOGICAL OBJECTS.

(E.) Devyatkov, N. D. (no affil.). *Sov. Phys.-Usp.* 16(4):568-569, Jan.-Feb. 1974.

In the past decade experimental studies made in the USSR in the millimeter band at very low microwave energy flux densities (no more than a few milliwatts per square centimeter) produced highly interesting information on the effects of irradiation: a) the effect of irradiation depends strongly on the frequency of the microwaves; b) in certain power ranges, the effect of exposure depends weakly on variation of the power through several orders of magnitude; c) the effects depend significantly on duration of irradiation. It was also established that the vital activity of microorganisms is affected by millimeter-wave irradiation. The effect may be positive or negative, depending on the particular part of the band and the particular conditions of irradiation. A machine for irradiation of microorganisms and direct observation of their behavior during and after irradiation was designed around a MIS-51 comparison microscope. Various yeast cultures were irradiated to demonstrate the effect of millimeter-wave electromagnetic irradiation on cell division. Irradiation of a culture of *Rhodotorula rubra* for 15 hr at wavelengths 7.16, 7.17, 7.18 and 7.19 mm (10 experiments at each frequency) showed a sharp frequency dependence: cell division was stimulated at 7.18 mm and slightly depressed at the other wavelengths. Irradiation of a *Candida* culture caused a marked change in the nature of cell division as compared with controls; the irradiated cells exhibiting accelerated division. Irradiation elevated temperatures in some cultures by approximately 4 C. There have been only a few attempts to develop approximate hypotheses to account for the resonant effect of irradiation and some of its other properties. Further experimental and theoretical confirmations are needed to these interesting scientific problems. (No references)

0264 CERTAIN METHODOLOGICAL PROBLEMS AND RESULTS OF EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF MICROWAVES ON MICROORGANISMS AND ANIMALS.

(E.) Bazanova, E. B. (no affil.), A. K. Bryukhova, R. L. Vilenskaya, E. A. Gel'vich, M. B. Golant, N. S. Landau, V. M. Mel'nikova, N. P. Mikaelyan, G. M. Okhkhonina, L. A. Sevast'yanova, A. Z. Smolyanskaya and N. A. Sycheva (Gen. Ed.: N. D. Devyatkov). *Sov. Phys.-Usp.* 16(4):569-570, Jan.-Feb. 1974.

Findings related to research methodology problems and the results of exposure of certain biological objects to millimeter-band electromagnetic waves are presented. The effects of frequency, power flux density, exposure time, ambient temperature, and the identity of biological conditions were investigated in detail. Polarization was held constant, and all experiments were performed with continuous irradiation. It was established for a wide variety of microorganisms and tests that at a threshold power flux density of 0.01 mW/cm², effects vary weakly over several (2 and 5) orders of magnitude when a marked thermal effect, not produced by other heating sources, begins to make its

appearance. The longer the time of irradiation, the stronger the observed effect, although saturation was noted after several hours. Effect of frequency on exposure is dependent on the acute resonant nature, and varies depending on the object and the test. Radiation of the fungus *Aspergillus aryazl* produced an increase in proteases with fibrinolytic activity. The original strain was irradiated at wavelength 6.6 mm, power flux density 0.1 mW/cm². Ten 2-hr doses were administered. Irradiation increased the proteolytic activity of the *aspergillus* by a factor of 1.5-2. The increase in fibrinolytic activity was not accompanied by an increase in biomass. Six months' observation verified that the effect was inherited. *Staphylococci* (strain 209) culture was irradiated repeatedly for 1 hr daily at 7.08 mm, power flux density 0.1 mW/cm². Over the course of multiple exposure, hemolytic activity, the ability to coagulate plasma, lecithinase activity, and gold pigment disappeared, in that order. In experiments on rabbits with 8 x 8 cm traumata on their backs infected with *staphylococci*, a decrease in the inoculability of the *staphylococci* was established after a series of daily radiation for 20 min, and healing time was reduced 20% compared to controls. Normal regeneration was observed on cytological examination of the secreta from the irradiated wounds. Peripheral blood showed moderate leukocytosis of neutrophilic nature, monocytosis and lymphopenia, indicating an augmented protective response of the organism. (No references)

0265 A STUDY OF THE EFFECTS OF MILLIMETER-BAND MICROWAVES ON THE BONE MARROW OF MICE.

(E.) Sevast'yanova, L. A. (no affil.) and R. L. Vilenskaya *Sov. Phys.-Usp.* 16(4):570-571, Jan.-Feb. 1974.

A decrease in the number of bone-marrow cells damaged by x-rays has been observed in previous studies when animals have been exposed to microwave fields. The present paper reports counts of mouse bone-marrow cells that remained undamaged by x-irradiation after prior irradiation with a microwave field in which the exposure time, power density of the field, and wavelength were varied. Counts of undamaged bone-marrow cells, normalized to the control (N/N₀), were plotted against power flux density (P) in the range from 1 to 75 mW/cm², for a constant 1-hr exposure time. X-ray dose was 700 rad. Preliminary microwave irradiation of the animals had no influence on N/N₀ up to a power flux density P = 10 mW/cm². This power density was then used for experiments in which the exposure times of the animals were varied. Microwave effects appeared at t = 30 min, and at 60 min N/N₀ reached 0.8. Further increase in time was not accompanied by any appreciable increase in the number of cells which remained undamaged by x-rays, indicating the optimum irradiation time to be 60 min. In experiments varying the wavelength of microwaves from 6.6 to 7.7 mm, undamaged-cell count rose from 0.5 to 0.85 at wavelengths of 6.7 and 6.82 mm, in the range 7.09-7.16 mm, and at 7.26 and 7.7 mm, while there was no protective effect at the other wave lengths studied. This behavior of the N/N₀(λ) relationship suggests a resonant mechanism for the action of the microwave field. (5 references)

- 0266 EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON THE FUNCTIONAL ACTIVITY OF CERTAIN GENETIC ELEMENTS OF BACTERIAL CELLS. (E.) Smolyanskaya, A. Z. (no affil.) and R. L. Vilenskaya. *Sov. Phys.-Usp.* 16(4):571-572, Jan.-Feb. 1974.

The effects of millimeter waves on intracellular systems responsible for lethal synthesis in bacteria; i. e., colicin, were investigated. The activity of colicin synthesis in colicinogenic strains *E. coli* C600 (E₁) and *E. coli* K12S, sensitive to the colicin of the former, was determined by the lacunae method, in which the numbers of individual colicin-synthesizing bacteria are counted and evaluated with the aid of the induction coefficient determined by the ratio of lacuna formation frequencies in experiments and controls. The number of cells that synthesized colicin increased by an average of 300% on irradiation at wavelengths 5.8, 6.5, and 7.1 mm; 6.15 and 6.57 mm showed no effect, indicating that the regulation of functional activity in certain (in this case of extra-chromosomal) genetic elements of bacterial cells may also be induced by microwaves. The behavior of the induction coefficient of colicin synthesis as a function of wavelength was investigated in greater detail in the range 6.50-6.59 mm. Results indicate that colicin synthesis is a resonant function of wavelength. The statistical significance ($P < 0.001$) of the differences between the comparison indicators in the control and experimental systems was demonstrated on statistical reduction of the results of repeated experiments (from 15 to 25 at each point). The effect was directly dependent on irradiation time. Irradiation for 30 min at 20 C had no influence on colicin synthesis; synthesizing increased by a factor of 1.5-2 after 1 hr, reaching a maximum at 2 hr. At 37 C, synthesis was induced by 30-min radiation. Variation of the power flux density through a factor of 100, from 0.01 to 1.00 mW/cm², had no influence on the induction coefficient. A reduction of the power to 0.01 mW/cm² resulted in a sharp decrease in the biological effect, indicating likely nonthermal effects of millimeter waves, since thermal effects depend primarily on flux intensity. Unlike other agents (both physical and chemical) which induce colicin synthesis by disintegrating DNA or blocking its synthesis, millimeter-band radiation is a fundamentally new agent that disturbs the functional regulatory mechanism of genetic elements in the cell, and extrachromosomal elements in particular, without causing direct damage to the DNA molecule. (2 references)

- 0267 EFFECTS OF MILLIMETER-BAND RADIO WAVES ON CERTAIN PROPERTIES OF BACTERIA. (E.) Kondrat'eva, V. F. (no affil.), E. N. Chistyakova, I. F. Shmakova, N. B. Ivanova and A. A. Treskunov. *Sov. Phys.-Usp.* 16(4):572-573, Jan.-Feb. 1974.

The influence of millimeter-band radio waves on sporogenesis, antigenic and proteolytic properties of bacteria was investigated. Three strains of *Cl. sporogenes*, two of *Cl. histolyticum* (anaerobic spore bac-

teria), and three strains of *Bact. prodigiosum* (an aerobic bacterium) were used. Each strain was irradiated 20 times at wavelength 7.20 mm for 3 hr. After irradiation, *sporogenes* and *histolyticum* shrank to half the size of controls, seldom appeared in pairs and chains, and showed a strong and consistent decrease in spore-forming ability. Two cultures lost their ability to form spores altogether without recovery after a year and 20 subculturings. There were changes in growth formations and color. The antigenic properties of bacteria were affected. Irradiated *sporogenes* and *histolyticum* cultures began to agglutinate at titers 1/2 to 1/4 those of controls. There was no change in the saccharolytic activity of bacteria, but proteolytic activity declined. The irradiated bacteria were slower to react on milk and fragments of meat, indicating a change in protein metabolism. Rabbits and white mice were inoculated with *histolyticum* cultures and observed for six days. Animals inoculated with unirradiated cultures perished during the first four days to a maximum dilution of 1:8. Of the eight rabbits inoculated with the irradiated cultures, one perished at the 1:8 dilution, and the rest after administration of undiluted or 1:2 diluted cultures. The survivability of bacteria irradiated at microwave lengths between 7.1 and 7.20 mm was diminished at all wavelengths, the strongest effect observed from the 7.15 mm wavelength. (No references)

- 0268 EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC WAVES ON CERTAIN ASPECTS OF PROTEIN METABOLISM IN BACTERIA. (E.) Manoilov, S. E. (no affil.), E. N. Chistyakova, V. F. Kondrat'eva and M. A. Strelkova. *Sov. Phys.-Usp.* 16(4):573-574, Jan.-Feb. 1974.

Material from an investigation of the effects of millimeter radio waves on certain aspects of the protein metabolism of anaerobic and aerobic bacteria and on fungi, whose protein metabolisms exhibit qualitative differences, are reported. *Cl. sporogenes*, *Cl. histolyticum* (anaerobes); *B. prodigiosum*, *Staphylococcus aureus* (aerobes); and *Act. noursei*, *Pen nigricans* (fungi) were studied. The microbes were irradiated at wavelengths of 7.2 and 7.6 mm by a backward-wave-tube source at an average power flux density of 4-5 mW/cm² in the radiation incident on the object. Equal numbers of irradiated and unirradiated microorganisms were introduced into the nutrient medium, and the free amino acid contents were determined by Baudet's method in this medium after one day of growth. All data were calculated as percentages of the amino acid contents in the nutrient medium after unirradiated microorganisms had been cultivated in it. A series of experiments also investigated the effects of different wavelengths (7.2 and 7.6 mm) on the *Staphylococcus*, and the protein metabolism of individual amino acids in the various microbes after irradiation at 7.2 mm. Qualitative and quantitative differences in the effects of different wavelengths were found. Wavelengths also acted variably on amino acids with acidic or alkaline properties. "Acidic"

amino acids increased after growth of microbes irradiated at 7.2 mm, with no difference at 7.6 mm. "Alkaline" acids decreased during growth of bacteria irradiated at 7.2 mm and increased at 7.6 mm. Changes in the contents of "acidic" and "alkaline" amino acids were also observed after irradiation of aerobes, anaerobes, and fungi at 7.2 mm. Findings indicate that millimeter band microwaves have a definite influence on the protein metabolism of bacteria, manifested either in the form of activation or inactivation of proteolytic enzymes or in a change in activity of enzymes participating in the metabolism of the individual amino acids. (3 references)

0269 REACTIONS OF LIVING ORGANISMS TO EXPOSURE TO MILLIMETER-BAND ELECTROMAGNETIC WAVES. (E.) Zalyubovskaya, N. P. (no affil.). *Sov. Phys.-Usp.* 16(4):574-576, Jan.-Feb. 1974.

The reactions of organisms in various stages of evolutionary development (viruses, microbes, insects, birds, and mammals) were studied. Exposure of microorganisms (*Staphylococcus*, *Streptococcus*, *E. coli*, typhoid bacillus) to mm waves lowered their survival rates by 60% and more, affected the morphological, culturing, and biochemical properties; increased their sensitivity to antibiotics; and modified their antigenic properties. The infective activity of irradiated viruses was lowered. The biological effects depended on wavelength and exposure time; bactericidal action was most pronounced at 6.5 mm. Irradiation of adult male and female *Drosophila* for 15-60 min resulted only in lessened fertility dependent on the wavelength of the radiation and duration. Prolonged exposure (3-5 hr) at 6.5 mm resulted in significant changes including lessened viability, fertility, and mutations in the second generation. Seven-day-old chick embryos were irradiated with millimeter waves 5 times for 30 min. None perished and there was no weight loss, but the incubation period was lengthened by 2-3 days, and hatched chicks were somewhat retarded in development, especially when irradiation had been at 6.5 mm. Irradiated chicks lagged behind controls in weight through observations up to 50 days. Irradiation of white rats and mice over 40-50 days for 10-15 min was not lethal, but physical and behavioral changes were noted. Food and drink were refused for some time; hair on shaved skin areas failed to grow back; and biopsies showed atrophy of the Malpighian layer, sclerosis of derma, and abnormalities in the outer layer of skin and underlying muscle. Blood coagulation rate was higher after irradiation (68.2 ± 1.5 sec in the control, 35.0 ± 1.3 sec after irradiation at 6.5 mm; $p < 0.01$). Hemoglobin content decreased, and blood-serum albumin was lower. Total nucleic acids and albumins were decreased in liver and spleen, and irradiated animals showed lower resistance to infection; antibody (agglutinin) and blood lysozyme levels were half those of controls.

The studies suggest that the action of millimeter waves is a general biological one not limited by phylogenetic differences between organisms, the effects being dependent on wavelength and exposure time. (No references)

0270 EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC WAVES IN THE CELL AND CERTAIN STRUCTURAL ELEMENTS OF THE CELL. (E.) Kiselev, R. I. (no affil.) and N. P. Zalyubovskaya. *Sov. Phys.-Usp.* 16(4):576-577, Jan.-Feb. 1974.

