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

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

The effect of microwave hyperthermia on the oncolysis of various solid tumors in mice by Clostridium oncolyticum was investigated. Tumor-bearing mice were treated with 461-MHz microwaves so that after 4 min the temperature in the middle of the tumors was 43 ± 0.5 C. After 12 hr, 10^8 Clostridia spores in physiologic saline were administered intravenously. Some mice received only Clostridia spores. In mice bearing solid Ehrlich carcinoma, the extent of oncolysis was increased from 27.65 ± 1.55% in mice treated with Clostridia spores alone to 61.31 ± 2.93% in mice treated with microwave hyperthermia before Clostridium injection. Microwave hyperthermia also decreased the tumor weight on day 5 from 2.36 ± 0.07 g for mice treated with Clostridia spores alone to 1.27 ± 0.10 g for mice receiving the combined treatment. Similar results were obtained in mice bearing Harding-Passey melanoma where the increase of lysis in animals receiving the combined treatment was about 70%. Mice bearing a 3-methylcholanthrene-induced fibrosarcoma were resistant to Clostridium treatment but responded to combined treatment with a tumor oncolysis of 22.40 ± 3.17%. These results indicate that oncolysis with Clostridium oncolyticum is markedly increased by microwave hyperthermia and that the effect is produced with histologically different tumor lines.

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

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

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

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

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

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

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

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

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

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

A book dealing with topics related to the electric stimulation of bone growth and repair is presented. The chapter titles (and their contributors) are as follows: Electric Stimulation of Bone Growth and Repair: a Review of Different Stimulation Methods (Ewa Herbst); Four-Point Measurement of the Impedance of Bone in Vivo (W. Sansen, F. De Dijcker, S. Stan, and J. C. Mulier); In Vitro Study of Electric Impedance of Bone (B. Durand, P. Christel, and J. Assailly); Achievements and Discrepancies in Understanding Bone Electric Phenomena (T. Cieszynski); Physicochemical Effect of an Electric Potential on Bone Growth (R. Wollast, M. Hinsenkamp, and F. Burny); Influence of Magnetic Fields on Growth and Regeneration in Organ Culture (H. Gerber, J. Cordey, and S. M. Perren); Effect of the Magnetic Field Component of the Kraus-Lechner Method on the Healing of Experimental Nonunions in Dogs (H. Blumlein, J. McDaniel, and S. M. Perren); Plated Cortices and Electric Potentials (M. Weigert); Effect of Direct Current on the Healing of Fractures (S. Stan, J. C. Mulier, W. Sansen, and P. De Waele); Electric Stimulation of Osteogenesis: I. Experimental Study of Bone Healing in the Rabbit Tibia. II. Clinical Study in Two Cases of Congenital Pseudarthrosis of the Tibia (G. von Satzger and Ewa Herbst); Hypothesis of Bone Remodelling and Fracture Healing by Electrostimulation (L. W. M. Janssen, J. M. M. Roelofs, W. J. Visser, and P. Wittebol); Corrosion of Implants During Electric Stimulation of Fracture Healing (M. Hinsenkamp, F. Burny, J. Jedwab, and R. Bourgois); and Necessity of Electric Standardization of Surgical Implants (T. Cieszynski).

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

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

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

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

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

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

The use of transcutaneous nerve stimulators (TNS) for the relief of pain is reported. The devices are simply pulse generators, which when attached to the surface of the skin, produce currents that relieve pain by interfering with the passage of pain signals along nerves to the brain. Independently adjustable currents, pulse widths, and repetition rates allow patients to modify their own treatment. Although the small number of clinical trials with TNS units are not well documented, experience so far indicates that chronic longstanding pain, such as, causalgias (nervous disturbances caused by peripheral nerve lesions), phantom limb pain, and back pain are particularly sensitive to TNS. A survey of five of the major pain treatment centers in the United States that have treated over 3,000 patients with TNS revealed that 25-30% of patients previously incapacitated by chronic pain were more or less completely relieved. A technique of moving the electrodes nearer the nerves by surgical implantation inside the body is offering new hope for painful conditions that do not respond to conventional TNS. In the United States some success with modified TNS has been claimed for cerebral palsy, epilepsy, and the rehabilitation of stroke victims. In Britain, direct stimulation of the spinal cord of patients with multiple sclerosis has produced worthwhile benefit in about 50% of these patients. Swedish workers have tried to improve the results of conventional high frequency TNS by replacing Chinese acupuncture needles with standard TNS surface electrodes. Of 50 patients with unspecified chronic pain conditions, only 20 responded to conventional TNS treatment, but 10 others benefited from acupuncture-like TNS. Drawbacks of the technique include the unreliability of results and complications, with contact dermatitis being the most likely problem.

