HF BAND. *(E.)* Kall, A. R. (Ark Electronics Corp., Willow Grove, Pa.). *Proc IEEE 1973 Electromagnetic Compatibility Symp* June 1973, p 53.

The results of two separate research programs are reported concerning intensive investigations into biological radio frequency hazards from high power, high frequency (HF) transmitting antennas. The programs consisted of two major phases: measurement of field strengths in the near vicinity of HF band antennas, and coordinated clinical irradiation studies on laboratory rats. The clinical studies established threshold values for E and H fields, and a level for the combined ExH field that is within the experimental error range of the ANSI limit of 10 mW/cm^2. Discussion of electronic irradiation techniques and the nature of the biological investigations are included. (No references)

0099 BASIC PRINCIPLES FOR SHIELDING ELECTROMAGNETIC FIELDS. *(Rus.)* Maksimenko, N. V. (Khar'kov Sci. Res. Inst. Industrial Hyg. Occupational Dis., USSR), G. I. Evtushenko and N. N. Goncharova. *Gig Sanit* 38:108-110, 1973.

Experimental investigations on reducing the field strength of pulsed and continuous electromagnetic fields produced by high-frequency generators showed good agreement between experimental data and theoretical values calculated for different wavelengths by the method of D. E. Shapiro (see graph for further details). According to this method, the effectiveness of continuous shielding is given by 4.2 $E_M \times R/\lambda$, where λ is the wavelength of the electromagnetic field in meters, E_M is the shielding effectiveness of the material, and R is the radius of the shield (spherical). (6 references)

0100 THE DEVELOPMENT OF SOME MICROWAVE MEASURING TECHNIQUES IN THE PAST 25 YEARS. *(Ger.)* Groll, H. (no affil.). *Nachrichtentechnik* 26(8): 352-353, 1973.

The evolution of microwave signal generators and receivers is briefly reviewed with consideration of techniques for measuring power, transmission, adjustment, impedance and frequency. (No references)

0101 EFFECT OF MICROWAVES ON BIOLOGICAL SUBSTRATES. *(Fr.)* Berteaud, A. J. (Lab. Magnetism, CNRS, Bellevue, France). *Electron Fisc Apli* 16(3):517-522, 1973.

The effects of microwaves on a biological substrate depend upon the dielectric properties of the substrate which contains large quantities of water (average of more than 70%). However, water interacts with various components in the substrate by forming bonds with them, the strength of which depends upon the extent of hydration. Microwaves are generally absorbed by water as a result of Debye relaxation, and this absorption is manifested by a thermal effect which, in some cases, is too small to measure. Absorption of quanta of radiation with wavelengths in the millimeter range is responsible for changes in the rotational energy of molecules or side chains of macromolecules having a permanent dipole moment. Mechanical effects exerted by microwaves on particles suspended in a liquid include (1) forces resulting from a nonhomogeneous field, (2) orientation of nonspherical particles, and (3) formation of chains of spherical particles. The electrical properties of these particles are analyzed mathematically. (4 references)

0102 THERMAL AND ATHERMAL EFFECTS OF 2.8 GHz MICROWAVES ON THREE HUMAN SERUM ENZYMES. *(E.)* Belkode, M. L. (Hlth. Protect. Branch, Hlth. Welfare Canada, Ottawa), A. M. Muc, and D. L. Johnson. *J Microwave Power* 9(1):23-29, 1974.

The effects of microwave radiation *in vitro* on the human serum enzymes lactate dehydrogenase, acid phosphatase, and alkaline phosphatase were investigated. Serum specimens were treated with 2.8 GHz microwaves (1 kHz mW/cm^2) at an incident power density of 400-1000 mW/cm^2. Treatments with and without microwaves were carried out in a heat exchanger at 37 C, 46.7 C, and 49.7 C for 4-1/2 or 18-1/2 min. Enzyme activities were determined and analyzed for the possible thermal or athermal effects of the microwave radiation. Inactivation of each of the three enzymes occurred following either 4-1/2 or 18-1/2 min treatment with and without microwaves at 49.7 C, the longer treatment generally producing greater inactivation. The relative activity difference between the irradiated and nonirradiated sample groups was not statistically significant for any of the three enzymes. These results suggest that the microwave field did not cause any athermal denaturation of the irradiated enzymes and that thermal denaturation was responsible for the observed inactivation. (13 references)

0103 I. MICROWAVE IRRADIATION AND THE CIRCADIAN RHYTHM OF BONE MARROW CELL MITOSES. *(E.)* Czerski, P. (Natl. Res. Inst. Mother Child, Warsaw, Poland) and E. Paprocka-Slonka. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 2B1/1-2B1/2.

Changes in the amplitude and phase of the circadian rhythm of the bone marrow mitotic index were observed in Swiss albino mice exposed for 4 hr to 2950 MHz pulsed microwaves (1200 Hz, 1μS) at 0.5 ± 0.2 mW/cm^2 power density. The changes were demonstrable 24 and 48 hr after exposure and regressed 72 hr after exposure (damped oscillation). (2 references)

0104 II. MICROWAVE IRRADIATION AND THE CIRCADIAN RHYTHM OF BONE MARROW CELL MITOSES. *(E.)* Czerski, P. (Natl. Res. Inst. Mother Child, Warsaw, Poland), E. Paprocka-Slonka and A. Stolarsak. *J Microwave Power* 9(1):31-37, 1974.

Changes in the amplitude and phase of the circadian rhythm of the bone marrow mitotic index were observed in Swiss albino mice following 4-hr irradiation at 2.95 GHz. The mean power density was 0.5 mW/m^2 and comprised 1.0 μS pulses at a repetition frequency of 1.2 KHz. Bone marrow smears were air-dried, stained with May-Grunwald-Giesma stain, and

mitoses/1000 cells were counted. Recognizable granulocyte precursor and erythroblastic mitoses were classified as such; the remaining mitoses (early erythroblasts, mycloblasts, and lymphocytes) were grouped as "stem cell" mitoses. Differences between irradiated animals and controls were wholly accounted for by stem cell mitoses. No significant differences between the two groups were noted in mitotic indexes of granulocyte precursors and erythroblasts. Temperature measurements did not differ significantly in irradiated and control animals. It is concluded that low-level microwaves do not interfere with the process of cellular division, but induce a response of stem cells probably dependent on physiologic attributes of the cell group. (10 references)

0105 EXPOSURE OF BIOLOGICAL SPECIMENS TO HIGH POWER HF BAND FIELDS. *(E.)* Frazer, J. W. (USAF Sch. Aerospace Med., Brooks AFB, Tex.), J. C. Mitchell, A. E. Gass, and W. D. Hurt. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada), May 1972, p 167-168.

