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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Supporting Agency:New Jersey State Government.

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

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

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

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

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

Supporting Agency:HEW, PHS, NIH, NCI.

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

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

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

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

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

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

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

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

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

Supporting Agency:HEW, PHS, NIH, NCI.

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

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

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

Supporting Agency:HEW, PHS, NIH, NIAMDD.

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

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

Supporting Agency:NSF, Div. Engineering.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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