The basic criteria for evaluation of millimeter-wave effects on cells were morphological and biochemical indicators, survival rates, and changes in antigenic, culturing, and virulence properties of the irradiated objects. Irradiation resulted in damage to the cell membrane, degeneration of protoplasm, and an increase in the cells and nuclei, and nucleic acid and albumin contents. It is possible that by affecting cell metabolism microwaves influence synthetic processes. The number of viable cells decreased after irradiation at various wavelengths, 6.50 mm showing more conspicuous biological activity. This wavelength also produced significant changes in hemolytic stability of red blood cells (erythrocytes), indicating functional and structural changes. Changes in nucleic acid and albumin contents also occurred in nuclei and mitochondria separated from liver cells. Millimeter-wave irradiation of viruses (adenoviruses, measles virus, vesicular stomatitis virus, and others) resulted in reduction of virus particles by a factor of 2-3. Lowered infectious activity of adenoviruses and measles virus was manifested in a delay of the cytopathogenic effect on tissue culture. The infectious activity in tissue cultures treated with DNA irradiated at 6.50 mm appeared between 15 and 16 days, as compared to untreated at 10 days, and corresponded morphologically to a manifestation of the whole virus, indicating a loss of infectious activity but not of transforming activity as shown in the later appearance of the cytopathogenic effect. The influence of microwave irradiation on the cellular genome was judged from the increase in latent-phage and colicin productive activity after irradiation of lysogenic and colicinogenic microbe strains. After irradiation of the latter at 6.50, colicin titer increased, and increased production of phage particles was observed in lysogenic microbe strains; the latter significant at 5.9, 6.1, 6.50, and 7.5 mm; $p < 0.01$. The data indicate a possible use of millimeter-band electromagnetic waves toward controlled modification of viruses and microbes. (No references)

0271 OUTLOOK FOR STUDY OF THE MECHANISMS OF THE NONTHERMAL EFFECTS OF MILLIMETER- AND SUBMILLIMETER-BAND ELECTROMAGNETIC RADIATION ON BIOLOGICALLY ACTIVE COMPOUNDS. (E.) Gaiduk, V. I. (no affil.), Yu. I. Khurgin and V. A. Kudryashova. *Sov. Phys.-Usp.* 16(4):577-578, Jan.-Feb. 1974.

Aqueous solutions of hemoglobin (Hb) were irradiated at millimeter band wavelengths around 7.35 mm for 5 hr at a radiation intensity of 1 mW/cm² and temperatures 37-40 C. After exposures, the percentage acid hydrolysis of the Hb (splitting off of heme) was lower than that in the control; i.e., there was increased strength in the bond between heme and protein after irradiation. This can be interpreted as an increase in the stability of the Hb to the transition (during irradiation) from the active *oxy* form to the inactive *met* form, since the rate of acid hydrolysis of *oxy*-Hb is much lower than that for *met*-Hb. These changes may be explained by either of two hypotheses: 1) A single molecular group in the active center, distal histidine E7, essential to the Hb function, may be responsible; the energy of the histidine oscillation and its average position with respect to the iron atom being changed under the influence of microwaves; or 2) The action of microwaves is transferred to the histidine as a result of excitation of vibrations of the macromolecule as a single entity--the "protein-machine" hypothesis. Microwave irradiation may assist in determining which, if either, theory is applicable, and be useful for resonance control of biological processes such as the addition of oxygen to Hb, in order to regulate enzyme reactions and study the properties of biopolymers; e.g., their catalytic activity. The use of physicochemical methods to indicate microwave exposure is also promising. There is the possibility of developing a microwave method for measuring the degree of hydration of biopolymers in solution at different temperatures (NMR and microcalorimetric measurements yield the amount of free water when frozen solutions are melted). The proposed method would yield information on the interaction of amino acids and other biologically active compounds with water, and could be used to construct a theory of resonant microwave effects on biopolymers. In addition, direct determination of the hydration number would be helpful to understanding the nature of the reactivity of organic compounds in the liquid phase and certain specific properties of macromolecules determined by their interaction with the aqueous medium. (12 references)

0272 REMARKS ON TWO POSSIBLE MECHANISMS OF THE EFFECT OF MICROWAVES ON HEMOGLOBIN. (E.) Chernavskii, D. S. (no affil.). *Sov. Phys.-Usp.* 16 (4):578-579, Jan.-Feb. 1974.

The direct action of microwaves on histidine, and on the molecule as a whole, with excitation of elastic oscillations of the entire structure of the protein, may be regarded as two aspects of the same mechanism, rather than alternatives. It might be appropriate to recall the hypothesis of the role of elastic deformation in enzymatic catalysis. These elastic deformations in the enzyme-protein may be thought of as a "spring" which at the proper time transfers energy into the active center, where the substrate molecule is located. Estimates have indicated that the di-

mensions of the "spring" would indicate a system of a size which has a natural vibration frequency of the same order of magnitude as the resonance frequency in the spectrum of the microwave effect. The conclusion that a preferred frequency exists follows from the hypothesis that the deformations are elastic in nature. The "protein machine" concept indicates that the one generalized degree of freedom that encompasses the entire molecule and is characterized by a common frequency should be preferred in the macromolecule. The vibration frequencies of the several parts of the machine that participate in the enzymatic event (in particular the histidine radical) are the same as the common frequency. The direct action of microwaves in the histidine in hemoglobin should cause the entire "machine" to oscillate; the two mechanisms representing different aspects of the same mechanism. The highly important question as to the influence of temperature on oscillation, which may, in fact, not be particularly strong, requires special attention. In classical physics there are many examples of the excitation and survival of low-frequency vibrations against a background of higher-frequency thermal vibrations. The protein macromolecule is sufficiently massive and "classical." The experimental trend in millimeter-band effects of microwaves may cast light on many fundamental problems of enzymatic catalysis. (2 references)

0273 AUGMENTATION OF BONE REPAIR BY INDUCTIVELY COUPLED ELECTROMAGNETIC FIELDS. (E.) Bassett, C. A. L. (Coll. Phys. Surgs., Columbia Univ., N.Y.), R. J. Pawluk and A. A. Pilla. *Science* 184:575-577, May 1974.

The effects of electromagnetic fields on bone repair in 43 adult beagles were investigated. Pulsing, magnetic fields produced by air-gap, rectangular coils were used to induce dynamic, orthogonal, voltage fields in bone and soft tissue. The basic coil, 215 by 3 cm, internal dimensions, allowed a homogeneous voltage field on 1.5 to 2 cm of bone, placed in a plane parallel to the inside coil edge. Bilateral, transverse, fibular osteotomies were performed 3.5 to 4.5 cm distal to the proximal fibular head. Two different, pulse-shaping, circuit designs were applied. In the first group of 22 animals, a pulse of 1 msec duration repeating at 1 Hz (1P, 1 Hz), produced a peak voltage field of 2 mV/cm in bone. In the second group of 21 animals, a circuit was used with a pulse of 15 μ sec duration repeating at 65 Hz (10P, 65 Hz) and producing a peak of 20 mV/cm in bone. In the first series employing the 1P, 1 Hz circuits, 20 animals were available for study at 28 days. In 10, the stimulated leg produced larger load values than the contralateral control. The remaining 10 had greater load values associated with the unstimulated side. The mean load values revealed no statistically significant difference. Thirteen animals bearing 10P, 65 Hz at pulse 15 μ sec (pulse varied on remainder) were available for analysis 28 days after operation; 10 demonstrated higher load values (greater stiffness)

in the treated legs, with percentage increases in load far larger than those produced by the inactive legs in this or the first series. Three animals had a greater load value associated with the control leg. The findings are significant by the sign test $P < .07$. The active values were also statistically significant when grouped by size of deformity and compared with controls. The studies demonstrate that low-frequency, low-intensity, external pulsing electromagnetic fields can be inductively coupled to tissue to achieve an increase in the tempo of a repair response. (17 references)

0274 POSSIBILITIES FOR CONTROLLING INSECTS WITH MICROWAVES AND LOWER FREQUENCY RF ENERGY.

(E.) Nelson, S. O. (Agric. Res. Serv., USDA, Univ. Nebraska, Lincoln) and L. E. Stetson. *IEEE Trans. Microwave Theory Tech.* MTT-22(12):1303-1305, Dec. 1974.

Insects that infest grain, cereal products, wood, seed and other stored products can be controlled through dielectric heating by microwave or lower radio frequency (RF) energy. The principles applicable to the control of stored-product insects with RF energy, and general research findings on this topic, are reviewed. Data are presented on the frequency dependence of the dielectric constant and dielectric loss factor of insects and grain, and use of such information is discussed in relation to RF treatment of infested products to control insects. Experimental data that confirm the usefulness of information on dielectric properties are presented. These data show that RF treatment at 39 MHz is much more effective for controlling adult rice weevils in wheat than is treatment at 2450 MHz. Complete insect mortality was obtained with much lower grain temperatures, indicating that a higher degree of differential heating was obtained in the lower frequency range than was obtained at microwave frequencies. Some aspects of practical application are also considered. (19 references)

0275 EXPOSURE OF BACTERIA TO 2450 MHz MICROWAVE RADIATION. (E.) Hamrick, P. E.

(Natl. Inst. Environ. Hlth Sci., Research Triangle Park, N. C.) *J. Microwave Power* 8(3):227-233, 1973.

Four strains of *Escherichia coli* and one strain of *Pseudomonas aeruginosa* were exposed to continuous 2450 MHz microwave radiation in a system designed to give uniform field of continuous wave radiation at the sample holder with no more than 10% variation in power density over a 6 inch diameter. Samples were exposed for 12 hr at an intensity of 60 mW/cm². The growth curves of control and exposed bacteria were compared for this 12-hr period. No effect on cell replication rate was detected that could not be explained as a result of temperature

variation. These findings do not imply that bacteria exposed to radiation at other frequencies will not exhibit changes in growth rate; or that 2450 MHz microwave radiation will not affect other biological systems, since studies on chick embryo indicate that differentiating tissues may be affected by low-level radiation. The fact that rapidly growing and dividing bacteria are not affected, whereas differentiating tissues are, should be important in discovering how microwave radiation interacts with biological material. (12 references)

0276 ORIENTATION AND FREQUENCY EFFECTS ON WHOLE ANIMAL ABSORPTION OF MICROWAVES--LETHALITY EXPERIMENTS. (E.) Hawkins, T. D. (Dept. Microwave Res., Walt. Reed Army Inst. Res., Washington, D. C.), J. Schrot, J. Sharp and O. P. Gandhi. *Proc. Int. Microwave Symp.*, June 12-14, 1974.

(E.) Hawkins, T. D. (Dept. Microwave Res., Walt. Reed Army Inst. Res., Washington, D. C.), J. Schrot, J. Sharp and O. P. Gandhi. *Proc. Int. Microwave Symp.*, June 12-14, 1974.

In recent experiments with rats and biological phantom and salinefilled prolate spheroidal bodies, radio frequency (RF) absorption was found to depend strongly upon the polarization and frequency of electromagnetic fields. Power deposition more than an order of magnitude greater was observed at resonance for waves polarized along the long dimension of the body. This paper describes the time to convulsion measured on 100 and 400 g rats, and 25 g mice exposed to microwave radiation at 985, 1700, and 2450 MHz with electric and magnetic fields along the lengths of the animals, resp. The presented data are based on observations on 198 animals, 33 at each frequency in each of two orientations. In each case, as expected, radiation polarized along the long dimension (\hat{a}) was more lethal than that along the shorter dimensions. The most dramatic results were observed on mice that convulsed at 985 MHz in the $\hat{E} \parallel \hat{a}$ orientation with an average time of 500 seconds as compared to no visible effects on such animals for up to 7200 seconds at $\hat{H} \parallel \hat{a}$ radiation exposure. This is ascribed to the resonance effect described previously. For 100 and 400 g rats, the resonance frequencies are predicted to be on the order of 550 and 325 MHz, resp., much lower than the lowest observation frequency of 985 MHz. Further experiments are in progress to define the mechanisms involved. (No references)

0277 CARDIAC PACEMAKER EMC IN PERSPECTIVE. (E.)

Miller, D. A. (IIT Research Institute, Chicago, Ill.). *Proc. IEEE Electromagnetic Compatibility Symp.*, June 20-23, 1973.

The susceptibility of cardiac pacemakers to electromagnetic interference has been investigated by both engineers considering electrical phenomena and by physicians deeply concerned with clinical impact. This summary reviews the significant work done so far in each field, and designates seven areas which need to be considered in future work to give a perspective

on cardiac pacemaker EMC: (1) the clinical significance of cardiac pacemaker interference susceptibility, (2) the response of different types of pacemakers to various interference situations, (3) various coupling mechanisms in the pacemaker, (4) test methods, (5) the role of animal tests, (6) the role of clinical studies, and (7) the requirements for standards development. A distinguished panel of six persons from medical, instrumentation and technical fields has been assembled to address these areas. (10 references)

- 0278 NERVE IN EXCITABLE STATE IN MICROWAVE FIELD. (E.) Kamal, A. K. (Electron. Comm. Eng. Dept., Univ. of Roorkee, UP, India), S. C. Gupta and S. Gupta. *Med. Biol. Eng.* 12(6):827-830, Nov. 1974.

The electrical conductivity of squid axon membrane was calculated in the excitable state under microwave radiation at frequencies from 100 kHz to 100 MHz. Since the conductivity of excited squid axon increases with the strength of stimulus, with the result that ionic currents such as sodium and potassium also increase, the behavior of ionic currents of nerve in excitable state was predicted theoretically in the presence of microwave fields, and an electronic model was proposed and used to find the behavior of nerve membrane. The curves of various ionic currents and membrane conductances were plotted for the squid, to show the various effects of microwave radiation fields. From the curves it is clear that, as the applied radiation frequency increases, currents also increase, due to the conductivity modulation of the membrane. (5 references)

- 0279 AGRICULTURAL MICROWAVE APPLICATIONS RESEARCH. (E.) Nelson, S. O. (Agric. Res. Serv., Univ. Nebraska, Lincoln). *IMPI Newsletter* 2(3):19-21, Aug. 1974.

Research on the use of radiofrequency (RF) energy to help solve agricultural problems conducted jointly by the USDA and the University of Nebraska, at Lincoln, is reviewed. Experiments have dealt with the possibility of using RF to dry grain, control stored-grain insects, improve seed germination and carotene retention in alfalfa, control loose smut in barley, improve the nutritional quality of soy beans, and non-destructively measure moisture content. The need for information on the dielectric properties of materials exposed to RF electric fields required the development of techniques, apparatus, and measurement methods over a wide range of frequencies. Experiments in recent years have included treatments at 2.45 GHz, and several microwave systems have been assembled. As is true with other potential RF and microwave power applications, economic factors have hampered the adoption of RF processes for commercial use. Studies are continuing to determine whether

the efficiency of RF applications to agriculture can be substantially improved. (1 references)

- 0280 MICROWAVE EMISSIONS IN THE AIR: ARE THEY A BIOLOGICAL TIME BOMB? (E.) Anonymous. *Med. World News* 15(29):22-23, Aug. 2, 1974.

