electromagnetic fields with nervous tissue. In a study on the effects of low-level, low-frequency fields on human circadian rhythms, a weak (2.5 V/m) square wave field at a frequency of 10 Hz shortened the period of human circadian rhythms in 10 experiments by an average of 1.3 ± 0.7 hr. It is speculated that circadian rhythms might be based on a single response to weak electromagnetic fields, with the response having a decay time of the order of 1 day. Recent studies are cited that suggest that the orientational responses of birds, insects, and some other invertebrates are sensitive to magnetic fields. Homing pigeons appear able to detect even minor fluctuations (10^{-4} to 10^{-5} G) of the magnetic field attributable to solar activity. Birds also appear to exhibit a sensitivity to weak oscillating electric fields (10 Hz, 2.5 V/m square wave), and it is speculated that the capacity of birds to discriminate between electric fields with single frequencies may be related to navigation. Experiments are described in which rabbits exposed for 3 hr/day to 10-cm microwaves (1-μsec pulse duration) at a frequency of 400/sec and a power density of 7 mW/cm^2 for a total of approximately 200 hr displayed widespread desynchronization and decreased amplitude of electroencephalogram rhythms. In other experiments on the effects of low-level pulsed and continuous microwave fields (2,950 MHz, 3 mW/cm^2, pulsed at 1,200/sec, pulse duration 1 μsec) on hematopoiesis in rabbits, 74 hr of exposure to pulsed microwaves or 158 hr of exposure to continuous microwaves produced highly significant reductions in iron transport rate, iron turnover rate, quantity of iron incorporated into erythrocytes, and percent erythrocyte production. Cation binding models for the interaction of membranes with electromagnetic fields have shown that very weak electric stimulation (20-50 mV/cm at a frequency of 200 pulses/sec, pulse duration 1 msec) of the cat cerebral cortex increases the release of calcium ion, gamma-aminobutyric acid, and taurine. These results indicate that calcium binding in the cerebral cortex is highly sensitive to small perturbations of the extracellular field. The electric gradient induced by the stimulation is at most 2.5 μV across a typical synaptic terminal 0.5 μm in diameter. Such high sensitivity is consistent with models of excitable membranes where small stimuli may lead to marked transition in the membrane through cooperative interactions among the membrane components. The bioeffects of electromagnetic fields are also discussed in terms of electromagnetic sensing in fish; effects of weak electric fields on behavior and electroencephalograms of laboratory animals; amplitude-modulated, very high frequency electric fields; and effects of microwave radiation on aplysian ganglion cells. Biophysical characteristics of electromagnetic fields are reviewed through studies on tissue determinants of interactions with electric fields, central nervous system responses to microwave-induced heating, the biologic significance of zero magnetic field conditions, and perturbations of microwave fields by living organisms. In the field of dosimetry and dosimetric techniques, a miniature implantable temperature-measuring device has been developed that does not interfere with incident microwave fields. This device consists of a small fluid crystal sensor, approximately 1 mm in diameter, connected by a fiber optic system to external photoelectric measuring equipment. The use of scaling techniques is discussed in relation to problems associated with accurately evaluating energy absorption in whole bodies of large test subjects. Molecular and physical bases of tissue interactions with electromagnetic fields are discussed in light of studies on the physical characteristics of electromagnetic field interaction with molecular systems, atomic and molecular mechanisms underlying biologic interaction with electromagnetic radiation, and the possibilities of long- and short-range electric interactions of biologic systems. A formulation of possible modes of long-range interactions at membrane surfaces is presented that proposes conformational changes in proteins by mechanisms of coherence in ferroelectret sheets with associated limit cycles. Realistically specified in these models are the required triggering energies, ranges of transition temperatures, and frequencies of oscillation that would occur in systems physically structured in the fashion of the greater membrane. Observed tissue thresholds are consistent with predictions from these models, even for tissue gradients below 10^{-7} V/cm.

6362 EFFECT OF THE MAGNETIC FIELD COMPONENT OF THE KRAUS-LECHNER METHOD ON THE HEALING OF EXPERIMENTAL NONUNIONS IN DOGS. *(Eng.)* Blumlein, H.; McDaniel, J.; Perren, S. M. *In: Electrical Stimulation of Bone Growth and Repair.* (New York: Springer Verlag): pp. 41-44; 1978. (8 refs)

The effect of the magnetic field component of the Kraus-Lechner method on the healing of twelve 6- to 10-mo-old experimental bilateral nonunions of the radii in six female beagles was investigated. The radii with the nonunions were placed into magnetic coils that produced a magnetic field of 30 G at a frequency of 22 Hz. The magnetic field treatment was given for a period of 5 hr/day, 5 days/wk, for 3 mo. The magnetic field lines ran parallel to the bone axis. X-rays, microradiographs, and histologic findings failed to demonstrate any effect of the alternating magnetic field on either vascularization or bone formation. During the 3-mo period of magnetic field application, two of the nonunions healed, one in a control group not subjected to the magnetic field and one in the magnetic field group.