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

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

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

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

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

Selected experimental and theoretical topics dealing with microwave-induced hearing are presented in this book. In the first chapter, some relevant information about microwave radiation and biological effects of microwaves is provided. A brief description of the auditory system is outlined in Chapter 2. Major experimental evidence of pulse-modulated microwave-induced auditory effects are presented in Chapters 3 and 4. The speculations and hypotheses regarding mechanisms are treated in the next chapter. Chapter 6 examines in detail the implications of induced thermoelastic theory using a spherical head-model. In the last chapter, the use of pulse-modulated microwave radiation as a tool in clinical medicine and laboratory investigations is given special attention. Statements regarding microwave exposure parameters are left in the terms used in the originating report. The International System of units is used exclusively; conversion factors for selected quantities are given in an appendix. A second appendix containing publications of pertinent conferences and symposia is also included. The book is indexed both by author and subject.

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

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

Meeting Abstracts

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

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

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

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

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

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

Accumulated evidence indicates that sensitivity of brain tissue to certain weak oscillating electromagnetic fields may involve a different class of non-equilibrium processes, based on long-range atomic interactions and quantum amplification processes, occurring in the absence of significant tissue heating. In position of environmental extremely low frequency (ELF) and very-high frequency/ultra-high frequency (VHF/UHF) fields amplitude modulated at ELF cause sharply modified efflux of calcium ions from brain tissue, a phenomenon closely linked to release of synaptic transmitter amino acids gamma-aminobutyric acid and glutamic acid. ELF fields decrease calcium efflux by about 15% only in narrow amplitude and frequency "windows," between 6 and 20 Hz and between 10 and 100 V/m (approximate tissue gradients, 10^{-7} V/cm). VHF (147 MHz) and UHF (450 MHz) fields increase calcium efflux by about 15% when amplitude modulated between 6 and 20 Hz but only for incident fields in the vicinity of 1.0 mW/cm^2. Measured tissue gradients are around 50 mV/cm, corresponding to electroencephalographic gradients weaker by 10^4 than in synaptic excitation. They suggest transductive coupling based on coherent charge states between anionic fixed charge sites on membrane surface glycoproteins, with long-range cooperative interactions triggered by weak extracellular electric fields. There is a possibility of proton "tunneling" at boundaries between coherent and non-coherent charge zones. Thus, some forms of cell-to-cell communication in brain tissue appear to involve energy exchanges far below those necessary for impulse propagation, and to occur through slow waves generated in spreading dendrites of cerebral neurons and passively spreading in fluid around brain cells.

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

Recent studies have revealed that exposure of various mammalian species to microwave radiation at intensities of 10 mW/cm^2 or less results in physiologic and behavioral responses. Acute or short-term exposures at these intensities prominently involve reversible alterations in the reticuloendothelial and neuroendocrine systems and specific types of behavioral responses. Neither the time-intensity thresholds, the mechanisms, or the long-term consequences of such exposures have been determined. The results of selected physiologic and behavioral responses will be reviewed to define the nature of the potential health hazards associated with microwave exposure and to suggest possible interaction mechanisms. Limitations on the currently available biologic response data for the assessment of microwave effects will also be discussed.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A generator operating at 500 KHz was used to produce localized electric current fields in tissue volumes. This energy was used to elevate the temperature of the volume for studying hyperthermia in the treatment of cancer. The tissue volume acted as a resistive load, and the power dissipated was proportional to the current density. The current density within a region was determined by the electrode configuration and was tailored to the treatment volume. The localized current field heating technique is described, including illustrations of hyperthermic treatments of spontaneous tumors in domestic animals.