With microwave ovens, radio and TV transmitters, radar dishes, medical diathermy machines, and other sources of non-ionizing radiation broadcasting unprecedented quantities of electromagnetic emissions through the air, there is a growing worry that some more subtle nonthermal effect may be occurring from this radiation. This article briefly reports the recurring expressions of concern with the possible dangers from uncontrolled exposure and the need to determine the effectiveness of present "safe exposure limits." The work of Drs. Przemyslaw Czerski and Maksymilian Siekierzynski, of Warsaw's National Research Institute of Mother and Child, and their concern with the still unexplored effects of microwave exposure on children, the aged, sick, pregnant women, and the general public is mentioned. Differences in national limitations and standards, the Office of Telecommunications Policy report and call for extended research, and Dr. Zorach Glaser's reported biological phenomena are also described. (No references)

- 0281 THE CIRCADIAN PERIODICITY OF MAN AS AN INDEX FOR THE BIOLOGIC ACTION OF ELECTROMAGNETIC FIELDS. (Ger.) Wever, R. (Max Planck Inst., Behav. Physiol., Seewiesen, West Germany). *Z. Phys. Med.* 2(6):439-471, 1971.

Under natural conditions biological periodicity is synchronized to 24 hr by environmental periodicities depending on the rotation of the earth; e.g., the natural light/dark cycle. In studies of autonomous circadian periodicity in 19 human subjects, internal desynchronization was observed with different periods in activity and in basic functions (e.g., in rectal temperature) over several weeks. Two experimental rooms were used, differing only in that the right room was shielded against electric and magnetic fields. The results from the two experimental rooms showed remarkable and statistically significant differences. In the subjects, unaware of the differences between the rooms, the period of activity ranged between 17 and 65 hr, without the subjects perceiving these abnormalities. It was hypothesized that the natural electromagnetic fields, which penetrated the left room, but not the right, accelerated the free running rhythm, reduced interindividual differences, and prevented internal desynchronization. The hypothesis was tested by equipping the right room, in addition to the shielding, with facilities for introducing various electric and magnetic fields. In preliminary experiments static electric and magnetic

fields proved insufficient. However, a weak electric field, alternating with a frequency of 10 cps, proved as effective as natural fields in significantly shortening the period of human circadian rhythms, reducing the interindividual differences, and preventing internal desynchronization. As was predicted by a mathematical model, additional parameters of the autonomous rhythm were also affected. In other experiments during which the artificial 10 cps field was switched on and off periodically it was found to act as a weak "zeitgeber," confirming the hypothesis that weak electromagnetic fields influence human circadian rhythms. (30 references)

0282 FIFTH SUPPLEMENT TO BIBLIOGRAPHY OF REPORTED BIOLOGICAL PHENOMENA ("EFFECTS") AND CLINICAL MANIFESTATIONS ATTRIBUTED TO MICROWAVE AND RADIO-FREQUENCY RADIATION. (E.) Glaser, Z. R. (Electromag. Rad. Proj. Off., Bur. of Med. and Surg., Washington, D. C.). *Med. Res. Dev. Command Report*, AD 784-007/7, July 1974.

This report is the fifth supplementary "up-dated" bibliographic listing to Naval Medical Research Institute Research Report No. 2, completed in 1971 by the author, and available in revised form, with Supplements 1 through 3, from NTIS as AD 750-271. The revised report contains more than 2300 literature citations, and includes as a first chapter, an outline of the effects which have been attributed to radio frequency and microwave radiation. Almost 500 additional references are contained in the latest supplement to this bibliography of the world literature. Particular attention has been paid to the effects of non-ionizing radiation on man at the radio and microwave frequencies. Citations are arranged alphabetically by the author (where possible), and contain as much information as possible to assure effective retrieval of the original documents. Soviet and East European literature is included in detail, and a final section lists pertinent national and international technical meetings with presentations and authors. Supplement No. 4, completed in June 1973, is available from NTIS as AD 770-621.

0283 BIOLOGICAL EFFECTS OF MICROWAVES: A BIBLIOGRAPHY WITH ABSTRACTS. (E.) Harrison, E. A. (Natl. Tech. Inf. Serv., Springfield, Va.). *Natl. Tech. Inf. Serv.*, WIN-73-070, Oct. 1973.

This bibliography contains 76 selected abstracts of research reports covering the biological effects on man and animals that can result from exposure to microwaves. The bibliography was prepared from NTIS's online interactive bibliographic retrieval system consisting of more than 360,000 records of documents dating from 1964 through September 1973. The documents were submitted by all major depart-

ments and agencies within the federal government, as well as leading private organizations or individuals with federal grants and contracts. Each citation indicates the availability of the document and, when available from NTIS, quotes the price. A special order form is included.

0284 CONTINUOUS MONITOR OF DANGEROUS LEVELS OF MICROWAVE POWER. (E.) Hannah, S. (Dept. Electr. Electron. Eng., Univ. Newcastle-upon-Tyne, U.K.). *Electron. Lett.* 10(14):274-276, July 1974.

A small-size instrument which can be carried in a pocket, similar to the well-known x-ray photographic monitor, is needed continuously to monitor dangerous maximum and average levels of microwave power. This paper reports the development of such a device. By solving Maxwell's field equations for a plane wave normally incident on an isolated thin conducting film, it was found that such a film can be made to exhibit a maximum absorption of 50% of the incident power over a broad frequency range, if its skin resistivity is made equal to half the intrinsic impedance of free space. Usable germanium (Ge) films were produced having skin resistivities within 4% of their desired value by depositing Ge on to a heated glass substrate. The resulting Ge film is 3 μm thick with conductivity of $1.75 \times 10^3 \Omega^{-1}\text{m}^{-1}$. Sensors were produced with a free Ge surface area of $2.3 \times 1 \text{ cm}^2$ on differing-thickness glass substrates of $3 \times 1 \text{ cm}^2$ size. Contact resistances are of the order of a few ohms, and the skin resistivities between 196 and 192 Ω/\square . Testing determined that the sensor is capable of reliably monitoring power levels from 1 mW/cm^2 to 1 W/cm^2 without deterioration. A signal processing circuit which is compact, light-weight and of low power consumption was also developed and an instantaneous display is obtained by driving light-emitting diodes from the ten outputs of a decade counter. This display can be switched on by hand or switched on automatically when a certain danger level is reached. An acoustic signal can also be activated if desired. Integrated exposure level is obtained by the use of either a 'log E' silver cell at the input to the counter, or by a piece of photographic film placed alongside a light-emitting diode, which is activated by the counter input. (3 references)

0285 INTERACTION OF A 2450 MHz MICROWAVE FIELD WITH THERMOCOUPLES AND THERMISTORS. (E.) McRee, D. I. (Natl. Inst. Environ. Hlth. Sci., Research Triangle Park, N. C.) and F. T. Pendergrass. *Health Phys.* 25 (August):180-182, 1973.

Research data on biological effects of microwave radiation is of limited value for establishing safe exposure levels because of lack of accurate dosimetry. The amount of energy absorbed by a biological speci-

men is usually measured by thermistors or thermocouples, but erroneous measurements may result from interactions of the incoming microwave field with the devices. This paper presents experimental results illustrating these interaction problems, and provides suggestions for eliminating them. The interaction of the microwave field with shielded and unshielded thermistors and thermocouples was evaluated. The devices were placed in a zone irradiated by a 2450 MHz, continuous wave microwave field. Both devices were connected to a strip-chart recorder, placed in the field in two different geometrical orientations, with power levels at sensing areas set at 100 mW/cm². Time-temperature profiles for thermistors, shielded or unshielded, were almost the same. Temperature rise was a real one, due to the heating of the absorber. Orientation of the thermistor leads to the electric field had no effect. Unshielded thermocouples were unsatisfactory because of interaction effects of microwave fields with leads. To eliminate these effects the leads were placed inside a 1/8 in. copper braided shield, grounded at the recorder ground terminal and extended to 1 in. from the thermocouple tip. Time-temperature profiles were similar to thermistor profiles, but the spread in the data was greater. Higher temperatures resulted when thermocouples were oriented parallel to the electrical field, indicating some small amount of interaction. Proper shielding and grounding of all components, selection of detectors which are less sensitive to electromagnetic fields, and high resistance and shielded leads oriented perpendicular to the field reduce the possibility of erroneous measurement. (3 references)

0286 FURTHER EXPERIMENTS SEEKING EVIDENCE OF NONTHERMAL BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. (E.) Lindauer, G. A. (Emerson Electric, St. Louis, Mo.), L. M. Lie, G. W. Skewes and F. J. Rosenbaum. *IEEE Trans. Microwave Theory Tech.* MTT-22(8):790-793, Aug. 1974.

Experiments undertaken to verify and augment earlier observations on teratological damage inflicted upon the darkling beetle *Tenebrio molitor* by low power microwave irradiation are reported. Individual experimental parameters--duty cycle, orientation, pupa age, power level, and total absorbed energy--were varied in a phenomenological approach to elucidate mechanisms by which teratological damage is realized. One- to two-day-old pupae (nominally, 3/16-in diameter x 5/8-in length) were mounted for irradiation in styrofoam blocks, then inserted along the center line of X-band waveguides with their anterior portions towards the power source. The waveguide was terminated in a matched load. The pupae were irradiated at 9 GHz, then placed for the duration of pupation in individual numbered vials in a darkened chamber at 21 C. The emergent adults were categorized for gross morphological defects in ignorance of whether a particular insect was from the irradiated or control group. The incidence of abnormality increased more than three-fold with irradiation, while

death rate remained essentially unchanged. The data do not reveal statistically significant evidence for the dependence of teratological damage on duty cycle, orientation, pupa age, or irradiation intensity. The incidence of damage does depend on the amount of energy absorbed by the pupa, which may depend on age when irradiated. Experiments conducted to date have not shown the incidence of damage to be dependent on whether the microwave power is pulsed or continuous wave, but only a small range of pulse repetition frequencies was used. (10 references)

0287 ACCELERATION OF FRACTURE REPAIR BY ELECTROMAGNETIC FIELDS. A SURGICALLY NONINVASIVE METHOD. (E.) Bassett, C. A. L. (Coll. Phys. Surg., Columbia Univ., N.Y.), R. J. Pawluk and A. A. Pilla. *Ann NY A Sci.* 28:242-262, 1974.

The effects of external electromagnetic coils on repair of fibular osteotomies were investigated in the beagle. The osteotomies were flanked medially and laterally by coils driven by 1-P 1-Hz or 10-P 65-Hz circuits. *In vitro* experiments showed that the level of induced voltage at the osteotomy site was 2 mV/cm for the 1-P 1-Hz circuits and 20 mV/cm for the 10-P 65-Hz circuits. In *in vivo* experiments, cantilever load values were computed for each of 3 deformations (0.025, 0.050, and 0.075 in.) in fibulae stimulated by pulsed 1-Hz or 65-Hz fields. At each deformation, stimulated values for the 10-P 65-Hz circuits were significantly higher than values for unpowered control circuits. Values for animals exposed to the 1-P 1-Hz circuits were not statistically significant. Specimens in the 10-P 65-Hz series were characterized not only by a small mass of callus on the 28th post-operative day, but also by fibrous or osseous tissue that united the osteotomized ends of the fibula. Newly formed tissue was aligned parallel to the long axis of the bone. Cartilage, when present, displayed advanced endochondral-like ossification. The results indicate that the major effects of electromagnetic field stimulation were exerted on architectural and maturation aspects of the reparative process; i.e., the healing process was accelerated. Controlled application of the 10-P 65-Hz induced wave form to human fractures appears justified. (45 references)

0288 MICROWAVE HALL MOBILITY MEASUREMENTS ON HEAVY BEEF HEART MITOCHONDRIA. (E.) Eley, D. D. (Med. Sch., Univ. Nottingham, U.K.), R. J. Mayer and R. Pethig. *Bioenergetics* 4:187-200, 1973.

At an applied field of 1.21 tesla, heavy beef heart mitochondria (HBHM) yielded initial microwave Hall mobility values at least 6 times greater than values for bovine serum albumin at similar resistivity values. The Hall signal was markedly reduced by cyanide, suggesting that the signal from untreated HBHM originated in the cytochrome oxidase part of the

respiratory chain. Measurements on completely or partially purified respiratory complexes confirmed that Hall mobility was greatest for cytochrome oxidase. Smaller Hall signals were given by NADH-cytochrome *c* reductase and succinate coenzyme Q reductase. Prolonged exposure to 9.2 GHz (60 mW) irreversibly damaged the electron transport pathway (as measured by Hall signal) of cytochrome oxidase. This was accompanied by complete loss of capacity to oxidize ferrocyanide. Such changes did not occur with HBHM or with the other respiratory complexes. To determine whether the reduction in the Hall signal of cytochrome oxidase with time in the microwave cavity was due to oxidation or denaturation by microwave power, experiments were performed with fully reduced and oxidized cytochrome oxidase. The results indicated that the decay in Hall signals from cytochrome oxidase was due to irreversible denaturation. A semiconductor model for mitochondria is outlined. (45 references)

0289 STANDARDS FOR PROTECTION OF PERSONNEL
AGAINST NON-IONIZING RADIATION. (E.)
Michaelson, S. M. (Sch. Med. Dent., Univ. Rochester,
N.Y.) *Am Ind Hyg Assoc J.* 35(12):766-784, 1974.

The biomedical effects of non-ionizing radiant energies must be realistically assessed not only to avoid undue exposure of workers or the general public, but to ensure that research, development, and beneficial utilization of these energies will not be restricted. Areas of disagreement on the potential hazards of non-ionizing radiation exist especially in relation to radiofrequency and microwaves (1 to 1×10^5 mm). According to the best evidence available, the most important, if not the only, effect of microwave absorption in the mammal is the conversion of the absorbed energy into heat. The ANSI standard of 10 mW/cm^2 is roughly a factor of 10 below thresholds of damage by thermal effects, assuming exposure of 0.25 hr or more. Eastern European reports of nonthermal microwave effects on the central nervous system, following exposure to less than 10 mW/cm^2 , have not been confirmed in the West. Department of Defense investigations and studies of workers exposed to microwaves for 15-20 yr suggest that the ANSI standard is sufficient. Proposals to adjust the standard to the temperature-humidity index ignore the ability of the body to adjust to considerable fluctuations in ambient temperature and humidity with little or no strain. Research into the biological effects of non-ionizing radiation must be fostered to avoid overly restrictive and unrealistic standards. (61 references)

0290 APPLICATIONS OF MICROWAVE THAWING TO THE
RECOVERY OF DEEP FROZEN CELLS AND ORGANS:
A REVIEW. (E.) Voss, W. A. G. (Surg. Med. Res. Inst.,
Univ. Alberta, Edmonton, Canada), R. V. Rajotte and J. B.
Dosssetor. *J. Microwave Power* 9(3):181-194, 1974.