6363 RADIOFREQUENCY RADIATION LEVELS AND POPULATION EXPOSURE IN URBAN AREAS OF THE EASTERN UNITED STATES. *(Eng.)* Athey, T. W.; Tell, R. A.; Hankin, N. N.; Lambdin, D. L.; Mantiply, E. D.; Janes, D. E. (Electromagnetic Radiation Analysis Branch, Office Radiation Programs, EPA, 9100 Rockvillle Rd., Silver Spring, MD 20910). 42 pp.; 1978. [available through National Technical Information Services, Springfield, VA 22161, Document No. EPA-520/2-77/008]. (19 refs)

Measurements of nonionizing electromagnetic radiation levels were made at 193 sites in seven cities in the eastern United States. The cities were Atlanta, Boston, Chicago, Miami, New York, Philadelphia, and Washington, DC. The measurements were made in seven frequency bands between 0.01 and 900 MHz. The power density values ranged over five orders of magnitude from 0.0001 to 10 $\mu W/cm^2$, with a median value of about 0.02 $\mu W/cm^2$. The data show that frequency modulated (FM) radio and very high frequency (VHF) television transmitters are the most significant environmental sources of nonionizing radiation. A model for population exposure was applied to the seven areas where measurements were made, and the results show that about 98-99% of the people reside in areas where the levels are less than 1.0 $\mu W/cm^2$. The median exposure level is about 0.01 $\mu W/cm^2$. These levels are quite low compared to the American National Standards Institute and OSHA occupational exposure guides of 10,000 $\mu W/cm^2$. Even the very restrictive environmental guideline of 1 $\mu W/cm^2$ proposed in the Soviet Union would be exceeded for only 1 or 2% of the population in these seven metropolitan areas; the actual levels of the latter exposures will have to be determined by examination on a case-by-case basis.

6364 FIFTH REPORT ON "PROGRAM FOR CONTROL OF ELECTROMAGNETIC POLLUTION OF THE ENVIRONMENT: THE ASSESSMENT OF BIOLOGICAL HAZARDS OF NONIONIZING ELECTROMAGNETIC RADIATION." *(Eng.)* Anonymous. (NTIA, U.S. Dept. Commerce. 1800 G St., N.W., Washington, DC 20504). *NTIA Report 79-19* 266 pp.; 1979. (488 refs)

Activities of the Federal Government's cooperative multi-agency program to investigate and evaluate biologic effects of nonionizing electromagnetic radiation (0-300 GHz) are summarized. The report covers calendar years 1976, 1977, and early 1978 and includes information on research in progress during fiscal years 1977 and 1978. The primary thrust of the program is to determine whether exposures at low power density levels have an effect, particularly over extended periods of time and with reference to environments that might realistically be encountered by general and occupational populations. Government agency activities and program summaries are presented for HEW, EPA, the Department of Defense, NBS, NSF, the Federal Communications Commission, the Federal Aviation Administration, the Central Intelligence Agency, VA, and the Department of Energy. Additional information, including details of research projects and results of specific experiments, is covered in a variety of technical and conference reports and publications that are cited in the extensive appendix to this report.

6365 EFFECT OF MICROWAVES IN THE NONTHERMAL INTENSITY RANGE ON MICE: RESPIRATION, RECTAL TEMPERATURE, AND MENTAL REACTION. *(Swe.)* Criborn, C. O. (Huvudavdelning 5, Forsvarets Forskningsanstalt, 104 50 Stockholm 80, Sweden). 23 pp.; 1978. [available through FOA Rep C 54021-H2, H6]. (7 refs)

The effects of 30-min exposure to microwaves of frequency 2,450 MHz and intensity 10 mW/cm^2 on the rectal temperature, respiration (minute volume), and reaction to sound (8 kHz, 3-sec pulses, 12 pulses/min) were studied in male CBA mice. No changes in the rectal temperatures of the test animals were observed compared with controls for at least 4 hr after irradiation. The respiratory minute volume increased significantly during the first 15 min of exposure, after which it decreased significantly, reaching its lowest level about 15 min after exposure. Respiration normalized within the first hour after exposure. Irradiation caused a considerable reduction of the sound reaction (reduction of the respiratory minute volume in response to the sound) between 5 and 30 min of the exposure, but the reaction normalized within 30 min after exposure.

6366 MICROWAVES--NEW TOOLS FOR THE MEDIC? *(Eng.)* Anonymous. (Office of Naval Res. Branch Office, London, England). pp. 27-29; 1979. [available through European Scientific Notes, ONRL Report No. ESN 33-1]. (0 refs)

Research on the diagnostic and therapeutic use of microwaves in cancer therapy is reviewed. Microwave radiometry is being investigated for the detection of tumors. In experiments employing 1.3-, 3.3-, and 6.0-GHz body radiometry, carefully matched waveguide antennas loaded with dielectric were directly placed on the skin of patients. Bandwidths used varied from around 100 to 500 MHz. Excess temperature differences sensed with this tumor detection technique varied from 0 to 4 C. To date, over 4,000 women in a breast cancer detection unit have been examined using this method, and true positive and true negative rates of 70% have been achieved. When infrared mapping was combined with microwave radiometry, the true positive rate increased to 90%. Microwaves are also being used in the hyperthermic treatment of tumors. Prostate tumors have been successfully treated by hyperthermia induced by microwaves from a coaxial probe inserted in the rectum. In other experiments, 433.9-MHz hyperthermia has been combined with megavoltage x-ray treatment in patients with radioresistant malignant tumors. In these experiments, the tumor temperature was raised to 42 C during irradiation. Favorable responses without noticeable side-effects were observed among 72% of more than 40 patients treated in this manner.