Primates and rodents were exposed to fields of 5000 V/meter at 10.5, 19.7, and 26.6 MHz, with the maximum rise in body temperature occurring at 26.6 MHz. Primates so exposed have shown no ill effects in over 1 yr. A transient sensitivity of lymphocytes to phytohemagglutinin as a division initiator is being investigated, but seems not to have been associated with long-term effects. Neonatal mice were exposed to fields of 5-7000 V/meter acutely on the 4th day postpartum at 10.5, 19.7, and 26.6 MHz. Without additional stress, there was no difference between growth curves in exposed and control groups. When small amounts of n-propanol were injected s.c. prior to exposure, a growth delay in the radiated group showed that precise experimental conditions must be met to demonstrate an effect of HF band fields on growing animals. (No references)

0106 PERCEPTION AND AVOIDANCE OF ILLUMINATION WITH LOW POWER PULSED UHF ELECTROMAGNETIC ENERGY. *(E.)* Frey, A. H. (Randomline, Inc., Willow Grove, Pa.) and S. Feld. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 130-135.

Experiments were conducted to determine the sensory and behavioral effects on Sprague-Dawley rats of illumination with low power pulse modulated UHF energy. Carrier frequency was 1.245 GHz; pulse width, 30 μs; and pulse repetition rate, 100 pps. The rats were exposed in an anechoic chamber containing two barrier boxes arranged so that one was lower and offset to the front and side of the other cage. The right half of the lower cage and the left half of the higher cage were shielded from the UHF energy. The average power density illuminating the unshielded half of the lower box was 0.4 mW/cm^2; the shielded half was exposed to 2% of the unshielded level. The unshielded half of the upper box was exposed to 0.9 mW/cm^2 average power density, the shielded half to 7% of this level. Test data indicate that rats perceive free field illumination with low power modulated UHF electromagnetic energy, find it aversive, and are actively motivated to avoid it. The animals responded equivalently to the 0.4 mW/cm^2 power level in the lower box and the 0.9 mW/cm^2 level in the upper box. This indicates that the perceptual and aversive threshold is less than 0.4 mW/cm^2 average power density and less than 133 mW/cm^2 peak power density. The effect appeared within the first 15 min of test sessions, persisted through the entire 90-min session, and was consistent over 7 days of testing. (7 references)

0107 DIELECTRIC STUDIES ON BIOLOGICAL MATERIALS NEAR 1 GHz: BIOPHYSICAL AND MEDICAL IMPLICATIONS. *(E.)* Grant, E. H. (Phys. Dept., Queen Elizabeth Coll., London, England). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 1B2/1-1B2/2.

A linear relationship between the permittivity of blood at 2 GHz and its hemoglobin concentration is reported. This linearity could become the basis of an electrical method for measuring hemoglobin concentrations. Other measurements on LDL β-lipoproteins at 800 MHz showed significant differences in permittivity between samples from normal patients and patients with hyperbetapoproteinemia. The most likely explanation of these differences is that normal lipoprotein samples have a very low value for the water of hydration (< 0.06), whereas abnormal samples require a hydration between 0.07-0.17). (No references)

0108 ELECTROMAGNETIC PULSE RADIATION: A POTENTIAL BIOLOGICAL HAZARD? *(E.)* Milroy, W. C. (Naval Weapons Lab., Dahlgren, Va.), T. C. O'Grady and E. T. Prince. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B1/1-3B1/2.

Concern has arisen over the bioeffects of electromagnetic pulse radiation (EMP) due to the very high field densities involved, i.e., hundreds of thousands of volts/meter. No significant effects were observed in an Air Force pilot study involving several dogs, a monkey, and maze-trained mice. A Russian study of EMP effects on humans showed an intensity-time relationship on the appearance of phosphenes in the visual field. In a study being conducted by the Armed Forces Radiobiological Research Institute, a large rat population is continuously irradiated by a pulsed field of ∿500 kV. The population is being monitored for a variety of physiological parameters; no significant results have been obtained thus far. In addition to these experimental studies, reviews of health records of several hundred workers at EMP generator facilities have shown no significant bioeffects. (No references)

0109 COMPUTATION OF PERSONNEL EXPOSURE IN MICROWAVE LEAKAGE FIELDS AND COMPARISON WITH PERSONNEL EXPOSURE STANDARDS. *(E.)* Osepchuk, J. M. (Raytheon Res. Div., Waltham, Mass.), R. A. Foerstner, and D. McConnell. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 4B4/1-4B4/2.

The meaning of personnel exposure to microwave radiation in the context of U.S. and Eastern Euro-

pean exposure standards is reviewed. From data on personnel location *versus* time and the nature of leakage spatial distribution, an upper limit to personnel exposure was computed based on several worst-case assumptions. An application to consumer oven usage is presented. The HEW emission limit insures very high safety factors for the case of localized leakage. In cases where the prime leakage occurs over a substantial area like a door screen or conveyor tunnel, the computed safety factors would be lower because of slower decrease of fields with distance. In conceivable industrial situations the emission standards proposed by IMPI would ensure operator exposure even below that of Eastern Europe. (No references)

0110 THERMOREGULATORY, CARDIOVASCULAR AND METABOLIC RESPONSE OF RATS TO SINGLE OR REPEATED EXPOSURES TO 2450 MHz MICROWAVES. *(E.)* Phillips, R. D. (Batelle Lab., Richland, Wash.), N. W. King, and E. L. Hunt. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B5/1-3B5/4.

Physiological measurements were made on young male rats immediately after single and repeated exposures to 2450 MHz microwaves (pulsed at 120 Hz) in a cavity arrangement that produced absorption of energy at 11.1 mw/g. Acclimation was evident in animals that received 10 exposures over a 2-week period. Incomplete heart block occurred in 67% of rats exposed only once to microwaves, compared with a 22% incidence in repeatedly exposed animals. Abrupt bradycardia developed in single-exposure animals, whereas animals that received repeated exposures had a regular heart rate through the test period. The magnitude of hypothermia was also greater in animals exposed once to microwaves. Oxygen consumption and carbon dioxide production were equally depressed (25%) in both exposed groups. Respiratory quotients were normal in the two groups. Results for a second experiment indicated that the degree of acclimation was dose-dependent. Less acclimation was noted in an additional group of animals exposed at 6.2 mw/g for nine 30-min sessions followed by a 10th session at 11.1 mw/g. (13 references)

0111 MICROWAVE RADIATION HAZARDS CONTROL PROGRAM IN THE U.S. ARMY. *(E.)* Taylor, J. R. (U.S. Army Environ. Hyg. Agency, Edgewood Arsenal, Md.). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 31-32.

The microwave control program in the U.S. Army is directed by the Army Environmental Hygiene Agency, which is an activity of the Army Surgeon General's Office. Every installation where Army personnel, military or civilian, could be exposed to radiated energy from microwave generating equipment would be surveyed to determine if a potential hazard exists. The standards used in the U.S. Army establish the safe exposure limit as any level below 10 mW/cm^2 and the denied exposure limit as 100 mW/cm^2 or greater. Between these two limits there is an allowable exposure period that applies only when mission function precludes shutting down the transmitting system. Performance standards are outlined for microwave ovens, and measurement of microwave leakage and visual inspection must be performed at least once a month. Operators of diathermy units are instructed to maintain certain controls and perform several checks prior to their use. One such control is that the unit can be used only at the direction of a physician. Radar systems receive the closest scrutiny; field measurements using power and power density meters are performed. Where measurements are impractical, calculations are conducted. In all cases controls are implemented to prevent exposure to power densities greater than 10 mW/cm^2. (2 references)

0112 EXAMINATION OF THE CORNEA FOLLOWING EXPOSURE TO MICROWAVE RADIATION. *(E.)* Williams, R. J. (Natl. Naval Med. Ctr., Bethesda, Md.) and E. D. Finch. *Aerosp Med* 45(4):393-396, 1974.