Two resonant microwave systems operating at 2450 MHz were applied to thawing of deep-frozen adult canine kidneys, fetal mouse hearts, and tissue culture cells. The electrical activity of fetal BALB-c mouse hearts, recovered from -196 C by microwave heating at 200 C/min, survived in a high percentage of cases. The hearts were taken from 17- to 19-day-old embryos, frozen in 5 ml samples of Minimum Essential Medium with 25 mM Hepes buffer, 10% dimethyl sulfoxide, and 10% fetal calf serum. Electrical activity, monitored for up to 35 days after s. c. implantation in syngeneic adult mice, did not differ from that of control implants. Overall survival for frozen, thawed, and implanted hearts was 67% (37/55) between 6-10 days and 59% (32/54) at more than 30 days. Survival of Chinese hamster cells was good following rapid microwave thawing at 100-250 C/min (from -79 to +10 C). Uniform thawing of adult frozen canine kidneys from -79 C was obtained at rates between 100-300 C/min. Heating could be controlled to an end point of 23 C with a variation across the organ of ± 12 C, providing prior perfusion of the organ was complete. Although subsequent functional success has not yet been achieved with frozen thawed kidneys, area of well-preserved glomeruli and capillaries were observed, indicating blood was being perfused. Histologic examination of normal or frozen kidney slices has been difficult and unreliable. (38 references)

0291 AN INTERNATIONAL PROGRAM FOR MICROWAVE
EXPOSURE PROTECTION. (E.) Michaelson,
S. M. (Sch. Med. Dent., Univ. Rochester, N.Y.) and
M. J. Suess. *IEEE Trans. Microwave Theory Tech.*
MTT 22(12):1301-1302, 1974.

In the developed countries there has been a remarkable increase in the number of processes and devices that utilize or emit microwaves. Such devices are used in all sectors of our society for military, industrial, telecommunications, medical, and consumer applications. Because of the world-wide implications of the rapidly developing technology and associated health-safety considerations, development and implementation of a program for international cooperation in the use and protective measures related to microwave/radiofrequency (MW/RF) exposure is required. Activity in this respect has been initiated by the Regional Office for Europe of the World Health Organization (WHO/EURO) which has developed a sector program concerned with the health effects of non-ionizing radiation (NIR) as part of its long-term program in environmental pollution control (see CL 0228). To implement this program, several steps have been taken with participation by scientists and administrators from several countries. These activities have engendered plans and proposals for facilitating exchange and evaluation of information on the biologic and health effects of microwave radiation and in focusing attention on those areas in which additional information and new approaches are needed. (28 references)

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- 0292 HOT SPOTS GENERATED IN CONDUCTING SPHERES BY ELECTROMAGNETIC WAVES AND BIOLOGICAL IMPLICATIONS. (E.) Kritikos, H. N. (Moore Sch. Electr. Eng., Univ. Pennsylvania, Philadelphia) and H. P. Schwan. *IEEE Trans. Biomed. Eng.* BMT-19 (1):53-58, 1972.

The distribution of the heating potential generated by an incident electromagnetic plane wave on a conducting sphere simulating the human head was investigated. It was found that for a sphere of 10-cm radius having the same electrical characteristics as those of biological tissues, no hot spots are generated inside. While at lower frequencies the heating is relatively uniform with some polarization effects, for frequencies above 1000 MHz only skin heating takes place. For a sphere of the same size but of conductivity of $\sigma=10$ mmho/cm (which for $f>1000$ is lower than that of biological tissues) hot spots occur inside for $f>1000$ MHz. Intense hot spots also occur inside spheres of radius 5 cm having the same electrical characteristics as those of biological tissues in the frequency region of 250 MHz $< f < 2800$ MHz. (10 references)

- 0293 A LIMITED MICROWAVE DIATHERMY FIELD SURVEY. (E.) Kantor, G. (Bur. Radiol. Hlth., Div. Electron. Prod., Rockville, Md.) and P. S. Ruggera. *DHEW Publ. (FDA)* 75-8018, Dec. 1974, 23p.

In a field survey of 5 treatment facilities and 1 educational institution, field patterns were obtained from 7 microwave diathermy machines using a total of 20 applicators. These patterns were compared with those generated in the Electromagnetic Branch Laboratory under anechoic conditions. Operator routine, frequency of use of microwave diathermy, and equipment type and maintenance are reviewed. Average applicator patterns, measured with a Narda 8300 probe, varied from 0.2 mW/cm² for a 4" hemisphere to 8.4 mW/cm² for a 22" by 5" corner reflector. Aperture leakage was 2.5 mW/cm² and 3.2 mW/cm², resp., for applicators with a 6" hemisphere and applicators with a 6 3/4" by 5 1/2" corner reflector. Leakage from other units was less than 0.5 mW/cm². In all cases leakage from the generator-module was less than 0.5 mW/cm². Malfunctioning equipment was observed and therapists and instructors had a limited understanding of electromagnetic radiation despite their awareness of the harmful effect of high-level microwave exposure. In general, operators relied on the recommendations contained in the manufacturer's manual. (3 references)

- 0294 ELECTROMAGNETIC FIELDS INDUCED INSIDE ARBITRARILY SHAPED BIOLOGICAL BODIES. (E.) Livesay, D. E. (Dept. Electr. Eng. Systems Sci., Michigan State Univ., East Lansing) and K. M. Chen. *IEEE Trans. Microwave Theory Tech.* MTT-22(12):1273-1280, 1974.

A theoretical method was developed to determine the electromagnetic field induced inside heterogeneous biological bodies of irregular shape. A tensor integral equation for the electric field inside the body was derived and solved numerically for various biological models. These models include a small dielectric cube illuminated by plane waves of varying intensity; a thin layer of conducting medium illuminated by a plane wave of 300 MHz; a tissue block comprising a fat layer and a muscle layer, illuminated by a 100-MHz plane wave; homogeneous and inhomogeneous muscle cylinders exposed to a 2.45-GHz plane wave; and homogeneous and inhomogeneous fat cylinders exposed to a 2.45-GHz plane wave. (10 references)

- 0295 FIRST REPORT OF I. M. P. I. SUB-COMMITTEE ON THE BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. *Int. Microwave Power Inst. Report*, May 25, 1971.

The purpose and program of the International Microwave Power Institute (IMPI) Subcommittee on the Biological Effects of Microwave Radiation, formed in 1970, are outlined. Subcommittee activities include compilation of an international list of references on the biological effects of microwave radiation, to be obtained and maintained through the MEDLARS (Medical Literature Analysis and Retrieval System) of the U.S. National Library of Medicine. The list will extend back to January 1964, and will be updated at 6-month intervals. Information on entries in the list is available to IMPI members from the MEDLARS computer printout and a punch card system. Of the journals currently publishing work on the biological effects of electromagnetic radiation, 89 are in English and 119 in other languages. Other ongoing Subcommittee activities are related to an international register of workers conducting studies on the bioeffects of microwave radiation, the yearly incidence of relevant publications, collecting abstracts and leading articles on the subject, the response to the Simple Language Summary project, problems of indexing and abstracting interdisciplinary journals, and problems of experimental design in the biology-microwave interdisciplinary. (No references)

- 0296 A MICROWAVE DOSIMETRY SYSTEM FOR MEASURED SAMPLED INTEGRAL-DOSE RATE. (E.) Christman, C. L. (Bur. Radiol. Hlth., Div. Biol. Effects, Rockville, Md.), H. S. Ho and S. Yarrow. *IEEE Trans. Microwave Theory Tech.* MTT-22(12):1267-1272, 1974.

An interface was developed to allow measurement of sampled integral-dose rate, defined as the change in the integral dose during a particular time interval divided by that interval, absorbed by test animals during exposure in a waveguide to 2450-MHz continuous

wave microwave energy. Irradiation data for 12 CF1 mice show that the sampled integral-dose rate varies with time due to movement of the animals. Comparative exposures performed on a dead mouse, anesthetized mice, and mice in small tubes demonstrated that variations in the sampled integral-dose rate are reduced when animal movement is limited. The variation in sampled integral-dose rate for anesthetized animals was approximately the same as that for the dead animal. The variation for animals in small tubes was greater than that for anesthetized animals, although it was significantly less than the variation observed for animals restricted to a volume in the waveguide. If the integral dose absorbed by the animal is the only factor determining the biological effect of microwaves, animal movement will not affect measurements of integral dose. However, if the biological effect is dependent on the integral-dose rate, animal movement may affect experimental results. The distribution of absorbed microwave energy may also vary with movement. Variations of integral-dose rate and the distributed-dose rate may need to be quantified if these variables affect the biological outcome of microwave radiation. (7 references)

0297 MICROWAVE SELECTIVE BRAIN HEATING. (E.)
Lin, J. C. (Univ. Washington Sch. Med.
Seattle), A. W. Guy and G. H. Kraft. *J. Microwave
Power* 8(3/4):275-286, 1973.

Maximum absorbed microwave power/unit mass internal distribution were calculated for homogeneous spheres simulating human and animal heads, assuming an incident power density of 1 mW/cm². Theoretically, hot spots occurred for spheres with radius between 2-8 cm at 918 MHz and between 0.9-5 cm at 2450 MHz. Distribution of absorbed power, as well as peak absorbed power, differed according to size and frequency. At 2450 MHz maximum heating was at the center for a 3-cm brain compared with the proximal portion for a 7-cm brain. At 918 MHz maximum heating occurred near the center for both 3-cm and 7-cm brains. Thermographic recordings made on spherical brain models were in close agreement with theoretical predictions. In selective brain heating (915 MHz) experiments, cats were exposed to 380, 190, and 95 mW/cm² at 90, 180, and 360 sec, resp. A temperature of 43 C was attained in 90 sec without tissue damage at any power density, thus suggesting the possibility of using microwave differential hyperthermia as an adjunct for combination therapy in brain cancer. (13 references)

0298 RESEARCH NEEDS FOR ESTABLISHING A RADIO
FREQUENCY ELECTROMAGNETIC RADIATION SAFETY
STANDARD. (E.) Johnson, C. C. (Inst. Biomed. Eng.,
Univ. Utah, Salt Lake City). *J. Microwave Power*
8(3/4):367-388, 1973.

The presence of radiofrequency electromagnetic radiation in the environment was negligible prior to World War II. Now man is being subjected to appreciable levels of this form of radiation due to the rapidly expanding use of radar, television, industrial and medical heating units, communication systems, and many other related devices. In 1966 the American National Standards Institute (ANSI) published a document "Safety Level of Electromagnetic Radiation with Respect to Personnel," establishing an incident power density safety level of 10 mW/cm² from 10 MHz-100 GHz for periods greater than 0.1 hr. This standard was formulated primarily from research results on tissue heating considerations. The safety level in the USSR and Eastern European countries is 10 μW/cm² based on research relating to central nervous system and behavioral effects. This fundamental difference of 1000 to 1 in the safety standard is due in part to both a different emphasis and standards philosophy. In view of the need for a scientifically sound standard and to clarify conflicting research data, ANSI Subcommittee C95.4 was directed to prepare a report on research needs for establishing an improved radiofrequency safety standard. This paper, based on the subcommittee report, contains recommendations for research in the following areas: biological effects, field variables, dosimetry and instrumentation, protocols for biological studies, extrapolation to man, effects of elevated temperature and environmental conditions, and population groupings. The importance of conducting research in groups is emphasized. Priority is assigned to research on the biological effects of long-term, low-level exposures and to the development of instrumentation that will improve knowledge of electric field and absorbed power distribution in biological specimens. (55 references)

0299 MICROWAVE CHARACTERISTICS OF HUMAN TUMOR
CELLS. (E.) Stamm, M. E. (Univ. California
Sch. Med., Los Angeles), W. D. Winters, D. L. Mor-
ton, and S. L. Warren. *Oncology* 29(4):294-301, 1974.

Microwave energy transmitted between 76-86 GHz was used to identify differences between human tumor cells and autologous normal cells grown in tissue culture. An interferometer configuration enabled the microwaves to be divided into a tumor beam and a normal beam; energy from the normal beam was continuously subtracted from that of the tumor beam. When both samples were of the same material; i.e., normal versus normal, and the same thickness, a null response was detected. In the case of normal versus tumor specimens, their two-characteristic spectra were automatically subtracted, resulting in the differential transmission spectra of the two materials. After samples were grouped according to spectral type, histological analysis showed that the tumors consisted of 1 carcinoma, 2 melanomas, and 6 sarcomas. Each spectral type corresponded to a specific type of malignancy. Comparative microwave analysis of

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primary tumor, metastatic tumor and normal cells from the same patient may provide data correlated with immunologic information such as levels of tumor-associated antigen in cells during *in vitro* culture. (2 references)

0300 ELECTROMAGNETIC FIELDS IN A HOMOGENEOUS MODEL OF MAN. Barber, P. W. (Dept. Electr. Bioeng., Univ. Utah, Salt Lake City). Proc. 1974 USNC/URSI-IEEE Meeting, Oct. 14-17, 1974.

The Extended Boundary Condition Method used to solve electromagnetic scattering problems is applied to the calculation of internal fields in a prolate spheroid which has been illuminated by a plane electromagnetic wave. The electrical parameters of the model were chosen to approximate a homogeneous distribution of muscle tissue. The problem is solved on a spherical basis, which results in a set of equations for the coefficients of expansion of the internal field in terms of the incident field coefficients. Solution of the system of equations required evaluation of a set of integrals over the surface of the spheroid, and a matrix inversion. Once the coefficients were obtained, the fields were calculated throughout the interior volume. Internal power density was calculated for different characteristics of the model, and for various orientations of the incident field. The technique can also be used to calculate the power deposition in small animal models. The capability to make calculations for both man-sized bodies and small animals will make it possible to extrapolate data obtained from animal experiments to man's body configuration, useful in determining an electromagnetic radiation safety level and in medical diagnosis and therapy. The technique can also be used to compute internal power density levels for *in vitro* tissue preparations. (No references)

0301 ELECTROMAGNETIC FIELD MEASUREMENTS FOR BIO-EFFECTS EXPERIMENTS AND THE CONTROL OF POTENTIAL HAZARDS. Bowman, R. R. (Nat'l. Bur. Stands., Boulder, Colo.). Proc. 1974 USNC/URSI-IEEE Meeting, Oct. 14-17, 1974.

The measurement of potentially hazardous electromagnetic (EM) fields is difficult because of complicated field configurations. Though it has long been realized that instruments designed to measure simple planewave fields are not adequate, more suitable instruments have not been available until the last few years. Since the power density S of complicated fields often has little meaning as a hazard index, these new instruments measure the Hermitian magnitude $E \equiv (E_x^2 + E_y^2 + E_z^2)^{1/2}$, or some derived quantity such as the electric field energy density $U = \frac{1}{2} \epsilon_0 E^2$. The new instruments, as presently designed, respond to E^2 and the field sensors are essentially independent of their orientation in the field, regardless of

the complexity of the field. Further development of this type of instrument is expected to allow direct measurements of electric fields inside subjects and phantoms. The capability to measure internal fields is important for determining the internal exposure of subjects in bioeffects experiments and for developing phantom "dosimeters." (No references)

0302 MEASUREMENT OF POWER ABSORBED IN THE TISSUE OF MAN AND ANIMALS EXPOSED TO ELECTROMAGNETIC FIELDS. Guy, A. W. (Univ. Washington, Seattle). Proc. 1974 USNC/URSI-IEEE Meeting, Oct. 14-17, 1974.