6367 A REVIEW OF MICROWAVE OVEN SAFETY. *(Eng.)* Osepchuk, J. M. (Raytheon Res. Div., Waltham, MA). *Microwave J* 22(5): 25, 26, 28, 29, 32-37; 1979. (32 refs)

See Current Literaure 5784 for description of this article.

6368 KEYNOTE ADDRESS AND C. C. JOHNSON MEMORIAL LECTURE. MICROWAVE BIOEFFECTS RESEARCH: HISTORICAL PERSPECTIVES ON PRODUCTIVE APPROACHES. *(Eng.)* Schwan, H. P. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 1-13; 1978. (0 refs)

The historic development of microwave bioeffects research is reviewed, and a rationale for standards of safe exposure is presented. Biomedical experimental evidence supports the conclusion that significant thermal effects appear somewhere above 10 mW/cm^2 for man and probably in the 1-10 mW/cm^2 range for smaller animals. Over the last 40 yr, no evidence has been discovered that suggests any scientific principles that may be useful in formulating nonthermal standards of exposure. However, it appears that the present exposure standard of 10 mW/cm^2 in the United States may no longer provide a safety factor of about 10 as originally thought, particularly in light of the resonance effect for man near 100 MHz and the specific absorption rate figures and calculated temperatures in hot spots at 1-2 GHz. On the other hand, it can be argued that at low frequencies the magnetic field contribution is significant, giving preference to surface heating and thus favoring a situation similar to the one above 3 GHz where the effective heating penetration depth is independent of frequency. It has been established that hot spot types of heating patterns appear significant only in the frequency range of 500 MHz to 2 GHz. Taking these data into consideration, it is suggested that the safe standard of 10 mW/cm^2 for microwave exposure may be lowered between frequencies of 0.3 and 3 GHz, but it may be retained at 10 mW/cm^2 for frequencies above 3 GHz; as the frequency decreases below 30 MHz, the standard may be drastically relaxed.

6369 THE EFFECTS OF LOW POWER DENSITY MICROWAVES ON RAT HYPOTHALAMIC TEMPERATURES. *(Eng.)* Brainard, G.; Albert, E.; DeSantis, M.; Postow, E.; Parker, J. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 14-31; 1978. (25 refs)

Thermistor measurements of the temperature response of the hypothalamus to 2,800-MHz pulsed microwaves waves were performed in unanesthetized male Long Evans Hooded rats to determine if neurocytologic and blood-brain barrier effects caused by microwaves are due to associated temperature increases. The microwave signal was pulsed 500 times/sec with a 2-μsec pulse width. The rats were exposed to 0, 5, 10, and 15 mW/cm^2 power densities for periods ranging from 10-60 min. In control animals, brains showed a slight net temperature decrease during recording (-0.17 C), whereas in rats exposed to 5 mW/cm^2, 10 mW/cm^2, or 15 mW/cm^2 of pulsed microwaves, there were net increases of +0.25, +0.65, and +0.85 C, respectively. These values demonstrate a nearly linear relationship between increasing power density and increasing hypothalamic temperatures. In no case was a microwave-induced temperature increase greater than 1.2 C observed. Thus, it appears unlikely that the increased permeability of the blood-brain barrier due to low power density microwaves is a result of increased temperature in a macroscopic sense. However, the results presented here do not rule out the possibility that the nonuniform deposition of energy could produce a significant heating at other foci in the rat brain or perhaps at the cell membrane or molecular level.

6370 ENDOCRINE FUNCTION IN RHESUS MONKEYS EXPOSED TO PULSED MICROWAVE RADIATION. *(Eng.)* Lotz, W. G. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 32-51; 1978. (21 refs)

Endocrine function was studied in three adult male rhesus monkeys exposed to 1.29-GHz pulsed microwaves (pulse width 3 μsec, duty cycle 0.001) at a power density of 20 mW/cm^2. Hormone levels in sequential blood samples obtained via chronic indwelling jugular catheters were determined. Over a 24-hr period, hourly samples were taken from monkeys restrained in a foamed polystyrene chair before, during, and after an 8-hr exposure to the pulsed microwave radiation. The animals were exposed to far-field conditions in an anechoic chamber. A small, delayed, and transitory depression of circulating thyroxine levels was the only effect on endocrine function produced by microwave exposure. Rectal temperature was elevated an average of 0.6 ± 0.1 C during the exposure. No differences were noted between plasma levels of cortisol or growth hormone during exposure sessions as compared with sham-exposed sessions. These data support the hypothesis that microwave exposure causes a drop in pituitary secretion of thyrotropin that results in a subsequent decline in circulating thyroxine levels.