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

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

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

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

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

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

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

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

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

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

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

The possibility of a hazard to a pacemaker-assisted patient, due to potential electromagnetic interference from a modern clinical accelerator is discussed. A brief review of the pertinent regulations governing such emissions is provided revealing that there is generally no special consideration given to the pacemaker-assisted patient. Measurements were undertaken at the University of California, San Francisco campus, prior to and following the installation of the Mt. Sutro commercial radio and TV tower in the immediate vicinity of the campus. These data, based on empiric values required to cause the model pacemaker to malfunction, resulted in a more stringent control of the allowable field strengths by the University Environmental Health and Safety Office than would be allowed by federal regulations. A second series of measurements were undertaken in the Radiation Oncology Department to investigate radio frequency interference emanating from the Clinac 4 linear accelerator. Initially, a Narda Survey Meter was employed, and the microwave transport system was surveyed (with the fiberglass cover removed). The most sensitive range on the survey meter had a full scale sensitivity of 0.2 mW/cm^2, 1/50 of the U.S. standard for continuous microwave exposure. No detectable level of radiation was observed with this instrument in the immediate vicinity of the treatment machine. A more sensitive detection instrument with a greater frequency range was then employed. A Tektronix 7L12 frequency spectrum analyzer was chosen, and one of two (depending upon frequency) calibrated antennas was placed on the treatment couch, simulating the patient. From 20 to 200 MHz a log spiral antenna was used, and for below 20 MHz, a linear wire was employed (uncalibrated). These measurements minimize the possibility of electromagnetic interference emanating from the treatment machine, as the strongest signals originated from outside the department. The commercial radio and TV signals could readily be identified, and other discrete signals were also found that were present even when the accelerator was turned off.

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

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

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

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

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

5862 EFFECT OF 2450 MHz MICROWAVE IRRADIATION ON PERMEABILITY OF THE BLOOD-BRAIN BARRIER TO MANNITOL IN THE RAT (MEETING ABSTRACT). *(Eng.)* Preston, E.; Vavasour, E. J.; Assenheim, H. M. (Biological Sciences, Nat'l. Res. Council Canada, Ottawa, Ontario, Canada K1A 0R6). *In: Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): pp. 5-6; 1978. (0 ref)

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

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

Neuroendocrine function was studied in adult male rhesus monkeys exposed to microwaves. Hormone levels were determined in sequential blood samples obtained via chronic indwelling jugular catheters. Hourly samples were obtained before, during, and after an 8-hr exposure to a pulsed microwave field, 1.29 GHz, covering a total time period of 24 hr. Rectal temperature was continually monitored during these experiments. The animals were exposed to far field conditions in an anechoic chamber. Blood samples were analyzed for growth hormone, cortisol, and thyroxine levels to investigate those neuroendocrine parameters that respond readily to adverse environmental stimuli. In addition to providing a time-course of any prompt changes in the secretion of the above hormones during microwave exposure, the use of chronic indwelling catheters made it possible to study the same animal repeatedly under exposed or sham-exposed conditions to evaluate the reversibility of any prompt changes observed. Results of exposures to 20 mW/cm^2 incident power density will be discussed.

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

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

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

The effects of radio frequency (RF) fields (1-30 MHz) modulated at 14 and 60 Hz on the electroencephalogram (EEG) of rabbits using time domain as well as frequency domain analyses were investigated. Unprocessed EEG signals were unsuitable for detecting effects of RF. Autocorrelograms are adequate only for qualitative studies. Therefore, analyses of EEG signals before and after exposure are based on the use of power spectra. A pair of stainless steel electrodes were chronically implanted and used for the recording of EEGs. Animal heads were exposed to modulated RF at the level of 2-3 kV/m using a pair of matched aluminum plates. Although acute exposures at these levels caused considerable changes in the power spectra, it may only be due to the effect of local fields produced by intracranial electrodes. To avoid local fields, the intracranial electrodes were replaced with a pair of silver electrodes, which were placed on the surface of the skull. With these electrodes, rabbits were exposed chronically for 4-6 wk, 2 hr/day, at the level of 0.5 to 1 kV/m at 3-5 MHz modulated with 14 Hz. After these prolonged exposures, the power spectra were found to change considerably. Namely, power spectra of normal rabbit EEGs were characterized by several continuously changing components between 4-20 Hz without a singularly dominant component. After the exposure, this feature was replaced by spectra, which was characterized by a low frequency dominant component at 4-5 Hz. This change was not permanent and could be reverted to the normal spectra if enough time was given.

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

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

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

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

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

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

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

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

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

A new variable frequency cavity applicator system was developed so that cultured mammalian cells could be exposed to radio frequency waves under controlled temperatures to investigate the thermal and possible nonthermal effect of radio frequency waves on cellular inactivation. Monolayers of Chinese hamster cells of ovarian origin (HA-1) were exposed for 30 min to 900 MHz radio frequency waves at various absorbed power densities up to 135 W/cm^3 and temperature range 27-45 C. Cellular survival was measured by the cloning assay. Pre-

liminary results showed that at a maximum power density of 135 W/cm^3 absorbed by the medium, no cytotoxicity was observed between 27-37 C after 30 min of irradiation. At temperature range 40-43 C, no excessive cell killing above that induced by the elevated temperature can be demonstrated. Above 43 C, a non-thermal component of radio frequency waves may contribute to cellular cytotoxicity. Survival studies extended to lower frequencies (~433 MHz) and/or pulsed radio frequency waves are currently underway.