Absorbed power may be quantified by: 1) theoretical calculations based on the particular source and geometric shape of the exposed object, 2) measurement of the fields within the tissues by field sensing probes, 3) indirect point-by-point measurement of the absorbed power by rate of change of temperature increase in the tissue under exposure, and 4) indirect thermographic measurement of the absorbed power by rate of change of two dimensional temperature patterns in sectioned phantom models of the tissues or in the actual tissues of sacrificed animals. In the first method, shape and sources are restricted to specific configurations. Specimens may be contained in cylindrical, disk-shaped or spherical containers and exposed to plane fields or waveguide fields so that total absorbed power or absorbed density distribution may be calculated from the incident fields, measured by standard means. Direct measurement in tissue by field sensing probes is difficult, and though such probes are under development, no satisfactory instruments are available at this time. The most straight-forward method of determining power absorption is measuring the rate of change of temperature rise at the site, and converting it to power absorption density and electric field strength from the known thermal and electrical properties of the tissues. This must be done without metallic probes or wires, and with sufficient applied power levels to provide rapid temperature rise. Thermistors or thermocouples with small diameter, high resistance lead wires may be satisfactory, or dielectric guides which allow metallic probes to be withdrawn and reinserted before and after irradiation. New dielectric fiber optic probes are promising for continuous monitoring. All methods require information on the thermal and electrical properties of the tissues. Development of internal field measurement instrumentation should be of high priority. (No references)

0303 THE EFFECT OF 2450 MEGAHERTZ MICROWAVE RADIATION ON LIVER ADENOSINE TRIPHOSPHATE (ATP). (E.) Albert, E. N. (Sch. Med., George Washington Univ., Washington, D. C.), G. McCullars and M. Shore. J. Microwave Power 9(3):205-211, 1974.

This investigation was designed to explore the effects of microwaves on the adenosine triphosphate levels of liver hepatocytes. Chinese hamster littermates were irradiated with 2450 MHz microwave radiation at a power density of 50 mW/cm² for 30 minutes to 4.5 hours over a period of 1 to 21 days. The animals were sacrificed immediately after the last exposure. Adenosine triphosphate levels per gram weight of tissue were measured by using luciferin firefly extract. It was found that, under these conditions, there was no significant difference between control and experimental animals, when littermates were used in each of the above groups. (16 references)

0304 THE INFLUENCE OF ELECTROMAGNETIC WAVES IN THE COURSE OF AN INFECTION WITH NEWCASTLE DISEASE VIRUS IN CHICK EMBRYO TRACHEAL ORGAN CULTURE. (Ger.) Henneberg, G. (Dept. Virology, Robt. Koch Inst., Berlin Mun. Brd. Hlth., Germany), S. Heller and H. Jordanski. *Zbt. Bakt. Hyg., I. Abt. Orig.* A226, p. 17-25, 1974.

The influence of electromagnetic waves from the range of infrared ($\lambda=1-2\mu$) and cm-waves ($\lambda=1.4$ cm) on the course of an infection with Newcastle Disease Virus (NDV) in chick embryo tracheal organ cultures is the subject of this report. The decrease of destruction of the ciliated epithelium and its ciliary activity, respectively, after radiation was found to be statistically significant. The effect of radiation by red light of the suspended inoculum was increased by an additional radiation of the organ cultures with cm-waves. This phenomenon caused by infrared and cm-waves may also point to the importance of these wave lengths as bioclimatic factors. (6 references)

0305 THE EFFECTS OF DECIMETER WAVES ON CATECHOLAMINE METABOLISM IN THE TISSUES OF HEALTHY RABBITS. (Rus.) Maksimova, L. I. (Central Inst. Health Resorts, Physiotherapy, Moscow, USSR). *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (38):490-493, 1973.

The effects of electromagnetic radiation in the decimeter range on the catecholamine metabolism in tissue and plasma were investigated in 45 healthy male, 2.5-3.5 kg, rabbits exposed to 65 cm radiation at power densities of 110 mW/cm² and 380 mW/cm², for 12 six-minute daily sessions. The generator's active surface of 12.56 cm² was set against the D₁₀ - L₄ region which corresponds to the plane of the adrenal glands. The animals were decapitated 24 hr and 20 days after the exposure. Studies were made of the blood, adrenal glands, cardiac muscle, pulmonary tissue and hypothalamus. Findings indicate that exposure of the adrenal glands at 110 mW/cm² stimulates the sympathetic part of the sympathetic-adrenal

system: the adrenalin content in the glands tended to rise ($P>0.05$); noradrenalin content increased from 29.87 to 123.46 μ g/g. In the cardiac muscle and blood the noradrenalin content rose from 1.19 to 1.49 μ g/g and from 6.9 to 10.64 μ g/g, resp. Adrenalin content rose from 0.05 to 0.09 μ g/g in the hypothalamus. Dopa content in the hypothalamus increased from 0.01 to 0.15 μ g/g. No change was observed in the pulmonary tissue. Studies of the catecholamine metabolism 20 days after the exposure revealed the noradrenalin content in the adrenal glands at 100.25 μ g/g (normally 29.87 μ g/g), while in the heart, hypothalamus and blood plasma it approached the norm. The adrenalin and dopa content in the hypothalamus remained elevated. Exposure at 380 mW/cm² produced substantial changes. In the adrenal glands the adrenalin content dropped by 47% to 137.6 μ g/g (normally 258.78 μ g/g), and dopa decreased from 25.11 to 10.82 μ g/g. Noradrenalin, adrenalin and dopa tended to decrease in the cardiac muscle, while in the blood plasma the adrenalin content dropped from 6.16 to 3.71 μ g/g and noradrenalin from 6.9 to 3.37 μ g/g. The experiment indicated a strong depressing effect of exposure in the decimeter range at 380 mW/cm² power density on the sympathetic part of the sympathetic-adrenal system. (13 references)

0306 THE EFFECT OF UHF ELECTROMAGNETIC WAVES ON THE INDUCED POTENTIALS OF THE AUDITORY CENTERS AND THE PROSPECTS FOR INADEQUATE AUDITORY STIMULATION. (Rus.) Sagalovich, B. M. (Moscow Sci. Res. Inst. Ear, Nose, Throat, USSR) and G. G. Melkumova. *Vestn. Otorinolaringol.* (4):3-8, 1974.

The experiments, involving 25 rabbits and 20 albino rats exposed to 2050 MHz, 2500 MHz, and 3000 MHz at power densities ranging from 0.15 mW/cm² to 14 mW/cm², studied the feasibility of transmitting sound information directly to the auditory centers of the cerebral cortex bypassing the ear. Needle electrodes were introduced into the auditory zone of the cortex of immobilized animals. Measurements were made of induced potentials of the auditory zone in response to clicking sounds. The results show that the mean amplitude drop of induced potentials in rabbits exposed to 2050 MHz at power densities of 0.5 mW/cm², 0.25 mW/cm², and 7.0 mW/cm² was 38% before the exposure, 0% at the time of the exposure, and 10% after the exposure; in rats 30%, 10% and 37%, resp. Exposure to 2500 MHz at 1.0 mW/cm², 0.5 mW/cm² and 14 mW/cm² produced the drop of 27%, 30%, and 30%, resp., in rabbits; 45%, 46%, and 45% in rats. Pulse frequencies were 2,000, 1,000 and 1,000 pulses per minute; duration: 18 μ sec, 18 μ sec and 500 μ sec; coefficient of charge: 0.036, 0.018, 0.05. The change of frequency from 2050 mW to 2500 mW involved a substantial rise in the response threshold, while at 3000 mW there was no reaction of the auditory centers. Findings suggest that the observed phenomenon was of a sensory nature as the thermal effect of the exposure was avoided by employing the power density of 10 mW/cm²

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sparingly. The inhibitory effect of induced potentials by electromagnetic waves correlated with the duration of pulses and the coefficients of charge, rather than with the mean power densities. (19 references)

- 0307 THE EFFECT OF 2450 MHZ MICROWAVE IRRADIATION ON THE GROWTH OF MICE. (E.) McAfee, R. D. (VA Hosp. New Orleans, La.), R. Braus, and J. Fleming. *J. Microwave Power* 8(1):111-116, 1973.

This study was conducted as a follow-up to previous research for which results were considered inaccurate or inconclusive. A correction is also made of the record of the authors' having confirmed experimentally a dielectric saturation effect which might cause denaturation of molecules in living material; no such confirmation was achieved. One hundred control and 96 experimental Swiss-Webster mice were used in the follow-up experiments. Experimental mice were irradiated daily for 2 min each hour at a power density of 10 mW/cm², and subsequently weighed over a 36-day period. Except for the 5th and 8th day, when mice were weighed *en masse*, mice were individually weighed to the nearest 0.1 g. Using data from the frequency distribution of mouse weights plotted on the initial, 18th, and 36th day of irradiation, the possibility of there being significant weight difference between groups of experimental and control mice was tested using "Student's" t test. No significant differences were found. (P values for all three days were much greater than 0.05.) (7 references)

- 0308 DIELECTRIC PROPERTIES OF MATERIAL FOR MICROWAVE PROCESSING--TABULATED. (E.) Tinga, W. R. (Dept. Electr. Eng., Univ. Alberta, Edmonton, Canada) and S. O. Nelson. *J. Microwave Power* 8(1):23-65, 1973.

A brief description is given of the dielectric dispersion and relaxation as a function of frequency and temperature. Important aspects of the behavior of dielectric mixtures with respect to frequency, temperature, and composition are summarized and referenced. In the tabulation, materials are classified as Agricultural, Biological, Foods, Forest Product, Leather, Rubber, and Soils and Minerals. The data tabulation entitled "Values for the Dielectric Constant, ϵ' , and the Dielectric Loss Factor, ϵ'' , of Materials Described at Indicated Temperatures, Moisture Contents and Frequencies," shows material description and frequency as the two basic variables and lists all other factors influencing the data as parameters. In many cases data are available at only a few frequencies, which results in many blank spaces in the table. On the other hand the table shows at a glance those frequency ranges where further data are necessary, and allows

for updating as data become available. The frequency range is set between 10 kHz and 10 GHz, since most important dielectric dispersion phenomena lie within this frequency range. The biological section of the table includes data on: bovine serum albumin, bacteria, blood, red blood cell, bone and bone marrow, bovine eye lens, fat and fatty tissue, G-actin, hemoglobin, insects, liver, lung, muscle and skin. (82 references)

- 0309 EFFECT OF SUPERHIGH FREQUENCY ELECTROMAGNETIC ENERGY ON MUTAGENESIS. (Rus.) Danilenko, I. I. (no affil.), V. I. Mirutenko and V. I. Kudrenko. *Elektron. Obrabotka Materialov* (4):71-72, 1974.

Two-day-old cultures of a histidine-dependent strain of *Candida tropicalis*, D-2, were washed twice with physiological saline and allowed to stand for 24 hr before they were resuspended in a pH 6.0 phosphate buffer containing N-nitroso-N-methylurea (NMM; 1 mg/ml) or N-methyl-N-nitro-N-nitroguanidine (NMG; 0.25 mg/ml) at 32-33 C for 3 hr. These treated cells were then diluted and inoculated into either complete or minimal media to study their viability, morphological variability, and yield of revertants. After exposure to the mutagens for 1.5 hr, 2 ml samples of some cell suspensions were exposed to superhigh frequency (SHF) radiation (37,000 MHz, 1 mW) for 30 min at a minimal distance from a GZ-30B waveguide generator. The cells were then treated again with mutagen for a total of 3 hr. While SHF radiation alone had no effect on cell viability, NMM reduced it to 72 ± 8% and NMG to 21 ± 2% of control values. SHF + NMM had little effect on viability, but SHF + NMG reduced it to 18 ± 3% of control values. While only 8 ± 2% of control cells and 17 ± 3% of those exposed to SHF showed morphological variability, 41 ± 6% of those exposed to NMM and 34 ± 3% of those exposed to NMG showed variability. Morphological variability was present in 66 ± 6% of cells exposed to SHF + NMM and in 42 ± 3% of those exposed to SHF + NMG. The yield of revertants was significantly increased by all forms of treatment, but was particularly pronounced in those given combined treatment. It is suggested that SHF radiation might affect DNA polymerase, increasing the number of his⁺ mutants and morphological variants. The lethal effect of SHF radiation was not due to heat production since no temperature increase was noted. The synergistic effect of SHF radiation + mutagen might be due to increased permeability of cell walls to mutagen. (8 references)

- 0310 NUTRITION AND IN VIVO ROTATIONAL MOTION: A MICROWAVE STUDY. (E.) Webb, S. J. (Physics Dept., Univ. S. Florida, Tampa) *Int. J. Quantum Chem.: Quantum Biology Symp.* (1):245-251, 1974.

Experiments conducted with mammalian cells revealed that microwave frequencies absorbed by normal cells are different from those absorbed by tumor cells, and that the frequencies all form a series separated by a constant frequency. Tissue cultures of normal baby hamster kidney (BHK), BHK tumor cells transformed by mouse sarcoma virus (MSV), and Ehrlich ascites cells, having different tumor producing capacities, were used along with tissue slices of "natural" human mammary and lung carcinoma. The cells and tissues were examined without any fixation processes. Following their exposure to a microwave field having a density of 50-100 mW/cm², the cells were cloned on agar media and implanted into susceptible animals to assess possible lethal effects. All the normal mammalian cells absorbed frequencies of MWs, between 50-90 GHz, which formed a series separated by 2.0 and 2.5 GHz, resp. The frequencies absorbed by tumor cells appeared to follow 2, and perhaps 3, series separated by 1.9, 2.3, and 2.7 GHz, resp. As a given strain of cell went from highly tumorigenic to nontumorigenic, the strength of attenuation in the 2.3- and 2.7-GHz series of frequencies absorbed decreased, and attenuation of frequencies in the 2.5-GHz series occurred or increased. The irradiation of both the BHK and Ehrlich tumor cells with each of two frequencies in the 2.3-GHz series resulted in a decrease in their tumorigenicity but not viability. The results indicate that an *in vivo* movement, possibly of water or other small molecules, in mammalian cells interacts with a set series of electromagnetic frequencies between 50 and 90 GHz and is quantized with only certain energy transition, from one quantum level to the next, allowable. The difference between normal and tumor cells seems to reside in their respective physical rather than chemical characteristics which determine *in vivo* motions and, hence, structural architecture. (30 references)

0311 EFFECTS OF ELECTROMAGNETIC ENERGY ON THE ENVIRONMENT--A SUMMARY REPORT. (E.) Cory, W. E. (Electron. Syst. Res., San Antonio, Tex.) and C. L. Frederick. *IEEE Trans. Aerospace Electron. Systems* AES-10(5):738-742, 1974.