6371 EFFECTS OF MODULATED RF ENERGY ON THE EEG OF MAMMALIAN BRAINS. II. APPEARANCE OF FAST AND SLOW WAVES AFTER CHRONIC IRRADIATIONS. *(Eng.)* Takashima, S.; Onaral, B.; Schwan, H. P. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 52-75; 1978. (28 refs)

The effects of acute and chronic irradiation with modulated radio frequency (RF) energy on the electroencephalograms (EEG) of rabbit brains were investigated. The frequency of the RF fields ranged from 1 to 10 MHz with two modulation frequencies at 14-16 Hz and 60 Hz. Two large aluminum plates (30 by 30 cm^2) were used for the application of the RF fields at a distance of 20 cm. The rabbits

were exposed at field strengths ranging from 60 to 500 V/m for 2-3 hr during acute experiments and for 4-6 wk during chronic experiments. Sequential displays of EEG power spectra were used to analyze the EEG signals. Acute irradiation at a level of 500 V/m did not produce significant changes in the EEG power spectra if the use of intracranial metal electrodes was avoided. Chronic exposures at levels up to about 70 V/m also did not produce any appreciable effects on the EEG patterns. However, at intensities of 80-100 V/m, RF fields (modulated with 14 Hz) stimulated high frequency neuron activities at 10-20 Hz, while chronic irradiation at a level of 500 V/m enhanced low frequency waves (4-5 Hz). These two effects seemed to be competitive in that an increase in low frequency components was usually coupled with the suppression of high frequency activities and vice versa. These changes were reversible, with the EEG returning to normal within several days after irradiation was discontinued.

6372 EFFECTS OF 8.6-GHz PULSED ELECTROMAGNETIC RADIATION ON AN *ESCHERICHIA COLI* REPAIR-DEFICIENT MUTANT. *(Eng.)* Dutta, S. K.; Hossain, M. A.; Ho, H. S.; Blackman, C. F. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 76-95; 1978. (12 refs)

The effects of pulsed microwave radiation on the growth of *Escherichia coli* strains Pol A^+ (normal) and Pol A^- (repair deficient mutant) were studied at a controlled temperature of 37 ± 0.1 C in a waveguide exposure system using 8.6-GHz radiation pulsed at a repetition rate of 1 kHz with a pulse width of 1 μsec. The average specific absorption rate of the samples was 12 W/kg, and the samples were exposed for periods of 1, 2, 4, or 7 hr. In one set of experiments, the effects of microwave radiations on actively growing (log phase) *E. coli* strains Pol A^+ and Pol A^- were investigated, while in another experiment the effects of microwaves on quiescent cells maintained in a non-nutritive salt solution were studied. No significant cellular damage was detected in either experiment at the 95% confidence limit. However, a trend towards microwave-induced growth for actively growing (log phase) *E. coli* Pol A^- cells was observed at the 90% confidence level.

6373 TECHNIQUES FOR PRODUCING STANDARD EM FIELDS FROM 10 kHz TO 10 GHz FOR EVALUATING RADIATION MONITORS. *(Eng.)* Larsen, E. B. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 96-112; 1978. (18 refs)

Techniques used by the NBS for producing standard electromagnetic fields from 10 kHz to 10 GHz are reviewed. The general approach used for evaluating and calibrating radio frequency radiation monitors is to generate a calculable or standard field and then immerse the probe of the monitor being tested in this known field. The optimum type of field-generating instrumentation depends on the frequency band and desired accuracy. A convenient device at frequencies from 10 kHz to 300 MHz is a rectangular coaxial transmission line known as a transverse electromagnetic mode (TEM) cell. In the frequency range of 300-1,000 MHz, a series of rectangular waveguide transmission lines can be used to generate a field with approximately known intensity. Also, in the frequency range of 100-500 MHz, high-level fields extending over a larger volume can be produced at an outdoor field site in the near zone of open-end waveguide radiators. Calibrating fields between 500 MHz and 10 GHz are produced in an anechoic chamber by a series of standard-gain pyramidal horns. In all of the above cases, it is possible to calculate the electric and magnetic field strengths (and equivalent free-space power density) in terms of the measured power flow through the cell or waveguide or the power delivered to the open-end waveguide or horn antenna. It is concluded that radiation monitors (and other antennas) can be easily calibrated over the entire frequency range of 10 kHz to 10 GHz with an uncertainty of less than ±0.5 decibels. It is possible to produce high-level fields greater than 200 V/m using only low-power radio frequency sources (less than 50 W).