Microwave irradiation of New Zealand rabbits with 2450 MHz continuous wave or 2860 MHz pulsed at an average power field density of 225 mW/cm^2 given daily for 20-30 min for up to 5 weeks had no detectable effect on the normal or the wounded cornea. In control corneas about 1 in 80 basal epithelial cells incorporated tritiated thymidine. Neither the number nor pattern of cells undergoing DNA synthesis in the normal and wounded cornea was altered by radiation. The wound healing process in corneas irradiated daily while healing was similar to that in corneas irradiated for 4 weeks prior to wounding. Because of the relationship of the depth of penetration of energy into the tissue to the frequency of the radiation, higher frequencies might be more efficient in producing thermal damage in the corneal epithelium. At 10,000 MHz, 50 mW of power would be absorbed by the cornea compared with 4 mW at 2450 MHz. Thus, further investigation into the effects of radiation at higher frequencies is warranted. (9 references)

0113 CONTINUOUS EXPOSURE OF CHICKS AND RATS TO ELECTROMAGNETIC FIELDS. *(E.)* Giarola, A. J. (Dept. Electr. Eng., Texas A & M Univ. College Station) and W. F. Krueger. *IEEE Trans Microwave Theory Tech* MTT-22(4):432-437, 1974.

Growth rate and feed consumption depression were observed in groups of 25-day-old male chicks when exposed in metal cage environments to the following continuous wave fields: a UHF wave at 880 MHz in a very low-Q cavity resonator energized by a 220-mW power source; a VHF wave at 260 MHz in a very low-Q cavity resonator energized by a 220-mW power source; an extremely low frequency (ELF) electric field at 45 or 60 Hz with calculated electric field strength of 3500 V/min; an ELF magnetic field at 45 or 60 Hz with 1.3 G. After 23 days exposure to the UHF field at 880 MHz, treated chicks had an average body weight of 217.0 g compared with 245.0 g for controls. Continuous 21-day exposure to a VHF field (260 MHz) reduced growth about 5% compared with comparable controls. Exposure of chicks to the ELF magnetic field depressed growth rate by 9-11% in comparison with nonexposed controls. Adrenal

glands of chicks exposed to the 880-MHz wave were smaller (18.03 mg) than those in control chicks (23.22 mg). Growth depression was also observed in rats exposed to the UHF field at 880 MHz from birth to 43 days of age. Mean adrenal weights of treated and control rats did not differ significantly, but spleen and thymus weights of the treated rats were notably larger. Potential causes of the observed growth depression could be localized RF currents, resulting from animal-to-metal wall contact and transmitted to body tissue. (12 references)

0114 CHICK EMBRYO DEVELOPMENT IN A 26-KHz ELECTROMAGNETIC FIELD. *(E.)* Zervins, A. (Westinghouse Res. Labs., Pittsburgh, Pa.). *Am Ind Hyg Assoc J* 34(3):120-127, 1973.

Sixty-two fertilized chicken eggs (White Leghorn) were exposed for the first 19 days of incubation to a 26-KHz, 160- gauss peak-to-peak a.c. field. Seventy similar unexposed eggs were maintained under the same environmental conditions. Of the exposed eggs, 64.5% hatched, while 48.5% of the unexposed eggs hatched. None of the dead embryos showed evidence of gross abnormalities or teratology and all of the hatched chicks appeared normal within the first 36 hours after hatching. Of 20 exposed and 16 control chicks which were maintained to adulthood, all grew normally and exhibited normal behavior patterns. Among the hatched chicks, a 50-50 sex ratio was observed. The results do not support the hypothesis that embryos exposed to an electromagnetic field have less chance of hatching than non-exposed embryos. (23 references)

0115 AMENDMENTS TO THE US DEPARTMENT OF HEALTH, EDUCATION AND WELFARE MICROWAVE OVEN PERFORMANCE STANDARD. *(E.)* Van De Griek, A. (U.S. Dept. Health Educ. Welfare, Rockville, Md.). and R. G. Britain. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 4B3/1-4B3/2.

The Department of Health, Education, and Welfare microwave oven performance standard is being amended, as a result of 2 yr of field experience and testing, to add explicit power density limits to each required interlock and to require a monitor which will prevent oven operation subsequent to interlock failures. The primary interlock is required to terminate microwave generation before leakage at 5 cm from the oven surface exceeds the prior-to-acquisition limit of 1 mW/cm^2. The secondary interlock is required to terminate microwave generation before leakage exceeds the post-acquisition limit of 5 mW/cm^2. (No references)

0116 EFFECT OF MICROWAVE RADIATION ON THE NASTIC RESPONSE OF SOME SENSITIVE PLANTS. *(E.)* Bigu del Blanco, J. (Queen's Univ., Kingston, Canada), C. Romero-Sierra, and J. A. Tanner. *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) Sept. 1973, p 3B6/1-3B6/2.

The effect of CW microwave radiation on the nastic response of some sensitive plants (e.g., *Mimosa Pudica*) were investigated. Experiments were conducted at X-band microwave frequencies (mainly 9.2 GHz) of low field intensities. During microwave radiation of 20 min or less, gradual but large changes were observed in the orientation of leaflets, leaves, and petioli. Dramatic changes were evident immediately after offset of the ration. The more marked effects included the collapse of some petioli and the sudden reorientation of leaves and leaflets. In all cases complete recovery occurred between 20-30 min after offset of the microwave field. The results clearly emphasize the complex interaction between electromagnetic fields and biological systems. (3 references)

0117 AN OVERVIEW OF THE PROBLEM OF MICROWAVE HAZARD MEASUREMENTS AND DOSIMETRY. *(E.)* Grove, H. M. (Walter Reed Army Inst. Res., Washington, D.C.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 1-2.

The area of measurement and dosimetry is critical to investigations of biological effects and hazards of nonionizing radiation. Consistent dosimetry has not been achieved as evidenced by differences in safety standards in Eastern Europe and the West. The first of at least three levels of the nonionizing dosimetry problem is the hazards survey-type measurement where accuracy is not an overriding consideration. Instrumentation is available but reasonable quantities of the instruments are needed. A more serious problem is instrumentation to support research into the nature of biological effects. The present ± 1/2 db accuracies are inadequate for dynamic ranges of 60 to 120-150 db of variation due to natural causes such as R^2 space loss, fading, multipath, and atmospheric attenuation. In the case of bioeffects, a 25% uncertainty is not acceptable considering the sensitivity of the biological system to count quanta of light or the analogue in audition and olfaction. The third area is the complex problem of personal dosimetry aimed at indication of integrated exposure of individuals in the industrial hygiene setting. In addition to these questions of field and dose, there is the problem of making temperature and electrophysiological measurements under irradiation. (No references)

0118 DESIGN OF A PYROELECTRIC MICROWAVE DOSIMETER. *(E.)* Bassett, H. L. (Eng. Exp. Station, Georgia Inst. Technol., Atlanta) and G. K. Huddleston. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 10-11.