The beneficial and potentially hazardous effects of electromagnetic (EM) radiation are reviewed. Included is a discussion of natural and man-made EM generators; the electrical nature of man; direct and indirect effects of EM on man; medical, industrial, agricultural, and telecommunication uses of EM technology; and their regulation by government agencies. Judgments on the beneficial *versus* harmful effects of EM energy can be based in part on evidence that the latter can destroy DNA in human cells, act selectively on the chemical structure of virus molecules, and affect chromosomes. Man-made generators that produce non-ionizing waves generate frequencies below 10¹⁵ Hz. These waves do not have sufficient energy to dislodge electrons from their orbits in atoms or

produce ion pairs. The approximate frequency ranges are reported for EM effects and treatments. Illnesses caused by exposure to EM fields can be largely eliminated by adherence to exposure levels found to be safe. The health of persons with diseases not caused by EM energy may be greatly improved by proper therapeutic uses of energy. (6 references)

0312 A MICROWAVE DECOUPLED BRAIN-TEMPERATURE TRANSDUCER. (E.) Larsen, L. E. (Methodist Hosp., Houston, Tex.), R. A. Moore and J. Acevedo. *IEEE Trans Microwave Theory Tech.* MTT-22(4):438-444, 1974.

Bench tests of conventional temperature transducers in microwave environments have demonstrated artifacts responsible for errors of several degrees centigrade. These findings led to a program for development of systematic test procedures and the design of microwave integrated circuit (MIC) electrodes with artifact reduced to 0.1 C, the criterion for measurements in the anterior hypothalamus/preoptic area of the brain. Tests of a glass electrode implicated lead-wire coupling as the major factor in artifact production. The MIC electrode has 5- μ m microline conductors, a thick-film thermistor, and 50-k Ω current-limiting resistors. For thermographic tests in a 50 mW/cm², continuous wave field at 2450 and 918 MHz, the needle was thermally isolated from the external conductive monofilament by means of a Teflon chassis. Temperature rise due to the presence of the electrode was below the limit of resolution of the thermograph for line scans taken at the electrode tip. (17 references)

0313 MICROWAVE RADIOMETRIC MEASUREMENTS OF THE TEMPERATURE INSIDE A BODY. (E.) Enander, B. (Div. Electromagnetic Theory, Royal Inst. Tech., Stockholm, Sweden) and G. Larson. *Electron. Lett.* 10(15):317, 1974.

Thermal radiation in the microwave region comes from a surface layer of a body with a depth that is the same magnitude as the depth of penetration--the distance where the planewave field decreases by a factor of e^{-1} . In order to measure this thermal radiation a radiometer of the type used in radioastronomy was built and temperatures inside a body were measured at 0.9 to 1.2 GHz. The radiometer, which is a broadband receiver, compares the noise from a matched termination at a known temperature with the noise from an antenna placed on the body. The theoretical accuracy of the system is about 0.1 C. By placing the antenna on a dissipative medium at a homogeneous temperature, the radiometer will measure the temperature, provided the antenna is matched to the medium. The antenna used was a small loop antenna designed to give a good match when placed on a human body or other dissipative medium with similar dielectric

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properties. In experiments with humans, the antenna was placed on the surface of the body, together with a thermistor that measured the surface temperature. On most parts of the body, it was possible to get a good match to the antenna (v.s.w.r.<1.2). Radiometer temperatures were generally 1 C above thermistor temperatures, because the radiometer is also sensitive to depth temperatures, which are higher than surface temperatures. Measurements of this type may have applications in medicine for diagnostic purposes. (2 references)

- 0314 MICROWAVE SICKNESS: A NEW DISEASE? (Ger.)
Werner, G. (Central Hosp. NVA, Bad Saarow, Germany) and G. Schubert. *Wissenschaftl. Z. Ernst Moritz Arndt Univ. [Med. Reihe]* 23(3/4):159-161, 1974.

The extent of microwave tissue damage depends upon the following factors: intensity; length of exposure; frequency; size, shape and water content of the biological object; the thermoregulatory condition of the tissue; and on environmental (especially meteorological) conditions. Acute and chronic forms of microwave damage can be distinguished. A classification of 3 degrees of severity of microwave damage is proposed for each form. Acute microwave damage: 1st degree--Acute crisis of the circulatory system and a thermoregulatory disturbance (at approximately 10 mW/cm²); 2nd degree--Various syndromes depending on organs, especially parts of the brain, which are exposed (15-20 mW/cm²); 3rd degree--Radiation shock. Chronic microwave exposure can result in disturbances or even changes in certain organs. Symptoms are varied, but a similarity to neurocirculatory imbalances can be detected. Chronic microwave damages can also be classified into 3 categories: 1st degree--Mild symptoms combined with hypertension. Symptoms recede after exposure is discontinued; 2nd degree--Hypotension fatigue, sexual potency disturbances, changes in the EEG and ECG. The critical intensity for possible damage to the testicles is 5 μW/cm²; 3rd degree--Symptoms are the same as 2nd degree, only more severe, combined with trophic disturbances of the skin. All past experience emphasized the importance of prevention. (No references)

- 0315 TUMOR SYNCHRONISATION THROUGH MICROWAVES. (Ger.) Dietzel, F. (Ctr. Radiol., Justus Liebig Univ., Giessen, Germany). *Strahlentherapie* 148(5):531-542, 1974.

This study examines the applicability of high-frequency waves in the treatment of malignant tumors by influencing the replicative metabolism of the tumor. NMRI-mice (380) with solid Ehrlich neck tumors were exposed to a single dose of high-frequency radiation (461.04 megacycles), so that the intratumoral temperature after 4 minutes was 42 - 43 C. The rate of the replicative metabolism of the tumors was deter-

mined by measuring the incorporation rate of ³²P. Immediately following the exposure, the rate of ³²P incorporation sank to minimum. The rate of ³²P-incorporation reached a maximum 72 hr after exposure, overshooting the baseline considerably and resulting in "tumor-synchronisation". Microwave therapy alone, therefore, can retard tumor growth significantly, mainly by deactivating enzymes involved in DNA synthesis. Microwave therapy with present instruments seems possible for superficial and semi-deep tumors. Treatment of deeper tumors would require more power output, and the development of a method for measuring the proliferation rate, since the ³²P incorporation method only works for superficial tumors. (85 references)

- 0316 MICROWAVES FOR COOKING APPLIANCES. (Ger.)
Schlumpf, K. (St. Gallen, Switz.). *Elektricitätsverwertung* 47(12):408-410, 1972.

Many years of tests have shown that no radiation damage occurs at frequencies of 2400 - 2500 Hz, as long as the intensity of the scattered radiation does not exceed 10 mW/cm². New regulations will set the maximum permissible intensity of scattered radiation at 1 mW/cm². Safety is also ensured by a switch disconnecting the generator when the oven door is opened. In some countries the power source must be disconnected to gain access to the electrical part of the instrument. Since the intensity varies inversely with the square of the distance from the energy source, distance is also very important. An intensity of 1 mW/cm² at a distance of 5 cm would only be 0.004 mW/cm² at a distance of 76 cm. (No references)

- 0317 EFFECT OF COMBINED EXPOSURE TO MICROWAVES AND X-RAYS ON THE PERMEABILITY OF THE HISTOHEMATIC BARRIER. (Ukr.) Faitelberg-Blank, V. R. (Odessa Agric. Inst., USSR) and A. V. Orlova. *Dopovidi Akad. Nauk Ukrainsk. RSR (Ser B)* (8):741-745, 1974.

Male rats were exposed to 800 r of x-radiation alone or to the same dose of x-rays followed by electromagnetic radiation (EMR; wave length 12.3 cm, 30 W) for 10 or 20 min. After 1-15 days, animals were injected i.p. with Na₂H³²PO₄ (4.5 μCi/100 g body weight), sacrificed after 60 min, and incorporation of ³²P was significantly increased in relation to its incorporation in the blood. However, 3 days after exposure, incorporation of ³²P decreased, reaching a minimum after 10 days. After 15 days, incorporation of ³²P was still decreased in most of the tissues examined. In contrast, 1 day after exposure to x-rays and EMR incorporation of ³²P in the tissues decreased. However, at later periods, ³²P incorporation, and thus permeability of the histoheuristic barrier, returned to normal values in rats exposed to both x-rays and EMR. These findings confirm those of other investi-

gators that microwave exposure increases the resistance of animals to x-irradiation and reduces their mortality. (8 references)

- 0318 CHANGES OF PERIPHERAL BLOOD PARAMETERS IN GUINEA PIGS CAUSED BY EXPOSURE TO AN ELECTROMAGNETIC FIELD IN THE THREE-CENTIMETRE RANGE. (Ukr.) Kartsovnik, S. A. (Odessa Agric. Inst., USSR) and V. R. Faitelberg-Blank. *Dopovidi Akad. Nauk Ukrainsk. RSR (Ser B)* (8):736-741, 1974.

Changes in the white blood picture were studied in 25 male guinea pigs which were exposed to superhigh frequency (SHF) electromagnetic radiation in the 3-cm range at intensities of 25-500 $\mu\text{W}/\text{cm}^2$ for 10 min/day over a 30-day period. Controls consisted of 7 guinea pigs exposed to noise from the generator, the field of which was not turned on. Periodic increases occurred in the white blood cells (WBC) of guinea pigs exposed to intensities of 25 and 50 $\mu\text{W}/\text{cm}^2$, while the WBC decreased in animals exposed to 200 and 500 $\mu\text{W}/\text{cm}^2$. Exposure to SHF radiation significantly increased the lymphocyte count at intensities of 50 and 500 $\mu\text{W}/\text{cm}^2$ with a corresponding decrease in the number of neutrophils. At an intensity of 200 $\mu\text{W}/\text{cm}^2$, periods of lymphocytosis were produced while some animals had a tendency to lymphopenia. Although no change occurred in the total number of monocytes, the number of old, inactive monocytes increased, indicating that the activity of the monocyte system was suppressed. This suppression increased with the intensity of SHF radiation. Qualitative changes produced in leukocytes by an intensity of 50 $\mu\text{W}/\text{cm}^2$ included anisocytosis of the hypersegmented macroforms and nuclear polymorphism in the monocytes. Exposure to 500 $\mu\text{W}/\text{cm}^2$ for 30 days significantly reduced the osmotic resistance of leukocytes. Exposure to SHF radiation probably resulted in the development of an osmotically less stable generation. (7 references)

- 0319 THE BIOLOGICAL EFFECTS OF RADAR WAVES. (E.) Boiteau, H. (no affil.) *Rev. Corps Sante Armees* 1(5):637-652, 1960.

In the late 1940s investigations in man and animals showed no pathological effects of radar waves on the human organism, but these results were obtained with low-power emitters. There are now radars with radiation as high as 0.01 W/cm^2 150 meters from the antenna in the beam axis. Animal studies in the U. S. have shown that ultra-short waves (e.g., 2500 and 10,000 megacycles) have indisputable biological effects on organs that are most sensitive to hyperthermia (eyes, testicles, nerve centers). The severity of the histological lesions varies as a function of the energy density received by the organ. To determine the effect of ultra-short waves on man, Lockheed Aircraft Corporation conducted a 2-yr survey of 226 employees

working on active radars (peak power slightly in excess of 1 Mw) for up to 4 hr/day. Length of such exposure was 3-4 yr in some cases and 13 yr in 1. The percentages of acute or chronic afflictions in the exposed group were comparable to those found in 88 nonexposed controls. Radar workers had an abnormally high proportion of ocular difficulties, but these appeared unrelated to their exposure. Subjective symptoms were modest on the whole. Some employees (25%) noted a sensation of heat in the face, neck, or hands while working near an antenna emitting in the S band; others complained of fatigue, headaches, and pain inside the eyeballs. For man, the energy density tolerable without risk for a prolonged period has been empirically fixed at 0.01 W/cm^2 . If exposure is of short duration, a much higher flux can be tolerated (3 W/cm^2 for 1 min). It is not clear whether ultra-short waves act on tissues by a simple release of heat or have a specific activity that is added to the effects of hyperthermia. The latter possibility is supported by animal experiments showing that ultra-short waves and infrared radiation have the same clinical manifestations but that the critical temperature is lower for radar radiation than for infrared. In the absence of precise knowledge of the activity of radar waves in man, care must be taken to protect workers from very high-power emitters (4 Mw at peak). (22 references)

- 0320 VARIATIONS OF NERVE EXCITABILITY AND CONDUCTION UNDER THE INFLUENCE OF MICROWAVES. (Fr.) Deficis, A. (U. E. R. des Sciences Pharmaceutiques, Toulouse, France), A. Delfour, J. C. Dumas and S. Laurens. *Experientia* 30(11):1276-1277, 1974.

The effects on speed of conduction, rheobase, and chronaxie of the sciatic nerve of the frog was studied as a function of the frequency of microwave irradiation. A preliminary test showed that the thermal effect of microwaves did not affect speed of conduction. Across a frequency range from 1 to 9 GHz, there was a marked decrease in speed of conduction between 2.5 and 9 GHz, with a maximum effect at 5 to 6 GHz, where the diminution was 8 to 10%. There was no appreciable effect on the chronaxie and rheobase. A systematic frequency study is suggested to obtain more specific biological effects of microwaves. (6 references)

PREPRINTS

0321 DO MICROWAVES ALTER NERVOUS SYSTEM STRUCTURE? (E.) Albert, E. N. (Sch. Med. Hlth. Sci., George Washington Univ., Washington, D.C.) and M. DeSantis.

Exposure of adult Chinese hamsters to microwaves of 2450 MHz frequency and at power densities of 25 mW/cm² for 1-22 days or 50 mW/cm² for 30 min to 24 hr resulted in severe structural alterations of neuronal cytoplasm in the hypothalamus and subthalamus. At the light microscopic level, the neuron cell bodies of the hypothalamus and subthalamus showed vacuolization and chromatolysis. Electron microscopy revealed that the neurons were devoid of polyribosomes and rough endoplasmic reticulum. In addition, myelin figures and swollen membranous structures were frequently observed in the dendrites of the hypothalamic neurophile. Application of the Fink-Heimer technique suggested that some axonal degeneration occurred after microwave irradiation. There was no evidence of gliosis, hemorrhage, or perivascular edema in the irradiated animals; however, vascular stasis or congestion was seen in some animals. No changes occurred in cell bodies of hippocampal pyramidal neurons, Purkinje cells of the cerebellum, mesencephalic nucleus of the trigeminal nerve, motor neurons of the spinal cord ventral horn, or cell bodies of the thalamic relay nuclei. It is not clear whether the electromagnetic radiation itself or tissue heating, due to radiation energy absorption, was responsible for the effects on the hypothalamus and subthalamus. (13 references)

0322 LONG WAVELENGTH ANALYSIS OF PLANE WAVE IRRADIATION OF A PROLATE SPHEROID MODEL OF MAN. (E.) Durney, C. H. (Dept. Electr. Eng., Univ. Utah, Salt Lake City), C. C. Johnson and H. Massoudi.