6374 TEMPERATURE CONTROLLED CAVITY APPLICATOR FOR RADIO-FREQUENCY WAVE IRRADIATION OF MAMMALIAN CELLS IN VITRO. *(Eng.)* McEuen, A.; Tanabe, E.; Vaguine, V.; Williams, N.; Li, G. C.; Hahn, G. M. (Radiation Div., Varian Associates, Palo Alto, CA 94303). *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 113-121; 1978. (5 refs)

A cylindrical re-entrant radio frequency (RF) cavity applicator for measuring thermal and nonthermal effects of RF power on an in vitro cell system under controlled temperature conditions is described. The applicator operates over a frequency range of 400-1,000 MHz and is capable of producing absorbed RF power densities up to 180 W/cm^3 in a biologic sample. The cavity is designed to produce a uniform electric field concentrated in the sample between two copper discs. The variation in field strength is about 1% over an area 3 cm in diameter for a 1 mm gap. Typically the sample is 1.6 cm in diameter, and the gap is 0.2 mm. Two separate loops of circulating temperature stabilizing liquid permit independent temperature control of the top and bottom disc-sample interfaces. The temperatures of the top and bottom surfaces of the sample are measured by two thermocouples that are embedded in the copper discs and are located at positions 1 mm from the sample-disc interfaces. The temperature distribution within the sample and sample holder can be obtained by

solving the heat transfer equation. The above system offers several advantages over previously published methods with respect to absorbed power density, field uniformity, accuracy of temperature control and measurement, and efficiency.

6375 EVALUATION OF LYMPHOCYTE FUNCTION IN MICE EXPOSED TO 2450 MHz (CW) MICROWAVES. *(Eng.)* Smialowicz, R. J.; Riddle, M. M.; Brugnolotti, P. L.; Sperrazza, J. M.; Kinn, J. B. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 122-152; 1978. (24 refs)

Female BALB/c mice were exposed under far field conditions in a temperature- and humidity-controlled environment to 2,450-MHz continuous wave microwaves to investigate possible effects on hematology and lymphocyte function. Exposures were performed at power densities ranging from 5 to 35 mW/cm^2 for periods of 15 or 30 min daily for 1, 4, 6, 8, or 22 consecutive days. Specific absorption rates, determined by twin-well calorimetry, ranged from approximately 4 to 25 mW/g depending on the incident power density. Hematologic variables including complete blood counts were compared between sham and exposed groups. Several techniques were used to assess both cellular and humoral immunocompetence of the exposed mice. Thymus (T)- and bone marrow (B)-derived lymphocyte function was assessed using the in vitro mitogen-stimulated response. Surface receptor assays were used to enumerate T- and B-lymphocytes in the spleens of microwave- and sham-exposed mice. B-lymphocytes were identified using the complement receptor assay, and T-lymphocytes were identified using cytotoxic antisera against the theta surface marker. The antibody response of microwave- and sham-exposed mice to the T-dependent antigen of sheep erythrocytes was measured by the direct plaque-forming cell assay. Colon temperatures were taken prior to and immediately after exposure to assess the possible heat load that exposed animals might experience at different power densities. No physiologically significant increases in colon temperatures were observed in mice irradiated at any of the power densities employed. Exposure of mice to 2,450-MHz microwaves caused no consistent significant alterations in any of the hematologic or immunologic parameters examined.

6376 RADIOFREQUENCY RADIATION ALTERS THE IMMUNE SYSTEM: MODULATION OF IN VIVO LYMPHOCYTE MIGRATION BY WHOLE-BODY HYPERTHERMIC RADIATION. *(Eng.)* Liburdy, R. P. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 153-174; 1978. (20 refs)

See Current Literature 6177 for description of this article.

6377 ACCELERATION AND DECELERATION OF FETAL GROWTH OF RATS BY 2450-MHz MICROWAVE IRRADIATION. *(Eng.)* Chernovetz, M. E.; Justesen, D. R.; Levinson, D. M. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 175-193; 1978. (11 refs)

The effect of electrically modulated 2,450-MHz microwave irradiation on fetal growth and development in the rat was investigated. Primigravid albino Sprague-Dawley rats were exposed in a multimode cavity for 20 min at average whole-body dose rates of 14 or 28 mW/g to 2,450-MHz microwaves electrically modulated as a bottom-clipped half-wave sinusoid at 60 Hz. On days 8, 10, 12, or 14 of gestation, 48 unrestrained rats were irradiated in pairs. An additional 24 rats were either sham exposed or were maintained as passive controls. Fetuses were delivered by Caesarean section on day 18 of gestation. No gross structural abnormalities were observed as a result of microwave irradiation. However, 330/540 nonresorbed fetuses presented hemorrhagic signs. The number of fetuses with hemorrhages was not associated with the day of gestation, type of treatment, or the interaction of gestational day and type of treatment. Fetal mass was significantly affected by microwave irradiation, but the degree as well as the direction of the effect was dependent on the interaction between the level of energy dosing and the day of gestation during which exposure occurred. Irradiation at the 28 mW/g level on day 8 of gestation resulted in smaller fetal mass, while similar dosing on day 12 or 14 of gestation resulted in larger fetal mass. In contrast, fetal mass was smaller in animals that received 14 mW/g of radiation on day 12 or 14 of gestation. Exposure to 14 mW/g of microwave radiation on day 8 or 10 resulted in no significant difference in fetal mass.