A pyroelectric probe has been developed for power density measurements at 1-10 GHz and for accurate measurements of field intensity close to and far from a radiator, both inside and outside of biological specimens. The probe operates on the principle of direct energy absorption in a lossy substance rather than as an antenna *per se*, with a pyroelectric crystal serving as the detector of absorbed energy. The crystal element is a slab of triglycine sulfate cut such that the broad faces are perpendicular to the spontaneous polarization axis. Conduct-

ing electrodes are placed on the two broad faces to form a small, parallel-plate capacitor. The detector is connected to a preamplifier which serves to transform the rather high impedance of the pyroelectric detector to a low impedance to facilitate further instrumentation. Amplitude-modulated microwave energy incident on the probe is converted to thermal energy *via* ohmic losses in the crystal, which in turn causes the temperature distribution of the crystal to vary periodically at the same frequency as the modulation waveform. A pyroelectric current is produced which is proportional to the rate of change of temperature with time. The corresponding voltage produced between the electrodes is applied to the input of the preamplifier. (No references)

0119 BRAIN TEMPERATURES AND EEG DATA ACQUISITION FROM ANIMALS DURING MICROWAVE EXPOSURE. *(E.)* Larsen, L. E. (Walter Reed Army Inst. Res., Washington, D.C.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 4-5.

Results from bench test studies of conventional temperature and EEG transducers in microwave environments are reported. The temperature sensor was fitted with PtIr lead wires and potted into a tubular glass mount. The glass test chamber containing the mount was filled with physiological saline and placed inside an S-band waveguide. Each time the penetration or configuration of the mount was changed, the E-H tuner was adjusted for zero reflected power with 22 mW/cm^2 transmitted power density. The response consisted of a faster (10^{-1} sec) and a slower (10^{0} sec) apparent heating. The former is artifactual since it is virtually coincident with onset of the fields and represents a faster heating than that which could actually take place at the incident power density. The slow phase is a mixture of slow artifact and real heating of the medium. The rate of increase of apparent temperature depended on penetration; and for a fixed depth of penetration, the rate of increase was markedly reduced by copper pipe shielding. The fast artifact was apparently due to the thin loop formed by lead wires in series with the thermistor; the slow artifact was due to a short dipole with parallel arms. The EEG transducers studied were chronic skull screws. The preparation was 4% agar gel cortained in a polyfoam block, while the microwave environment was a plane wave S band carrier 100% amplitude modulated with a 10 Hz signal. The outputs with continuous wave fields on and off were indistinguishable. When the 10 Hz amplitude modulation was added, a 10 Hz signal at about 6 db voltage over the control was noted. The signal disappeared when electrodes were shortened and was lost in noise when the agar was withdrawn. (No references)

0120 PITFALLS IN MEASUREMENT OF ELECTROMAGNETIC FIELDS. *(E.)* Hollis, J. S. (Scientific-Atlanta, Inc., Georgia). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 3.

A presentation was made of the underlying principles of electromagnetic radiation and diffraction which lead to problems in measurement of electromagnetic fields and particularly near-zone fields. The electromagnetic field parameters and Maxwell's equations were reviewed, the basic wave equation was introduced, and the concepts of traveling and standing waves were discussed. The process of summation of phasors was reviewed and this concept employed to illustrate far- and near-zone diffraction effects using the scalar diffraction integral. Polarization of electromagnetic waves, the concept of orthogonality of fields, and polarization efficiency in transfer of energy from a wave to a measuring probe were discussed from the viewpoint of the Poincare sphere. Simple electromagnetic field probes were shown and problems associated with their use in measurement of near-zone fields were described. (No references)

0121 EFFECT OF RADIOFREQUENCY CURRENTS ON STRICHNINE-INDUCED EPILEPTOGENIC FOCI IN THE CAT. *(It.)* Marchesi, G. F. (Clin. Neurol. Mental Dis., U. Perugia, Italy), C. Cianchetti, A. Casotto and F. Angeleri. *Boll Soc Ital Biol Sper* 48(19):535-539, 1972.

The effect of radiofrequency currents (frequency 4 MHz, power ranging from 0.1 to 10 watts) on experimentally induced epileptogenic foci was studied in 5 adult cats to determine whether these currents caused reversible or irreversible inactivation of the foci. Ten epileptogenic foci were induced in these cats by applying a disk of blotting paper, about 2-3 mm in diameter, which had been soaked in a 1% strichnine solution to a previously established point in the primary motor cortex which controlled the upper extremities. Simultaneous tracings were made of electrocortical activity and the electromyographic response of flexor and extensor muscles in the upper extremities. The radiowave current was applied to the epileptogenic foci by slowly increasing the power until the desired temperature value was reached. Temperatures of 45 C for 30 sec, 55 C for 15 sec, and 60 C for 10 sec were employed. At temperatures above 45 C, lesions produced in adjacent tissue were not reversible because coagulation had occurred. Coagulation was partial around 55 C and complete at 65 C. However, reversible inactivation occured at 45 C. (14 references)

0122 ABSOLUTE PHYSICAL DOSIMETRY FOR WHOLE ANIMAL EXPERIMENTS. *(E.)* Hunt, E. L. (Battelle - Pacific Northwest Lab., Richland, Wash.) and R. D. Phillips. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 74-77.

A whole-animal calorimeter was developed for measuring energy absorbed by fresh rat carcass during exposure to the microwave field in a multipath modal resonating cavity. Five pairs of carcasses in each of three weight groups were exposed to a 2.45 GHz source operated at a repetition rate of 120 pulses/sec. The 190 g carcass absorbed 434 ± 9 mW-min/W-min of cavity energy; the 290 g carcass, 482 ± 8 mW-min/W-min; and the 290 g carcass, 518 ± 8 mW-min/W-min. The average dose density decreased with increased carcass

mass and thickness. The smallest carcasses absorbed 2.29 ± 0.05 mW/g/W-min of available energy; the middle-sized carcasses, 1.67 mW-min/g/W-min; and the largest carcasses, 1.38 ± 0.01 mW-min/g/W-min. Within reasonable limits of animal body size, the system provides a practical laboratory standard for calibrating various exposure arrangements for whole-animal irradiation. (4 references)

0123 POTENTIAL MEDICAL AND BIOLOGICAL APPLICATIONS OF ELECTROMAGNETIC RADIATION. *(E.)* Ecker, H. A. (Eng. Exp. Station, Georgia Inst. Technol., Atlanta). *Digest of Papers US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 91-95.