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

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

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

A total of 180 male F1 mice (B6C3 strain) were exposed in an anechoic chamber to 2,450-MHz continuous wave microwaves for 1, 2, 4, 8, or 20 hr, or for 16 hr/day for 1, 2, 4, or 7 days. Mice housed singly in polypropylene cages were exposed in a multi-unit cage array located within the 1.8 m diameter zone. Measured changes in a blank position of power density following inclusion in the array of cages, bedding, feed, mice, and small water reservoirs were not greater than 1 dB from the free space measurement. Power density incident on each animal depended on its position-angle relative to the central axis of the horn. Measured values varied from 50 to 25 mW/cm^2. End points studied included: cell survival (as indicated by dye exclusion by a dispersed testis cell preparation) measured immediately following exposure (except in the case of 1- and 2-hr exposures when it was measured 4 hr after the start of exposure); sperm counts and scoring of abnormally shaped mature sperm, assayed immediately and 2 wk after exposure; testis histology, describing changes in cell development and maturation, assayed at zero time and 2 wk post-exposure. Comparisons with anechoic chamber control animals indicate significant ($p\leq0.05$) increases in the percentage of cells that failed to exclude dye. These differences were seen in groups exposed for 8 hr and for the 2 x 16 hr and 7 x 16 hr series. Sperm counts were also significantly reduced ($p<0.05$) 2 wk following a 2-hr exposure, as well as immediately following a 16-hr exposure for a 4x 16 hr exposure series. The results will be compared with earlier data on the exposure of the hind end of mice in a waveguide or in a heated water-bath.

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

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

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

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

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

Lymphocyte migration was significantly altered in mice experiencing acute microwave hyperthermia. Spleen lymphocytes or thymus cells were obtained from naive Balb/c or C57Bl/6 mice, labeled with ^{51}Cr, and introduced intravenously (iv) into autologous recipients. Animals were then exposed to a 2.6-GHz field (25 mW/cm^2, 19 specific absorption rate (SAR), 1.5 C increase in core temperature) for 15 min. Lymphocyte migration patterns were determined 24-hr postexposure. No change in lymphocyte traffic was observed in nonthermogenic microwave-exposed mice (5 mW/cm^2, 3.8 SAR). Significantly, plasma corticosteroid levels in thermogenic-exposed mice were three-fold elevated over sham-irradiated controls: 158 ± 18 ng/ml (n=10), compared with 46 ± 6 ng/ml (n=10). Administration of hydrocortisone sodium succinate at 4 mg/kg iv resulted in alteration of splenocyte and thymocyte migration qualitatively similar to that observed following thermogenic microwave treatment. These results suggest that whole-body microwave hyperthermia leads to alterations in lymphocyte migration that is associated with steriod release due to thermal stress.

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

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

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

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

although rats at 80 F evidenced a dramatic body weight loss compared with their own pre-exposure baselines. On the other hand, rats exposed to 20 mW/cm^2 at 70 F, although exhibiting a larger initial decrement in weight gain, showed only a moderate body weight decrement compared with controls. These data indicate that a rat's adaption to 20 mW/cm^2 can be more successful than its adaption to an 80 F environment.

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

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

5879 BEHAVIORAL AND PHYSIOLOGICAL EFFECTS OF CHRONIC LOW LEVEL 2450 MHz MICROWAVE RADIATION IN RATS (MEETING ABSTRACT). *(Eng.)* D'Andrea, J. A.; Gandhi, O. P.; Astle, L.; Durney, C. H.; Lords, J. L.; Johnson, C. C. (Univ. Utah, Salt Lake City, UT 84112). *In: Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 33; 1978. (0 refs)