6378 SHUTTLEBOX SIDE PREFERENCE AS MEDIATED BY PULSED MICROWAVE AND CONVENTIONAL AUDITORY CUES. *(Eng.)* Hjeresen, D. L.; Doctor, S. R.; Sheldon, R. L. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 194-214; 1978. (18 refs)

Rats were exposed in an anechoic chamber to the far field of a 2.88-GHz pulsed microwave beam to test the possibility that preference for the shielded side of a two-compartment shuttlebox as well as increased activity responses are due to audition of the pulsed microwaves rather than to some other aspect of the exposure. The characteristics of the 2.88-GHz microwave beam were as follows: average power density, 9.5 mW/cm^2; peak power density, 33 W/cm^2; pulse repetition rate, 100 pulses/sec; pulse width, 3.0 μsec; average energy/pulse, 100 μJ/cm^2; and absorbed dose rate, 2.1 W/kg. In one

experiment, a 37.5-kHz tone was substituted for microwave exposure during one of nine test sessions. In a second experiment, microwave audition was masked by pink noise with a suppressed spectrum below 20 kHz, a 60 dB/octave rise from 20 to 40 kHz, and a slow roll-off (11 dB/octave) above 45 kHz. In the first experiment, both microwave audition and exposure to 37.5-kHz tone caused the rats to show an increased preference for the shielded side of a two-compartment shuttle box; side-to-side traverse activity was also increased by both microwave exposure and exposure to the 37.5-kHz tone. In the second experiment, in which microwave audition was masked, no preference for the shielded side of the shuttle box was observed in microwave-irradiated rats; however, the number of traverses made by rats progressively increased with repeated exposures. It appears that while audition of pulsed microwaves may be responsible for the side preference effect, the increased traverse activity among continuously exposed rats may be due to accumulated heat load or an as yet undefined motivating factor.

6379 DISRUPTION OF BEHAVIOR IN MAMMALS OF THREE DIFFERENT SIZES EXPOSED TO MICROWAVES: EXTRAPOLATION TO LARGER MAMMALS. *(Eng.)* de Lorge, J. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 215-228; 1978. (9 refs)

In three separate studies, four albino rats, three squirrel monkeys, and three rhesus monkeys were exposed to 2.45-GHz microwave irradiation (100% amplitude modulated at 120 Hz) under far field conditions in anechoic chambers to examine the effect of microwaves on the disruption of behavior in mammals of three distinctly different body masses. All animals were performing on operant schedules for food reinforcement during microwave irradiation. 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 immediately after exposures in rats. Exposure sessions lasted 60 min and were usually scheduled during the 5-day work week. The typical result of microwave exposure was a decrement in response rate and an increment in the pause time following a reinforcement. The threshold for disruption of lever responding was 28 mW/cm^2 in rats, 45 mW/cm^2 in squirrel monkeys, and 67 mW/cm^2 in rhesus monkeys. When these thresholds were plotted as a function of body mass (0.3, 0.7, and 5 kg, respectively), a semilog relationship was observed. In addition, power densities associated with behavioral disruption approximated those power densities that produced an increase in rectal temperatures of at least 1 C above control levels. Hence, disruption of behavior may have been caused more by the greater heat load than by any direct action of microwaves on the central nervous system. It is concluded that scales based on dependent variables other than absorbed energy (or rate of temperature increase) might be more useful for predicting actual effects of exposure to microwave irradiation.

6380 MONITORING OF ARTERIAL WALL MOVEMENT BY MICROWAVE DOPPLER RADAR. *(Eng.)* Stuchly, S. S.; Goldberg, M.; Thransandote, A.; Carraro, B. (Dept. Electrical Engineering, Univ. Ottawa, Ottawa, Ontario K1N 6N5, Canada). *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 229-242; 1978. (8 refs)

The application of continuous wave microwave Doppler radar for monitoring arterial wall movements is reported. The technique is based on the measurement of the frequency and amplitude of the microwave signal back scattered (reflected) by the arterial wall. The feasibility of this technique was verified by using a low power Doppler transceiver operating at a frequency of 10.525 GHz during several experiments with humans. An open-ended dielectric loaded rectangular waveguide was used as an antenna. The dimensions of the radiating aperture were 10.7 by 4.3 mm, and the dielectric constant of the material filling the waveguide was 5. The input reflection coefficient of the antenna facing the skin was lower than 23 dB (voltage standing wave ratio of less than 1.7). The experiments were performed by placing the radiating aperture directly in contact with the skin over different peripheral arteries. The results indicate that clear, low noise Doppler responses from different peripheral arteries can be obtained. The output signal provides information about the relative movement of the artery during the heart cycle. Although absolute calibration is not possible at this time, it seems that viable diagnostic information can be obtained by comparing the responses from two sides of the body, particularly the limbs, as well as from the relative pattern of the response. The data provided by this technique should generate valuable diagnostic information in the determination of stress-strain characteristics of peripheral arteries.