Preliminary experiments indicate at least three potential medical and biological applications of electromagnetic radiation: selective heating of cancer tumors to enhance chemotherapy, thawing of frozen organs with electromagnetic radiation and microwaves for insect control. Differential hypothermia with selective electromagnetic heating and chemotherapy (5 fluorourcil) produced significant regression of spontaneous and chemically induced tumors in mice and rats. Brain tumors were treated with high frequency electromagnetic radiation (3-30 MHz) in combination with doping the tumor with high loss magnetic or ferrite material. This technique may be useful for treatment of cancer in most body tissues, without surgery. Rapid and uniform thawing of frozen canine kidneys was obtained using a combination of 2450 and 7 MHz radiation. Energy from the 7 MHz radiation produced heating from the center toward the surface of the kidney, while the energy from the 2450 MHz radiation produced heating from the surface to the center of the kidney. In insect control experiments, powder post bettle larvae and pupae were irradiated at 2450 MHz with a power density of 4.6 w/cm^2. Under these conditions, 100% mortality was attained for all radiation times greater than 5 min; 77% mortality was achieved with a 2-min radiation. Irradiation of cotton boll weevil larvae at 9100 MHz and 6 w/cm^2 power density produced 100% mortality for radiation times of 3 sec or greater and 53% mortality for 1 sec of radiation. (4 references)

0124 INFRARED THERMOGRAPHY IN MICROWAVE/BIOLOGICAL RESEARCH. *(E.)* Guy, A. W. (U. Washington, Sch. Med., Seattle). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 85-90.

Cross-sectional relative heating patterns in phantom models of tissue exposed to electromagnetic radiation were recorded with a thermograph camera. The temperature information was converted to normalized power absorption patterns and compared with theory. Thermograms and calculated absorption patterns are presented for phantom human limbs exposed to 915 MHz radiation, phantom cat or monkey brain exposed to 2450 MHz, and a phantom rat exposed to 500 MHz. Measured absorption patterns appearing in the center of phantom brain tissue compare favorably with that calculated from theory, verifying the existence of hot spots in the central nervous system exposed to electromagnetic radiation. The results also clearly indicate that thermal effects can be produced in rats exposed to low level radiation even though other parameters such as incident power level, average absorbed power density, and core temperature of the animal would indicate otherwise. Thermograms were also obtained for an actual cat brain exposed to 918 MHz radiation. In the absence of a metal coaxial type physiological recording electrode in the animal's head, peak absorption corresponded to 2.27 mW/cm^2/watt input power to the source of 2.5 mW/cm^2 of incident power density. Peak absorption measured with the electrode in place was 113 mW/cm^2, indicating the possibility of inducing thermal effects in the central nervous system by improper experimental protocol when using power density levels believed thermally insignificant. (1 reference)

0125 THE USE OF RF MAGNETIC PROBES FOR THE MEASUREMENT OF PENETRATION OF MICROWAVE ENERGY IN BIOLOGICAL SPECIMENS. *(E.)* Knott, E. F. (U. Michigan, Ann Arbor) and R. E. Hiatt. *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 82-84.

Enclosed system measurements of synthetic brain and synthetic bone at 1.0-5.5 GHz were carried out with six small radio frequency magnetic loop probes made from semi-rigid copper coaxial line. The probes were calibrated by supplying known values of field frequency and magnetic flux density threading the loop, then measuring effective voltage, thus determining coefficient C, i.e., probe area. Values of coefficient C show that, for certain fixed frequencies, all six probes behaved similarly. One probe had a fairly consistent response over all four frequencies tested and some came close to the theoretical C value of 23.8 mm^2. However, there is enough variation to warrant checking and calibrating the given probe before laboratory use. (No references)

0126 BIODOSIMETRY--THE SCALING OF MICROWAVE ENERGY BY BEHAVIORAL AND BIOLOGICAL RESPONSES. *(E.)* Justesen, D. R. (VA Hosp., Kansas City, Mo.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 78-81.

The efficiency with which individual rats discriminated complex modulated, 2450 MHz energy, as assayed by the technique of conditional suppression, was often highly correlated with microwave power as dosed in terms of mW/g of body weight (0.6-6.4 mW/g; "on-time" duty cycle = 6.7%). Rat behavioral response was reliably more sensitive than whole-body (colonic) thermal response to microwave irradiation. Even at a much higher level of energy dosing (~11 mW/g; duty cycle 50%) than the doses which efficiently cued a perceptual response, the mean of the peak hyperthermia of unrestrained rats was barely greater in irradiated than in sham-irradiated rats. The thermal data also indicate that psycho-physiological stressing led initially to an elevation of colonic temperature; further, restraint and irradiation in combination were apparently synergetic with respect

to the hyperthermal response. It is suggested that data from classical studies of the lethal dose of irradiation are tainted by the compounding of stressors, including the stress of irradiation *per se*. (7 references)

0127 GHOSTS AND WITCHCRAFT IN RF MEASUREMENTS OR POWER ABSORPTION MEASUREMENTS IN FIELDS. *(E.)* Frazer, J. W. (USAF Sch. Aerospace Med., Brooks Air Force Base, Texas), J. C. Mitchell, A. E. Gass and W. D. Hurt. *Digest of Papers Joint US Army/ Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 56-73.

Experiments to determine power absorption by primates (Macacca Mulatta) suggested that the uncertainty of dosimetry in high frequency fields can be decreased by avoidance of close separation capacitors and more proper calculation of scattering in the wavelength region being used. Under conditions of wider separation of conductor and ground plain, power deposition in primates exposed to an electric field of 5880 V/meter and power density of 1.56 W/cm^2 was a function of frequency. Variation in precise power absorption was 3-9% of incident power density. A year after exposure to high intensity radio frequency fields, none of the primates used for thermal studies in high fields has shown evidence of lens opacities. Although a thermal effect was found in primates, rectal temperatures changed little, if at all, in rats exposed to an electric field of 5880 V/meter. Two systems of growth and maturation (mice neonates and Tenebria metamorphosis) revealed no demonstrable effects of 5880 and 10,000 V/meter fields, resp. In other experiments, pyridine nucleotides in eight brain areas were measured in rats exposed to 7000 V/meter continuous wave radiation at 24 MHz. Rapid microwave inactivation of enzymes was an appropriate analytical tool, but statistical variability was greater than any apparent differences between exposed and control rats. The consequence of power deposition from high frequency fields remains unknown, as does the nature of the charge carriers instrumental in absorbing the power. (8 references)

0128 THE DESIGN OF BROADBAND, RESISTIVE RADIATION PROBES. *(E.)* Hopfer, S. (General Microwave Corp., Farmingdale, N.Y.). *Digest of Papers Joint US Army/Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 32-52.