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

5880 ALTERATION OF BEHAVIORAL AND BIOCHEMICAL PARAMETERS DURING AND CONSEQUENT TO 500 mW/cm^2 CHRONIC 2450 MHz MICROWAVE EXPOSURE (MEETING ABSTRACT). *(Eng.)* Lovely, R. H.; Guy, A. W.; Johnson, R. B.; Mathews, M. (Dept. Rehabilitation Medicine, Univ. Washington, Seattle, WA 98195). *In: Abstracts of Scientific Papers: 1978 Symposium on Electromagnetic Fields in Biological Systems held June 27-30, 1978 in Ottawa, Canada.* Sponsored by Internat'l Microwave Power Inst. and Inst. of Electrical & Electronic Engineers. (Edmonton, Canada): p. 34; 1978. (0 refs)

To replicate Soviet microwave research findings, rats were exposed 7 hr/day for 3 mo to 500 mW/cm^2 2,450-MHz, continuous wave microwaves in individual anechoic chambers. Monthly assessments of urinary ketosteroids failed to reveal any differences between exposed and control animals. Blood cholinesterase and sulfa-hydral (glutathione) activity revealed initial decrements in the exposed animals relative to sham-exposed control rats followed subsequently by no differences between groups. At the end of the 3-mo exposure protocol, significant differences in Na^+, K^+, CO_2 and ion gap were re-

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

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

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

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

Previous research has indicated that rats, able to occupy either shielded or unshielded regions in a pulsed microwave beam, spend more time in the shielded region; rats exposed without this choice show significantly higher activity levels than unexposed controls. Experiments were conducted to determine if audition of pulsed microwaves could be a mediating factor in either response. Rats were exposed in an anechoic chamber to the far field of a pulsed microwave beam (2.88 GHz, 100 pulses/sec, 2.3 μsec pulse width, 10 mW/cm^2 average power density, 100 $\mu J/cm^2$/pulse). In one experiment a 37.5-kHz tone was substituted for microwave exposure in one of nine test sessions; in the second experiment, microwave audition was masked in some of the test sessions using 20-100 kHz noise. The results indicate that while microwave audition may be responsible for shielded region preference, it has little or no influence on activity level.

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

In three separate studies, rats, squirrel monkeys, and rhesus monkeys were exposed to 2.45 GHz microwaves (100% amplitude modulated at 120 Hz) under far field conditions in anechoic chambers. Incident fields at power densities from 0-75 mW/cm^2 were measured in the absence of the animal. All animals were performing on operant schedules for food reinforcement during the microwave exposures. Rats worked unrestrained in a response chamber of Styrofoam, while monkeys worked restrained in Styrofoam chairs. Rectal temperature was measured continuously during exposures of the monkeys and measured immediately after exposures in rats. Exposure sessions lasted 60 min and were repeated on a daily basis. Stable performance on the operant schedules was disrupted in all three animals at power densities positively correlated with the body mass of the animals. The behavior of rats was perturbed at lower power densities while that of the rhesus was perturbed at higher power densities. The behavior of the squirrel monkeys was disrupted at the middle level of power densities. When the averages of these power densities (23, 45, and 67 mW/cm^2) were plotted as a function of body mass (0.3, 0.7, and 5 kg) a semilog relationship became evident. Extrapolation allowed prediction of the power densities needed to disrupt ongoing operant behavior in larger animals, such as, man. Also, the power densities associated with behavioral disruption approximate those power densities that produce an increase in rectal temperatures of at least 1 C (above control levels) in the corresponding animals. It is concluded that under the environmental conditions of these studies a well-controlled behavior is not disrupted in most mammals by microwaves until extra body heat exceeds the level that an animal is capable of dissipating within the exposure duration.

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

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

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

An analysis of existing radio frequency (RF) and microwave (MW) energy absorption data was performed to examine the frequency dependent phenomenon of biologic tissue heating. The analysis was restricted to thermal considerations and examined the exposure field intensities associated with the various levels of RF- and MW-induced thermal loading on both the body as a whole and on specific selectively absorbing tissues in adult humans and infants. An underlying absorption factor of 1 W/kg, equivalent to the basal metabolic rate for the adult, averaged over total body mass, was used for comparative purposes. A method of specifying safety standard limits, based on the electromagnetic field energy density rather than the plane wave free-space equivalent power density, is presented. The analysis revealed a particularly important resonance frequency range, $10 \leq f \leq 1{,}000$ MHz, in which RF and MW absorption could lead to whole body thermal loads several times the whole body basal metabolic rate for exposures equal to the present safety standard in use in the United States. A discussion is developed for applications of this analysis to occupational environments and short duration exposure conditions. Some implications of this thermal analysis of RF and MW energy are discussed in terms of existing safety standards in use in the United States and the Soviet Union and in typically encountered exposures in the United States.

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

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

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