6381 THERMOGRAPHIC COMPARISON OF TEMPERATURE PROBES USED IN MICROWAVE DOSIMETRY STUDIES. *(Eng.)* Olsen, R. G.; Hammer, W. C. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 243-270; 1978. (12 refs)

A muscle-equivalent test sphere was used to compare the accuracy and perturbation characteristics

of five readily available temperature probes with thermographic results at two microwave frequencies, 1.7 and 5.95 GHz. The temperature probes were implanted in the sphere that was thermographically analyzed after irradiation for orthogonal probe orientations. The temperature probes tested were the following: a common rectal-type thermistor; a fine-wire, copper-constantan thermocouple; a simple nonmetallic thermocouple; a liquid crystal optical fiber probe; and a prototype four-lead high-resistance thermistor. At 1.7 GHz, thermographic results showed distortion of the internal microwave absorption for probes with either metallic or highly conducting leads. However, the quantitative results at 1.7 GHz showed that all probe-determined specific absorption rate (SAR) data were consistent with thermographically derived SAR data. At 5.95 GHz, the consistency between probe-determined SAR data and thermographically derived SAR data was not as good. In general, wide variations with a rather poor correlation to probe results were seen in the thermographic SARs. Most of the problems contributing to the disparities seen in the 5.95 GHz data concerned technique or physical inadequacy. Implicit in the wide variations for the 5.95 GHz data is the fact that accurate microwave dosimetry becomes more difficult at higher frequencies. At such frequencies, the probes are not as small relative to wavelength; moreover, hot spots or hot regions are formed over smaller areas, making probe size and exact placement more critical.

6382 TEMPERATURE PROFILES IN SPHERES DUE TO ELECTROMAGNETIC HEATING. *(Eng.)* Kritikos, H. N.; Foster, K. R.; Schwan, H. P. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 271-303; 1978. (30 refs)

Theoretical estimates of the temperature rise produced in tissue spheres by microwave irradiation are presented. The results are discussed for the three chief frequency ranges of the microwave absorption properties of the head. For the low frequency or Rayleigh region (<500 MHz for head radii <10 cm), head heating is characterized by electric and magnetic dipole terms. For large spheres (radius of about 10 cm), the magnetic dipole term dominates, and the steady state temperature pattern shows a maximum occurring near the front surface of the sphere; the maximum increase in tissue temperature is <0.03 C for 10 mW/cm^2 incident intensity, with a much lesser temperature increase in the core of the brain. For smaller spheres (5 cm radius), the electric dipole term dominates and the heating pattern is more uniform; the increase in tissue temperature is negligible everywhere. In this low frequency range, significant heating of the entire body occurs, but the purely local model used in this study cannot be used to pinpoint thermal damage in the body. In the resonance region (1 GHz for the human head) for spheres with radii of about 5 cm, the absorbed energy is focused in a hot spot near the center with a radius of approximately 1 cm. For a 5-cm radius tissue sphere exposed to an incident field of 10 mW/cm^2 at 1 GHz, the maximum increase in tissue temperature of about 0.6 C occurs in the center of the head. In the high frequency region (greater than 5 GHz), heating occurs only at the front and side surfaces of the sphere, and the calculated temperature increases are similar to those found in a semi-infinite tissue plane irradiated by plane wave energy. Because of thermal conductivity and blood perfusion, the effective heating depth of the energy is about 1 cm, even though the microwave energy might be absorbed much nearer to the surface. For an incident field of 10 mW/cm^2 intensity, the maximum tissue temperature rise is about 0.3 C and is located near the front surface of the tissue.

6383 APPROXIMATE CALCULATION OF SAR FOR PLANE-WAVE IRRADIATION OF MAN MODEL NEAR A GROUND PLANE. *(Eng.)* Iskander, M. F.; Durney, C. H.; Massoudi, H.; Johnson, C. C. *In: Proceedings of the 1978 Symposium on Electromagnetic Fields in Biological Systems held in Ottawa, Canada, June 27-30, 1978.* IMPI and IEEE-Microwave Theory and Techniques Society. (Edmonton, Alberta, Canada): pp. 304-323; 1978. (9 refs)

An approximate analysis for calculating the average specific absorption rate (SAR) of a model of man irradiated near or on a ground plane is presented. The analysis involves two approaches. One approach is based on the equivalent circuit of a receiving antenna. The antenna internal impedance is approximated by the internal impedance of a finite cylinder, while the radiation impedance is calculated by extrapolating available data for a cylindrical antenna. The other approach involves a combination of circuit theory and a curve fitting procedure. A simple series circuit (resistance, conductance, capacitance) is used, with the circuit elements being calculated by curve fitting the available theoretical data for a man in direct contact with the ground plane. In both cases, the introduction of a separation between the feet of the man and the earth (e.g., due to a rubber sole or shoe) is taken into account by introducing a lossy capacitor in the equivalent circuit. Numerical results show that the ground plane effect on the average SAR values is basically important at lower frequencies. For example, at 10 MHz, the average SAR of a man on a ground plane is an order of magnitude larger than its value for the free-space irradiation at the same frequency. This order of magnitude ratio decreases to a factor of 3 at 50 MHz. Furthermore, the ground plane effect decreases rapidly with increasing gap distance. Thus, even for the worst case of a barefoot man placed at a distance from a wet earth, a distance of 7.5 cm is sufficient to restore the conditions of free-space irradiation.