A broadband microwave radiation probe is based on a finite resistive screen in free space. A resistive grid is formed by two noncontacting meandering lines deposited on two separate substrates. The lines are interconnected by through-holes in the substrates and form one continuous path which does not intersect itself. The resistive line is made up of alternating segments of bismuth and nichrome; these segments overlap slightly to form the thermoelectric junctions. By forming one continuous path, all thermocouples are connected in series to produce an output which is the sum of all the emf's generated by the individual couples. The resistive grid is sandwiched between two boron nitride discs and contact between the discs and substrates is made only at the apparent intersection points. The discs are held together by a section of heat-shrinkable tubing and the overall assembly is encased in foam for further isolation from ambient changes and infrared radiation. The response of the probe at 1-18 GHz is plotted, as is response to an ambient temperature of 40 F. Full-scale ranges of the battery-operated probe extend from 0.2-200 mW/cm^2, with an overload capability in excess of 1 W/cm^2. Due to probe stability, meaningful measurements can be made at 10 μW/cm^2. (6 references)

0129 DETERMINATION OF BIOLOGICAL TISSUE DIELECTRIC CONSTANT AND RESISTIVITY FROM IN VIVO IMPEDANCE MEASUREMENTS. *(E.)* Magin, R. L. (Eng. Exp. Station, Georgia Inst. Technol. Atlanta) and C. P. Burns. *Digest of Papers Joint US Army/ Georgia Inst Technol Microwave Dosimetry Workshop* 1-2 June, 1972, p 12-31.

A new relatively simple technique permits the *in vivo* measurement of the physical parameters which determine absorption of electromagnetic radiation by biological tissues. The complex radio frequency impedance of tissue at 1-100 MHz is measured by a small probe which acts like a short antenna operating in a lossy medium. Utilization of an antenna impedance theorem allows the relative dielectric constant and resistivity of the tissue to be calculated. Measurements of *in vivo* brain and chemically induced tumor tissue were performed on laboratory rats. A table of power absorption, penetration depth, dielectric constant, and resistivity of brain and tumor tissue at 1-100 MHz is presented. The data show no resonance phenomena in this frequency which would enhance the selective heating of specific body tissues with respect to surrounding tissues. The calculation of penetration depths in the brain and tumor tissue shows relatively large values (approximately 10 cm) even at 100 MHz. Therefore, uniform heating can be expected at lower frequencies or for tissue sizes less than 10 cm. The electromagnetic power absorbed/unit volume in tumors is approximately twice that of brain tissue at 1-100 MHz. This result would enhance the selective heating of brain tumors by electromagnetic radiation at these frequencies. (8 references)

0130 EFFECT OF EPHEDRINE AND NIKETHAMIDE ON THE OUTCOME OF MICROWAVE-INDUCED DAMAGE IN MICE. *(Rus.)* Koldaev, V. M. (Vladivostok Med. Inst., USSR). *Biull Eksp Biol Med* 77(3):79-81, 1974.

Ephedrine (0.25-10 mg/kg i.v.), nikethamide (10-500 mg/kg i.v.), or a mixture of these 2 drugs (2 mg/kg ephedrine and 80 mg/kg nikethamide) was given to noninbred male albino mice which had been exposed to acute and chronic doses of microwaves. Mice were observed for 3 weeks after dorsal irradiation by the contact method using a power density of 62 ± 5 milliwatts/cm^2 and a wavelength of 12 cm for 10-12 min. One group of mice were exposed for 10-12 min until they had reached a terminal state while the other was exposed for 5-6 min/day for 20 days. While

administration of ephedrine alone had no effect on the survival rate of mice exposed to a single large dose of microwaves, nikethamid increased the survival rate almost 1.5-fold. No synergistic effect was observed when the 2 drugs were given in combination. Mortality decreased and the total survival rate increased 1.6-fold when mice exposed to chronic doses of microwave radiation were given nikethamid. The survival time was longer in chronically exposed mice given ephedrine than in untreated controls, but ephedrine had no effect on survival rate. These findings indicate that respiratory stimulation with nikethamid increases the survival rate and has a favorable effect on regenerative processes occurring in mice after microwave-induced damage. (7 references)

0131 HARMFUL EFFECTS OF RADIATION FROM MICROWAVE OVENS. *(Dan.)* Ennow, K. (Radiation Hygiene Lab., Ministry Health, Copenhagen, Denmark). *Fra Sundhedsstyr* 22:277-279, 1971.

Problems relating to the establishment of safety standards for microwave ovens in Denmark are reviewed. Absorption of microwaves by tissue accelerates molecular motion, thus producing heat; the thermal effects of microwaves are most important biologically, although non-thermal effects also occur at high field strengths. Reports of nervous and cardiac disorders in Soviet radar operators, exposed to radiation at 0.01-1 mW/cm^2, remain controversial. Cataract development has been reported in persons exposed to microwave radiation from various sources, but no threshold values for this phenomenon have been established. A possible relationship has been demonstrated between radar exposure of fathers and the number of children with Down's syndrome. Serious consequences of microwave exposure included one case of vasculitis and one death due to intestinal damage three days after intensive microwave exposure. Measurements on commercial and home microwave ovens in the United States revealed that about one third had excessive radiation leakage. High radiation levels can occur following failure of the contacts designed to interrupt radiation production when the oven door opens. Three countries have proposed standards for microwave exposure, but these standards differ by a factor of 4000. (13 references)

0132 MECHANISM OF THE MICROWAVE EFFECT ON ERYTHROCYTE PERMEABILITY TO K^+ AND Na^+ IONS. *(Rus.)* Ismailov, E. Sh. (Dept. Human Animal Physiol., Dagestan State U., USSR). *Nauchnyi Dokl Vyshei Shkoly Biol Nauki* (3):58-60, 1971.

Human erythrocytes were exposed to microwaves (frequency 1009.076 MHz, power density 45 milliwatts/cm^2) for 30 min in a thermostat so that the temperature did not exceed 37 C, and concentrations of K^+ and Na^+ in the solution surrounding the erythrocytes were measured by flame photometry. When erythrocytes were exposed to microwaves, the concentration of Na^+ increased and that of K^+ decreased in the cells. This effect was even more pronounced when erythrocyte solutions were incubated for 30 min after exposure to microwaves. Since about half of this movement was inhibited when monoiodoacetate, an inhibitor of active ion transport, was added to the solution surrounding the cells, it is concluded that microwaves act both by increasing passive diffusion and active transport. This, in turn, may be caused by increases in the size of existing pores, the formation of new pores, or by changes produced in the ion radius by the hydrated membrane without any change occurring in the pore area in the erythrocyte membrane. (5 references)

0133 CHROMOSOMAL ABERRATIONS OF LIVING CELLS INDUCED BY MICROWAVE RADIATION. *(E.)* Chen, K. M. (Dept. Electr. Eng. Systems Sci., Michigan State U., East Lansing), A. Samuel and R. Hoopingarner. *Environ Lett* 6(1):37-46, 1974.