Electromagnetic field perturbation techniques were applied to obtain the first-order internal electric fields and absorbed power for planewave irradiation of a prolate spheroid model of man when the wavelength is long compared to the dimensions of the spheroid. Power calculations based on the results show a striking change in absorbed power with a change in orientation of the spheroid in the incident fields. In a given radiation field, the absorbed power varies with the size of the absorbing body. The derived expressions for absorbed power density and absorbed total power should be useful in studies of radiation hazards to man. (11 references)

0323 RATE EFFECTS IN ISOLATED TURTLE HEARTS INDUCED BY MICROWAVE IRRADIATION. (E.) Tinney, C. E. (Univ. Utah, Salt Lake City), J. L. Lords and C. H. Durney.

Experiments were conducted to test the hypothesis that excitation of nerve remnants, or direct transmitter release, contributed to the bradycardia observed at low power levels of microwave irradiation (960 MHz, continuous wave, 2-10 mW/cm³ absorbed power). First, the action of the parasympathetic system of isolated turtle hearts was blocked by addition of atropine to Ringer's solution, and 8 mW/cm³ absorbed power was applied. Second, the sympathetic system was blocked by addition of propranolol hydrochloride (β blocker) to the Ringer's solution and similar power applied. Atropine allowed the microwave neural effect to stimulate the sympathetic system only, thus causing tachycardia rather than bradycardia. Propranolol hydrochloride allowed the parasympathetic system to cause even greater bradycardia than that noted when only microwaves were applied. The results confirm that microwaves can cause neural transmitter release effects. At 100 mW total applied power (8 mW/cm³ absorbed power), the temperature rise within the heart was about 0.02 C. This indicates that the neural effect of microwaves is dominant at lower power levels in contrast to generalized heating effect of higher power levels. (No references)

0324 EFFECT OF LOW INTENSITY MICROWAVES ON ISOLATED NEURONS. (E.) Wachtel, H. (Dept. Biomed. Eng., Duke Univ., Durham, N.C.) and R. Seaman.

Changes in the electrical activity of individual neurons from *Aplysia* ganglion were recorded before, during, and after exposure of the ganglion to microwaves at 1.5 and 2.45 GHz. In addition to monitoring incident and reflected microwave power levels, ganglionic temperature was recorded. Pronounced changes in the firing patterns of pacemaker neurons with regular beating rhythms and those with regular bursting rhythms occurred at absorbed microwave power levels below what human brain cells would be exposed to at the accepted safety level of 10 mW/cc. In large part, these effects are attributable to slight ganglionic warming, but effects are found that are not accompanied by, or not reproduced by, ganglionic warming. No significant differences were detected in the effects of pulsed or continuous wave radiation at the two frequencies used. (11 references)

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CURRENT RESEARCH

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SOURCES: Smithsonian Science Information Exchange

0071 DEVELOPMENT OF MICROWAVE INSTRUMENTATION.
Wyatt, R. H.; Joines, W. T. (Environ. Biophysics Branch, Duke Univ., Durham, N. C.).

The proposed work of this contract is threefold: (1) Study the electrical dipole model of the neural membrane and its implications, and determine the unknown parameters in the interaction of the dipole model with microwave radiation; (2) Develop microwave instrumentation and methods to investigate microwave-neuron interactions over the 0.2 to 3.0 GHz frequency band; (3) Develop the instrumentation and dosimetry of a more accurate method of determining the microwave power absorbed by a neuron.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

0072 EFFECTS OF MICROWAVE RADIATION ON THE NEURAL RESPONSE. McRee, D. S. (Environ. Biophysics Branch, Duke Univ., Durham, N. C.).

The objective of this project is to determine the effects of microwave radiation on the functioning of the central nervous system when exposed to CW and modulated microwave radiation in the frequency range of 1-10 GHz. Isolated neurons and surviving spinal cords of decerebrated cats will be exposed. The effects of the radiation on action potentials, conduction velocities, and firing patterns will be observed.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

0073 INVESTIGATION OF NON-THERMAL MICROWAVE RADIATION EFFECTS ON NEUROLOGICAL FUNCTIONING. Wyatt, R. H.; Somjen, G.; McRee, D. I. (Environ. Biophysics Branch, Duke Univ., Durham, N. C.).

The project objective is to conduct an investigation into the non-thermal effects of microwave radiation on neurological functioning. More specifically, recent efforts have been aimed at investigating the effects of microwave radiation on spinal reflex function in the cat. The lower lumbar spinal cord was exposed, and the ventral roots of L7 and S1 segments were cut at their exit from the vertebral canal. Pulses of 0.05 msec were used to stimulate the sciatic nerve, and the response at the ventral root was recorded for both irradiated and non-irradiated controls. Microwave radiation at 2450 MHz with power levels from 2 to 10 mW/cm² was used. Only preliminary, pilot results have been obtained.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

0074 EFFECTS OF 2450 MHZ MICROWAVE RADIATION ON BIOLOGICAL MATERIAL AT CELLULAR AND MACROMOLECULAR LEVEL. Hamrick, P. E.; Zinkl, J.; Staples, R. (Environ. Biophysics Branch, Duke Univ., Durham, N. C.).

The objectives of this project are to determine the effects of 2450 MHz microwave radiation on biological material at the cellular and macromolecular level and relate the amount of microwave energy absorbed to the effect. Various cellular and macromolecular systems will be tested by exposure to microwaves under carefully controlled temperature and dose conditions. Parameters such as viability, cell membrane permeability and denaturation will be used as indicators of microwave effects.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

0075 EFFECTS OF 2450 MHZ CW MICROWAVE RADIATION ON THE EMBRYONIC DEVELOPMENT OF JAPANESE QUAIL. Hamrick, P. E.; McRee, D. I.; Zinkl, J.; Thaxton, P. (Environ. Biophysics Branch, Duke Univ., Durham, N. C.).

The objective of this project is to determine the effects of 2450 MHz CW microwave radiation on the embryological development of Japanese quail. Fertilized quail eggs will be exposed to 2450 MHz microwave radiation under carefully controlled temperature and dose conditions. Parameters such as percent hatching, gross deformities, and blood values will be used as indications of microwave effects.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

0076 VARIABLE FREQUENCY MICROWAVE EXPOSURE SYSTEM. McRee, D. I. (Environ. Biophysics Branch, Duke Univ., Durham, N. C.).

The objective of this project is to design, build and calibrate a variable frequency microwave exposure system for biological material. A field uniformity at the specimen of 90 percent over a 4 inch diameter circle, a continuous frequency variation in the range of 1 to 10 GHz, and a power level range at the specimen of 0.010 to 10 mW/cm² are specified for the desired system. The electromagnetic radiation produced by the system can be either continuous wave fields or modulated fields.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

- 0077 MICROWAVE EXPOSURE SYSTEM AND MICROWAVE
DOSIMETRY. McRee, D. I.; Walsh, P. J.
(Environ. Biophysics Branch, Duke Univ., Durham, N.C.).

The objectives of this project are to develop a microwave exposure system for biological material which has a well-defined, uniform field characteristic, to study the mechanisms of interaction of microwave radiation with matter, and to develop dosimetric relationships for energy absorption. Techniques using thermistors, liquid crystal probes, infrared microscope and other type detectors will be evaluated as they become available.

SUPPORTING AGENCY:HEW, Publ. Hlth Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

- 0078 EFFECT OF MICROWAVE RADIATION ON AUDITORY
SYSTEM. Konishi, T.; McRee, D. I.;
Hamrick, P. E.; Cook, R. O. (Environ. Biophysics
Branch, Duke Univ., Durham, N. C.).

Anesthetized guinea pigs are exposed to modulated microwaves of frequencies from 1 to 10 GHz. The cochlear microphonics and whole-nerve action potentials are measured during exposure to microwaves. The stimulus-response relationships will be tested. The possible mode of microwave-induced auditory responses will be explored.

SUPPORTING AGENCY:HEW, Publ. Hlth. Serv., NIH, Natl. Inst. Environ. Hlth. Sci.

- 0079 DEVELOPMENT OF HIGH POWER MICROWAVE
FOCUSED OVEN. Guidotti, A.; Hawkins, R.
A.; Cheney, D. L.; Trabucchi, M.; Doteuchi, M.;
Wang, C. (Lab. Preclinical Plasmacolog., St. Eliz.
Hosp., Washington, D.C.).

A high power microwave oven was developed to study the effect of drugs on the concentrations of various label substrate in brain nuclei of small laboratory animals. With this method the brain of mice can be fixed in 0.5 sec and that of rats in 2 sec - cAMP, cGMP, choline, GABA, acetylcholine and intermediate metabolites concentrations were comparable to those found after freezing and blowing technique. The device is now being modified to inactivate instantaneously the enzyme in the spinal cord of rats and in the brain of cats and rabbits.

SUPPORTING AGENCY:HEW, Pub. Hlth. Serv., Natl. Inst. Mental Hlth.

- 0080 BEHAVIORAL AND BIOLOGICAL EFFECTS OF
RESONANT ELECTROMAGNETIC POWER ABSORPTION
IN RATS. Gandhi, O. P.; Johnson, C. C. (Sch.
Eng., Univ. Utah, Salt Lake City).

The objective of this research is to determine behavioral and biological effects of resonant electromagnetic power absorption in rats in order to develop understanding which may lead to projection of effects in humans and the development of realistic and scientifically based exposure criteria for military personnel. A parallel - plate wave guide is used to generate plane waves for exposure of experimental animals oriented along the E, H, + K, axes. Frequency will be established based on the frequency of peak absorption. Frequencies of 0.5, 0.75, 1.0, 1.25 and 1.5 times this resonant frequency will also be used.

SUPPORTING AGENCY:MDRDC, Med. Res. Dev. Command,
U.S. Dept. Defense, Army.

- 0081 UHF BAND RADIOFREQUENCY RADIATION FOR
CARDIAC PACEMAKER ELECTROMAGNETIC INTER-
FERENCE. Toler, J. C. (Georgia Inst. Tech., Atlan-
ta).

To provide research support and use of Georgia Tech radiofrequency (RF) radiation facilities to generate and apply UHF band fields at two nominal frequencies (450 MHz and 3100 MHz) for USAFSAM studies of the effects of RF radiation on 'new generation' cardiac pacemakers. The contractor will set up and calibrate nominal 450 MHz and 3100 MHz radiation fields having an intensity of at least 200 volts per meter. Contractor will assist USAFSAM personnel in the evaluation of human phantoms and in the conduct of cardiac pacemaker electromagnetic radiation interference tests.

SUPPORTING AGENCY:U.S. Dept. Defense, Air Force.

- 0082 NONTHERMAL EFFECTS OF MICROWAVE RADIATION
ON THE GROWTH, DEVELOPMENT AND BEHAVIOR
OF BIOLOGICAL SYSTEMS. Barnes, F. S.; Gamon, E. I.
(Sch. Eng., Univ. Colorado, Boulder).

Previous work by the contractor has indicated that significant alterations occur in developing embryos when exposed to microwave radiation for periods of less than that necessary to induce thermal effects. Further investigation of this phenomenon is desired in order to ascertain the effect of stage of embryonal development, frequency and time exposure, and the interrelationships thereof. Validation of these results could have a major impact on the setting of standards for safe exposure to microwave fields under conditions of high pulse powers. Embryos of the zebra fish (*Brachydanio rerio*) will be exposed to microwave pulses of varying intensity and duration to clearly delineate the thresholds of damage for these parameters. Additional exposures will be done to assay the effect of various initial embryo temperatures, as well as varying stages of

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embryological development. Theoretical considerations for nonthermal damage will be undertaken, utilizing data from previous experiments in order to develop a mathematical and physical model to explain and predict nonthermal effects.

SUPPORTING AGENCY:U.S. Dept. Defense, Air Force.

0083 OCULAR PATHOLOGY FROM ELECTROMAGNETIC RADIATIONS. Fine, B. S.; Hirsch, S. E.; Tso, Mo (Univ. Assoc. Res. Educ., Bethesda, Md.).

With development, in recent years, of a wide variety of sources of powerful electromagnetic radiations, some of which are, in addition, coherent (i.e., masers and lasers) the potential for accidental injury to the eye grows. The principal investigator and his colleagues propose to evaluate the sequence of morphologic events produced in ocular tissues by such devices in both the visible and invisible portions of the spectrum. Current methods of light and electron microscopy will be applied to these studies. The project consists of two parts: (1) An evaluation of two important regions of the invisible spectrum using (a) an ultraviolet laser to determine effects on cornea, lens, and possibly the retina in short (days, weeks) and medium terms (months to a year) experiments; (b) microwave radiations to determine mainly the effects on the lens in short, medium, and long term (i.e., years) experiments. (2) An evaluation of damage to the primate fovea by coherent visible light using a continuous (CW) laser (Argon). The proposed studies are of great clinical importance in evaluating the potential for accidental injury and determination of standards of safety.

SUPPORTING AGENCY:HEW, Pub. Hlth. Serv., Food & Drug Adm.

0084 IRRADIATION OF BIOLOGICAL PRODUCTS. Bickert, W. G. (Agri. Exp. Sta., Michigan State Univ., East Lansing).

Radiation is to be applied to biological products, particularly in the areas of disinfection of grains, improvement of germination, water intake rate of seeds, and the effects of radiation noted from the standpoint of the basic compounds of the treated products. Sources provide energy from the ultraviolet to the infrared portion of the electromagnetic spectrum. Studies have been initiated to determine effects of various wavelengths of electromagnetic radiation on different stages of cereal leaf beetle development. Sugar beets irradiated with high energy electrons and gamma rays showed approximately the same quality deterioration during storage as control beets. This work will be continued with emphasis on the chemical and physiologi-

cal changes caused by irradiation.

SUPPORTING AGENCY:Michigan State Government.

0085 NON-IONIZING ELECTROMAGNETIC RADIATION HAZARDS. Bowman, R. R. (Natl. Bur. Stand., Boulder, Colo.).

This project will develop instrumentation, measurement techniques, and calibration services required for effective measurement and control of hazardous non-ionizing radiation and for understanding the interactions of such radiation with biological systems. A new miniature E-field sensor has been developed and three versions (high, low, and medium power) of a simplified and improved EM hazard meter designed and partially constructed. Equipment to provide limited calibration and evaluation facilities for EM hazard meters above 1GHz is also in progress. A study of a HF near-field synthesizer indicates such a device is feasible and development is proceeding. This on-going project is the Dept. of Commerce portion of the 5-year national program recommended by ERMAC.

SUPPORTING AGENCY: U. S. Dept. Commerce, Natl. Bur. Stand.

0086 A PRELIMINARY SURVEY OF VETERANS WHO MAY HAVE BEEN EXPOSED TO CATARACT PRODUCING RADIATION. McAfee, R. D.; Cazenavette, L. L.; Holland, M. G. (VA Hosp., New Orleans, La. 70140).

See CR 0030, I(1), for description of this project. (Renewed 7/73 to 6/74).

SUPPORTING AGENCY:U. S. Veterans Administration

0087 A RADAR INVESTIGATION OF THE EFFECTS OF NAVAL COMMUNICATIONS SYSTEM ON FREE FLYING MIGRANT BIRDS. Williams, T. (Dept. Biol., State Univ. New York, Buffalo 14214).