MEETING ABSTRACTS

6384 MICROWAVE LEAKAGE DURING PATIENT TREATMENT (MEETING ABSTRACT). *(Eng.)* Kopecky, W. J. (Div. Radiation Oncology, Mallinckrodt Inst. Radiology, Washington Univ. Sch. Medicine, St. Louis, MO 63110); Perez, C. A. *Med Phys* 6(4): 353; 1979. (0 refs)

In response to the proposed BRH draft standard for a maximum microwave radiation leakage of 5 mW/cm^2 at 5 cm from the source, measurements of leakage radiation during hyperthermic treatment of patients with two different applicators operating at 915 MHz were made at the Mallinckrodt Institute of Radiology. Some treatments, involving the head and neck region, give rise to large air gaps between the patient surface and applicator, while other treatment sites, including the limbs, present a curved surface. A comparison of these data with data obtained using tissue equivalent phantoms will be presented.

6385 EFFECTS OF FOUR NITROSOUREAS WITH LOCAL HYPERTHERMIA ON PRIMARY TUMOR AND LUNG METASTASES (MEETING ABSTRACT). *(Eng.)* Marmor, J. B. (Dept. Radiology, Stanford Medical Center, Stanford, CA 94305); Hahn, G. M. *Proc Am Assoc Cancer Res* 20: 67; 1979. (0 refs)

The effects of local radio frequency (RF) hyperthermia in combination with four different nitrosoureas on primary tumor development and lung metastases were examined in C3H mice bearing KHT flank tumors. The nitrosoureas were given intraperitoneally, and the flank tumors were locally heated to 42-43 C. Local heat with 1,3-bis(2-chloroethyl)-1-nitrosourea was superior to either modality alone or to both given 24 hr apart (5/40 cures versus 0/40 cures; median growth delay 30 days versus 13 days). In addition, combined therapy was more effective in controlling lung metastases than was chemotherapy alone or chemotherapy plus heat given 24 hr apart (32/47 lungs negative versus 3/38 lungs negative). The effects of chlorozotocin on both primary tumor growth and lung metastases were also markedly potentiated by RF hyperthermia. The effects of 1-(2-chloroethyl-3-[*trans*-4-methylcyclohexyl])-1-nitrosourea were only slightly enhanced by simultaneous local RF heating. The effects of streptozotocin were not enhanced by RF heating. These findings suggest that local RF heating of tumor masses may increase the effectiveness of some, but not all, nitrosoureas and that hyperthermia does not increase the incidence of metastases as suggested by some studies.

6386 EFFECT OF MAGNETIC FIELDS ON CHROMOSOMES (MEETING ABSTRACT). *(Ger.)* Eberle, P. (Fach Humangenetik und Cytogenetik, Technische Universitat Braunschweig, Gaussstrasse 17, D-3300 Braunschweig, W. Germany); May, C. *Hoppe Seylers Z Physiol Chem* 360(3): 252; 1979. (0 refs)

The effects of 15-min to several-hour exposures of static and homogeneous magentic fields of 10,000 to 140,000 G on mitotic processes in human blood cultures and in fibroblast cultures (Chinese hamster Vt 79 and human embryonal lung) were studied by light microscopy. The disturbances observed in the mitotic processes included the migration of the chromosomes into the equatorial plane, the migration of the daughter chromosomes to the spindle pole, and multipolar chromosome arrangements. The frequency of chromosome and chromatid mutations did not appear to be significantly affected by the exposure. The disturbances in the mitotic processes observed after the application of magnetic fields may result from interference with the synthesizing processes in the chromosomes, nuclear membranes, and tubular structures of the spindle apparatus. Shifts in the enzyme activities and changes in the orientation of biologically important macromolecules may also play a role.

6387 TOLERABLE EXTENT OF MICROWAVE-INDUCED HYPERTHERMIA IN NORMAL AND 5-HTP-TREATED MICE (MEETING ABSTRACT). *(Eng.)* Nishimoto, Y. (Aichi Cancer Center, Nagoya, Japan); Nakamura, W. *J Radiat Res (Tokyo)* 20(1): 28; 1979. (0 refs)

The effect of 5-hydroxytryptophan (5-HTP) on the tolerance of mice to 2,450-MHz microwave-induced hyperthermia was investigated. In normal mice, the anal temperature for 100% tolerable instantaneous hyperthermia was 43 C. However, when mice were injected intraperitoneally with either 0.1 or 0.4 mg/g of 5-HTP 40 min prior to irradiation, the snal temperature for 100% tolerable hyperthermia dropped to 42 and 40 C, respectively.

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

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