Chinese hamster cells and human amnion cells were examined for the chromosomal effects of exposure to microwave radiation of 2.45 GHz at various intensities over various periods of time. Microwave-induced chromosomal aberrations in Chinese hamster cells with an initial temperature of 22 C included chromatid breaks, chromatid gaps, polyploidy, acentric fragments, deletions, and translocations. These aberrations were apparently nonthermal in nature since cell temperature was kept under 41 C. Cells preheated to 37 C required much lower radiation exposure (20-50 mW/cm^2) to attain the degree of chromosomal aberrations observed in cells with lower initial temperature and exposed to higher radiation (50-80 mW/cm^2). While some chromosomal aberrations and fragmentation were present two generations (48 hr) after exposure, chromosomal aberrations were significantly reduced after four generations (96 hr). This suggests that chromosomal damage due to microwave radiation can be repaired after a few generations. Some chromosomal aberrations were observed but no fragmentation was found in human amnion cells exposed to 2.45 MHz at an initial cell temperature of 22 C and final temperature of 37 C. These results indicate that an S-band microwave of moderate intensity has an effect on chromosomes of living cells. (11 references)

0134 II. ISOTROPIC ELECTRIC-FIELD PROBES FOR COMPLICATED FIELDS. *(E.)* Bowman, R. R. (Natl. Bur. Standards, Boulder, Colo.). *Proc Microwave Power Symp* (Inst. Microwave Power, Canada) May 1972, p 29-30.

An electromagnetic hazard meter with an isotropic probe accurately measures the strength or intensity of complicated fields. The probe would be useful in measuring the fields within microwave ovens or within subjects or models exposed to high-power sources. In essence, the probe consists of three mutually orthogonal dipole antennas with a common center, a means for separately detecting the three RF signals induced across the dipole gaps, and a means for transmitting the three separate detected signals or a combined signal away from the dipole set without substantially perturbing the field to be measured or substantially affecting the operation of the dipole antennas. (No references)

0135 THE EFFECT OF MICROWAVE RADIATION ON THE EYE. *(E.)* Aurell, E. (no affiliation). *Acta Opthalmol (Kbh)* 51(5):742, 1973.

Of 54 workers occupationally exposed to microwaves, five were found to have central or paracentral changes in the eyeground. Two men were aware of paracentral scotomas and one had reduced visual acuity (VA = 0.7). The average age of the five men was below 30 yr. Investigations to test the hypothesis that these retinal changes are due to microwave radiation are in progress. (No references)

0136 COMPATIBILITY OF MEDICAL ELECTRONIC INSTRUMENTATION WITH THE ELECTROMAGNETIC INTERFERENCE ENVIRONMENT IN HOSPITALS. *(E.)* Kall, A. R. (Ark Electronics Corp., Willow Grove, Pa.). *Proc IEEE 1973 Electromagnetic Compatibility Symp*, June 1974, p 41.

The increasingly severe electromagnetic interference environment found in hospitals, together with electrical power line fluctuations, pose a dual problem for medical electronic instruments: assuring satisfactory operation of sensitive instrumentation within this hostile environment and assuring that newly introduced instruments do not create additional interference. Several typical case histories are presented. Techniques for measuring emitted interference and susceptibility are reviewed together with existing standards considered for application to the hospital environment and instrumentation. The essentials of a proposed standard specifically designed for this purpose are outlined. The correlative topic of electrical and radiation hazards is discussed briefly in relation to the general hospital electromagnetic environment. (No references)

0137 MATHEMATICS OF INTERACTION BETWEEN BLOOD AND ELECTROMAGNETIC FIELDS. *(E.)* Rashid, A. (Boeing Co., Kent, Wash.). *Proc IEEE 1973 Electromagnetic Compatibility Symp* June 1973, p 60-64.

The interaction between blood and electromagnetic energy is considered as a basic mechanism responsible for unexplained effects to the human system. Basic magnetohydrodynamic equations are derived which relate electric and magnetic field intensities to the velocity, density, pressure, and temperature of blood. Equations are also presented relating changes in these parameters to exposure to electromagnetic fields. No attempt has been made to solve the equations. (12 references)

0138 A METHOD OF MEASURING RF ABSORPTION OF WHOLE ANIMALS AND BODIES OF PROLATE SPHEROIDAL SHAPES. *(E.)* Gandhi, O. P. (Dept. Electr. Eng., U. Utah, Salt Lake City). *Proc Microwave Power Symp*, May 29-31, 1974 p B2-2/1-B2-2/4.

Radio frequency absorption of brain-phantom prolate spheroidal bodies of different aspect ratios was measured to 4000 MHz using a parallel plate waveguide. Results for mice and rats agree with the observed resonances of the prolate spheroids of aspect ratios similar to these animals. Absorption observed at resonance for vertical orientation was an order of magnitude greater than for horizontal and longitudinal configurations. For prolate spheroids of aspect ratio 5.75, the temperature increase found for exposure to microwaves in the vertical direction is ten times higher than for the horizontal configuration. Important frequencies for maximum absorption for humans are derived by extrapolation as 40-55 MHz for vertical and 135-165 MHz for the other two configurations. (3 references)

0139 THERAPEUTIC APPLICATIONS OF ELECTROMAGNETIC POWER. *(E.)* Guy, A. W. (U. Washington Sch. Med., Seattle), J. F. Lehmann, and J. B. Stonebridge. *Proc IEEE* 62(1):55-75, 1974.

The use of electronmagnetic (EM) power for therapeutic applications has existed since EM sources became available to man. Physical medicine has been a major user of both shortwave (27.33 MHz) and microwave (2450 MHz) diathermy over the decades in which EM power has been used to heat deep tissues to stimulate physiologic responses beneficial in the relief of certain pathological conditions. Experimental and clinical research indicates that these responses are obtained when tissue temperatures are raised 41-45 C, which requires absorbed power densities from 50-170 W/kg in the deep tissues. The combination of pain responses and a large reserve of blood cooling capacity seems sufficient for limiting the heating to safe but therapeutic levels in vasculated and innervated tissue. Recent research has shown that the industrial, scientific, and medical frequency of 915 MHz is more efficient that the currently used 2450-MHz frequency in terms of maximum power transfer to deep tissues. In addition to thermal applications, microwave energy can be used for controlled transcutaneous stimulation of nerve action potentials via implanted miniature microwave diodes. Stimulation is attained with absorbed power density levels as small as 0.0003 W/kg. (73 references)

0140 MODIFICATIONS OF IN VIVO RAPID MICROWAVE INACTIVATION OF ENZYMES IN THE CENTRAL NERVOUS SYSTEM. *(E.)* Lenox, R. H. (Walter Reed Army Inst. Res., Washington, D.C.), O. P. Gandhi, J. L. Meyerhoff, and P. V. K. Brown. *Proc Microwave Power Symp*, May 29-31, 1974, p A3-1/2-A3-1/5.