The objective of this study is to evaluate the possible effect of the electromagnetic fields of the Sanguine antenna on the behavior of free flying birds which migrate over the Wisconsin Test Facility. A small, low power radar, mounted in an Econoline van, will be located at several locations within and near the Test Facility during the fall and spring migration periods. Each observation period will last approximately 2 weeks. The paths of migrating birds will be observed with the radar during alternating periods of radiating and inactive modes of the Sanguine transmitter to determine if the headings and flying patterns of the birds will be altered when the transmitter is operating. Times of observation will be selected to include both songbird and water fowl migrations. (9/74-8/75)

SUPPORTING AGENCY:Naval Electronics Systems Command

0088 LIQUID CRYSTAL FIBEROPTIC PROBES FOR MEASURING TEMPERATURE AND MICROWAVE FIELDS IN BIOLOGICAL MATERIALS. Johnson, C. C. (Dept. Biophysics Bioeng., Univ. Utah, Salt Lake City 84112).

As a large user of microwave power, the Navy is concerned with its biological effects, especially on humans. The objective of this project is to conduct research and development of nonperturbing, dielectric probes for measuring temperature and microwave fields in biological materials used in microwave hazards research. Liquid crystals and optic fibers are being used to fabricate probes for measurement. The optimum liquid crystal mixtures will be determined as will be the response and sensitivity as a function of time. The optimum tip design will be studied and 8 to 10 prototype temperature units will be fabricated for evaluation by other investigators. The feasibility of a liquid crystal/optic fiber power probe (LCOFPP) using spherical shells of a resistive material (carbon) will be determined. (3/75 - 2/76).

SUPPORTING AGENCY:Office Naval Research.

0089 INFLUENCE OF ELECTROMAGNETIC FIELDS GENERATED BY NAVAL COMMUNICATIONS SYSTEMS ON GROWTH, DEVELOPMENT AND BEHAVIOR IN DOMESTIC BIRDS. Durfee, W. K. (Coll. Resource Dev., Univ. Rhode Island, Kingston 02881).

This project is part of a Navy program to investigate the possible effects of extremely low frequency electromagnetic radiation on living organisms. This research continuation will seek to determine if modulated 75 Hz electric and magnetic fields will have effects upon growth, development and behavior in the domestic fowl *Gallus domesticus*. Growth and development of the chick embryo is studied by exposing the growing eggs in a specially modified incubator. Observations will be made on hatchability, embryonic abnormalities, growth rates and CO₂ production. Chicks will continue to be exposed after hatching and growth rate, behavior, feeding efficiency and learning/memory consolidation will be observed. (7/74 - 6/75).

SUPPORTING AGENCY:Naval Electronics Systems Command.

0090 RESPONSE OF PLANT AND SOIL MICROORGANISMS TO ELECTROMAGNETIC FIELDS GENERATED BY NAVAL COMMUNICATIONS SYSTEMS. Gardner, W. R. (Dept. Soil Sci., Univ. Wisconsin, Madison 53706).

The purpose of the research is to determine whether ELF electric fields have any effect on metabolic activity of plants and soil micro-organisms. Micro-organisms were chosen from representative soil sap-

rophytic and pathogenic bacteria and fungi in the Northern Wisconsin area. Initial emphasis was placed on evaluation of the effect of electric fields on solute transport and metabolic activity using a radiotracer-enzyme kinetic approach to determine transport constants, uptake velocities and turnover times and rates for solutes such as sugars and amino acids being assimilated through active transport processes by microbial cells in aqueous solutions. Single plants were grown in the desired growth media under conditions of controlled temperature, light, relative humidity and CO₂ concentration. The soil water potential and soil aeration was controlled and measured. The relation between the transpiration flux to water through the plant and the water potential drop across the plant were determined for a range of environmental conditions. Stomatal resistance and the components of the leaf water potential were measured periodically. Where effects upon photosynthesis are indicated, these effects will be confirmed by direct measurements of net CO₂ assimilation. Particular attention will be paid to systems which are poorly aerated as well as to relatively dry soil systems. (4/73 - 3/74).

SUPPORTING AGENCY:Naval Electronics Systems Command.

0091 A PHYSIOLOGICAL AND BIOCHEMICAL STUDY OF THE EFFECTS OF ELECTROMAGNETIC FIELDS GENERATED BY NAVAL COMMUNICATIONS SYSTEMS ON *Physarum polycephalum*. Goodman, E. M. (Univ. Wisconsin, Kenosha 53140).

This project is part of a Navy program to investigate the possible effect of extremely low frequency (ELF) electromagnetic radiation on living organisms--both plant and animals. This research is designed to examine the possible effects of ELF electromagnetic radiation (both short and long term exposure) on growth and development of the slime mold *Physarum polycephalum*. Three simulators will be set up to expose the *Physarum*. The first will be a continuation of present studies at 75 Hz, 2 G and 0.7 V/m. ATP concentrations will also be studied in this simulator. The second simulator will operate at 75 Hz with modulation and with 60 Hz CW superimposed. The third simulator paradigm will be decided upon in consultation with the scientific officer and the Sanguine Division. In all cases, the critical indicators in *Physarum* will be: (1) time to mitosis, (2) reproductive differentiation, (3) protoplasmic streaming period. (7/74 - 6/75).

SUPPORTING AGENCY:Naval Electronics Systems Command.

0092 BIOLOGICAL EFFECTS FROM ELECTROMAGNETIC FIELDS GENERATED BY NAVAL COMMUNICATIONS SYSTEMS. Holberg, F. (Dept. Pathol., Univ. Minnesota, Minneapolis 55455).

CURRENT RESEARCH

This research will evaluate possible effects of extremely low frequency (ELF) fields on circadian and other biological rhythms in organisms such as silk tree, flour beetle, mouse and rat. Effects on susceptibility to drugs and life span will also be studied. Body core temperature of rodents will be monitored by implanted sensors. Leaf closing rhythms in silk tree will be studied using whole plants as well as excised pairs and stems. Flour beetles will be exposed to ELF then given varying doses of insecticide and susceptibility compared with controls. O₂ consumption vs ELF exposure will be studied. Rodents will be exposed to ELF then given barbiturates to study variation in susceptibility. Long-term effects on aging and development of the mouse will also be studied. (12/73 - 11/74).

SUPPORTING AGENCY: Office Naval Research.

0093 AN EVALUATION OF POSSIBLE EFFECTS OF 60 HZ AND 75 HZ ELECTRIC FIELDS ON NEUROPHYSIOLOGY AND BEHAVIOR OF MONKEYS. Medici, R. G. (Brain Res. Inst., Univ. California, Los Angeles 90024).

This project is part of a Navy program to investigate the possible effects of extremely low frequency electromagnetic fields on living organisms. This research seeks to evaluate the possible effects of 60 and 75 Hz (modulated) electric fields on neurophysiology and behavior in monkeys. In this study monkeys are surgically implanted with cortical and subcortical EEG electrodes. After recovery, the monkeys are trained to perform a fixed-interval, limited hold lever pressing task. Once they attain a high, stable performance level they are put through several 4-day experiments in which they are exposed to electric fields of either 0, 1, 10 or 57 V/m. Frequency conditions will be 75 Hz modulated alone and with a 60 Hz component. EEG will be monitored as well as changes in performance levels and inter-response times. In addition, calcium efflux will be studied in neonatal chick brains exposed to the modulated fields. (7/74 - 6/75).

SUPPORTING AGENCY: Naval Electronics Systems Command.

0094 QUANTITATION OF MICROWAVE RADIATION EFFECTS ON THE HEAD AND EYES OF RABBITS, PRIMATES AND MAN. Kramar, P. O. (Dept. Ophthalmol., Univ. Washington, Seattle 98195).

The production of opacity and damage in the eye by exposure to microwave radiation can occur. The exact conditions under which the effect occurs are yet to be established. Consequently, there is a great deal of controversy concerning the safe level of human exposure to microwave radiation. The increased use of high power microwave equipment by the Navy and other Armed Services, as well as the general

population, demands well-planned and expertly executed theoretical and experimental investigations. The proposed on-going research [see CR 0029, I(1)] is designed to: (1) ascertain the conditions and mechanisms of cataract production by microwave irradiation; (2) extrapolate quantitatively the animal results to human exposures. This will involve a theoretical determination of the internal absorption characteristics of animal and human eyes as related to source frequency and aperture size; a laboratory investigation of the threshold of eye damage by CW and pulsed microwaves during acute and chronic exposure for frequencies ranging from 915 MHz to 2.5 GHz; and improved dosimetry through the use of thermographic and thermocouple recordings of temperature changes in the tissue. In the coming period, a cataractogenic threshold will be established in the rhesus monkey for 2450 MHz. A computer model based on the power absorption patterns found in the monkey will be developed. This should enable extrapolations to the human. Rabbits will be exposed to a 2450 MHz slot applicator and power absorption patterns will be established. Rabbit lenses which have been exposed to threshold and sub-threshold levels will be studied by electronmicroscopy. Rabbits will also be exposed continuously to low levels (i.e., 20 mW/cm²) in the far field at 2450 MHz. In addition to periodic eye examinations, the basic blood picture and coagulation parameters will be monitored. Finally, rabbits under general hyperthermia (hot water) will be studied in an attempt to determine if a temperature rise equivalent to that obtained by a cataractogenic dose of microwaves is capable of producing cataracts. (12/74 - 11/75).

SUPPORTING AGENCY: Office Naval Research.

0095 NEUROPHYSIOLOGICAL AND BEHAVIORAL EFFECTS DUE TO MICROWAVE IRRADIATION. Guy, A. W. (Dept. Rehab. Med., Univ. Washington, Seattle 98195).

See CR 0032, I(1), for a complete description of the on-going project. This phase involves: (1) a study of the effects of microwaves on the central nervous system with particular attention to the spinal cord using a segment of cord exposed in live cats; (2) the use of combined physiological and behavioral methods in primates, cats and rats. Primary emphasis will be on the interaction of microwave energy and the auditory system. Attempts will be made to determine the threshold of perception of audible microwave pulses. Information on mechanisms for this phenomenon will be sought using sequential ablation of structures of the auditory system of the cat. (12/74 - 11/75).

SUPPORTING AGENCY: Office Naval Research.

0096 THE EFFECTS OF IONIZED AIR AND RADIO ENERGY UPON THE PERFORMANCE OF NAVAL PERSONNEL. Frey, A. H. (Randomline, Inc., Huntingdon Valley, Pa. 19006).

See CR 0064, I(2), for a complete description of this research. Work planned for the coming year includes: (1) continuation and extension of work exploring changes in the permeability of the brain after exposure to pulsed rf energy, (2) extension of work on behavioral effects of pulsed rf energy and (3) continuation of work on electrical space charge and its bearing on habitability of enclosed spaces. (1/74 - 12/75).

SUPPORTING AGENCY:Office Naval Research.

0097 EFFECTS ON BIOLOGICAL SYSTEMS DUE TO MICRO-WAVE IRRADIATION. Durney, C. H. (Dept. Electr. Eng., Univ. Utah, Salt Lake City 84112).

See CR 0037, I(2), for description of this research. (Renewed 3/75 - 2/76).

SUPPORTING AGENCY:Office Naval Research.

0098 X-RAY AND MICROWAVE RADIATION INTERACTION WITH MUSCLE CELLS; APPLICATION TO PROTECTION AND TREATMENT. Portela, A. (Inst. Biophysics Res., Buenos Aires, Argentina).

See CR 0025, I(1), for description of this research. (Renewed 9/74 - 8/75).

SUPPORTING AGENCY:Office Naval Research.

0099 EVALUATION OF THE SAFETY EXPOSURE LIMITS OF RADAR USED BY NAVAL PERSONNEL. Hunt, E. L. (Battelle Mem. Inst., Richland, Wash. 99352).

See CR 0027, I(1) for further information of this research. Current studies will be limited to behavioral and neurophysiological investigations for the detection and characterization of effects that might be produced by short term exposure to pulsed microwaves at low power levels, 10 mW/cm² or less average power, or following chronic exposures to pulsed microwaves at low average levels. Discrimination performances will be tested using operant conditioning procedures. One test will look for a disturbance in the level of performance following exposure. Another will look for disturbances in the learning of a simple discrimination task. Research will continue attempts to verify the avoidance by rats of the pulsed microwave field. Finally, susceptibility to sound-induced seizures will be studied in sensi-

tive and insensitive mice following exposure to pulsed microwaves in a series of daily 3-hr exposures. (Renewed 7/74 - 6/75).

SUPPORTING AGENCY:Naval Medical Res. Dev. Command.

SOURCES:Author, Principal Investigator, or Other

Schmitt, Otto H., Biophysics Group, University of Minnesota, Minneapolis, Minnesota 55455 (612) 373-3345.

Studies of human perception of moderate strength 60 Hz magnetic fields are being continued. After eliminating subliminal clues, there no longer is any striking evidence indicating that humans can perceive moderate strength low frequency magnetic fields, either uniform or gradient. Presently computer-assisted learning experiments are being employed in an attempt to "teach" subjects to recognize the presence of a field. The preliminary data from these experiments do not suggest any earnable magnetic perception ability, but do strongly confirm the ability to learn to perceive previously sub-threshold levels of vibration or sound.

Schwan, Herman P., Professor, Department of Bioengineering, University of Pennsylvania, Philadelphia, Pennsylvania 19174 (215) 594-8533.

"Electric and Acoustic Properties of Biological Material" (Research Grant). Research on the electrical and acoustic properties of biological particles. Present and future emphasis will be on: (a) the behavior of electrodes used for impedance measurements and excitation purposes in physiology and cardiology (pacemakers) in frequency and time domain, with particular emphasis on their nonlinear characteristics; (b) electrical characteristics of macromolecules and water bound to their surface; (c) electrical characteristics of biological and artificial cells and membranes as related to their structure and function; (d) acoustic properties of tissues and biological macromolecules and the reasons why specific absorption varies so considerably from one type to another. The scattering of ultrasound by cells and its contribution to apparent absorption; (e) field induced force effects, particularly alternating field induced forces acting on biological cells and of significance from either a hazard point of view or with a potential for new biological research techniques.

Stavinoha, William B., Department of Pharmacology,
University of Texas Health Science Center,
San Antonio, Texas 78284 (512) 696-6416.

In addition to research reported earlier [see
CR 0055, I(2)], the following studies are in
progress: (1) Research and Reports on Biologic-
cal Effects of AF Transmitter Near Field (Re-
search Contract); (2) Labile Metabolites, Trans-
mitters in the Heart Cycle (Research Contract);
(3) Use of Microwave Radiations for the Study of
Brain Neurochemistry (Research Grant).

Takashima, Shiro, Associate Professor, Department
of Bioengineering, University of Pennsylvania,
Philadelphia, Pennsylvania 19174 (215) 594-
8537.

The triggering of nerve impulses by use of
radiofrequency fields is being investigated.
So far, it has been found that continuous ac
field has a cut-off frequency about 15-20 KHz.
The use of pulsed a.c. waves extends the cut-
off to much higher frequencies. (Research
Grant)

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