Advanced modifications over previously reported microwave methods for rapid inactivation of the brain are reported. The modified technique offers not only a more rapid inactivation of enzyme systems but also a significant improvement in the homogeneity of the microwave fixation process suitable for highly complex dissection. The system used is a WR430 waveguide driven by a Varian PPS 2.5 generator and terminating in a short-circuiting end-plate with a 3.8 cm diameter hole. To concentrate microwave power into the rat head and to obtain uniformity of field distribution over the longitudinal extent of the rat brain, the shorter dimension of the waveguide was gradually reduced to 3.8 cm by use of tapered aluminum plates. Uniformity of fields along the x-axis is obtained because of the dielectric loading

due to the rat head and the concentration of fields therein. Consistently uniform inactivation of the brain of 325-g rats was observed at 2.8 sec. The high degree of uniform inactivation throughout the brain has enabled measurement of cyclic 3'5'-adenosine monophosphate and cyclic guanosine monophosphate in 13 brain regions. (10 references)

0141 BIOLOGICAL EFFECTS OF MICROWAVES AND OTHER DIFFERENT FREQUENCIES. *(E.)* Richardson, A. W. (St. Louis U., Mo.). *Final Report* Contract NR-102-362, Proj. Nonr-1304 (02), Nov. 1967, 12 p. NTIS:AD 729379.

The results of an 11-yr research program on the biological effects of microwaves are summarized. Microwaves, whether continuous wave or pulsed (radar), are lethal with high energy and hazardous with low energy. Pulsed microwaves with a field density of 70 mW/cm^2 were lethal to albino rats with 30-min exposures. A field density of 25 mW/cm^2 over the head for 18 min produced extensive brain damage that was not overtly apparent. Rats exposed to excessive microwaves always maintained a compensation of physiologic condition up to 60-70% of the lethal time. After 75% of the lethal time, the rats went into fatal respiratory and cardiac distress. Brain temperature was very dependable for the prediction of the lethal point in time. Postmortem rat autopsies showed distinct damage to the colon at sites of low vascularization, and at sites where serous fluid was found outside the colon. In longevity studies using multiple exposures at 35-46 mW/cm^2, the lifespan of exposed rats was 48% of controls. At 82 mW/cm^2, the lifespan was only 20% of the control rats. It is thus important that longevity studies be made on radar workers and on persons in the vicinity of radar. No human personnel should be exposed to more than .01 W/cm^2 over short periods or over .0035 W/cm^2 over long periods of time. These dosages are permissible but not safe. The performance of a miniature radar dosimeter, an electromagnetic flow meter, a transistorized cardiac output meter, and other inventions is evaluated. (28 references)

0142 BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. *(E.)* McRee, D. I. (Natl. Inst. Environ. Hlth. Sci., Res. Triangle Park, N.C.). *J Air Pollution Control Assoc* 24(2):122-127, 1974.

The biological effects of microwave radiation are usually designated as thermal or nonthermal (specific). Thermal effects are those interactions caused by heating of the biological specimen. Nonthermal effects are due to the direct interaction of the electromagnetic field of the incoming microwave radiation and the biological specimen. The testicles and eyes are particularly sensitive to the thermal effects of microwaves at 150-10,000 MHz. In dogs, rabbits, and rats, a power density of 10 MW/cm^2 is the threshold for testicular damage for indefinite exposure. The pathological damage to the testes in these animals includes degeneration of the epithelium lining of the seminferous tubules and a sharp reduction in the number of maturing spermatocytes. The reduction in testicular function appears to be temporary and reversible. In rabbits the threshold for cataract formation is approximately 100 mW/cm^2 for continuous wave radiation. Eye cataracts in man due to microwave exposure have been reported at the same power density. Threshold levels for pulsed radiation have not been adequately established. Nonthermal effects, caused by low-level microwave radation, are most often neurological. Effects on animals include changes in EEG patterns, changes in conditioned reflexes, alterations in biocurrents of the cerebral cortex, and changes in behavior. Many subjective symptoms in exposed workers have been reported by investigators in the USSR and Eastern Europe. Genetic effects produced by microwave fields include abnormal development of chick embryos and "mealworm" beetle pupae. These effects were apparently caused by inhibition of growth and cell differentiation. In man a higher incidence of Down's syndrome has been reported in children whose fathers had prior occupational exposure to radar. Determination of the safe level of microwave exposure for the general population will require adequate measurements of the exposure and dosimetric parameters. Mechanisms of interaction of microwave radiation and the biological system must also be determined. (30 references)

0143 ANECHOIC CHAMBER DESIGN FOR PRECISION HIGH POWER MEASUREMENTS. *(E.)* Brownell, F. P. (Emerson Electr. Co., Calabasa, Calif.) and D. McCutchan. *Proc Microwave Power Symp*, May 29-31, 1974, p A1/51-A1/56.

Anechoic chambers are used to create low reflection laboratory environments approximating free space. For precision measurements involving high power microwave testing, control of reflections in the test region (or the quiet zone) is required. A straightforward design procedure has been developed during production and testing of over 300 rectangular and tapered chambers in the United States. Performance of completed chambers is evaluated by probing the quiet zone using the "Free-Space VSWR" technique. (No references)

0144 CHANGES IN THE PERIPHERAL BLOOD OF THE RAT EXPOSED TO MICROWAVE RADIATION (2400 MHz) IN CONDITIONS OF CHRONIC EXPOSURE. *(E.)* Djordjevic, Z. (Inst. Aviat. Med., Beograd, Yugoslavia) and A. Kola. *Aerosp Med* 44(9):1051-1054, 1973.

Changes in peripheral blood and some biological parameters were investigated in male Wistar rats chronically exposed (2 hr/day for 10-30 days) to microwave frequency of 2400 MHz and to power density of 10 mW/cm^2. Rectal temperature increased about 1 C during the first 30 min of exposure, then remained stable for the remainder of the 2-hr exposure. In contrast, a high increase (about 6 C) was recorded in animals exposed to 50 mW/cm^2 for up to 20 min. Hematocrit and hemoglobin values tended to increase during the first phase of irradiation at 10 mW/cm^2 with a subsequent return to normal values. Eosinophyls decreased during the first 20 days of exposure, then increased during the later phase of irradiation. Erythrocytes increased steadily during all phases of exposure. Opthalmologic investigations showed no significant changes in

eye transparent coats and eye fundus in animals exposed to 10 mW/cm^2 for up to 30 days. Results of a survival test at a simulated altitude of 11500 m, conducted after microwave irradiation, showed no significant differences in survival times between chronically exposed animals and controls. Survival of rats exposed to 50 mW/cm^2 for 20 min was significantly shorter. These findings suggest an adaptive reaction to microwave radiation at 10 mW/cm^2 and demonstrate that this power density does not cause cataracts in rats or affect resistance to hypoxic stress. (14 references)

0145 MUSCLE HEATING PRODUCED IN HOG SPECIMENS BY MICROWAVES AT 915 AND 433.92 MHz. *(E.)* Lehmann, J. F. (Dept. Rehabil. Med., U. Washington, Seattle), J. Stonebridge, G. Warren and B. J. DeLateur. *Arch Phys Med Rehabil* 55(5):213-217, 1974.

A round field microwave applicator operating at 433.92 MHz and a direct contact applicator, with a cooling plate, operating at 915 MHz were compared with respect to their effectiveness in heating hog musculature. The heating on skin surface and in superficial tissue was less with the direct contact applicator due to the cooling plate. The average maximum temperature change produced with the 9.5 MHz applicator was 10.7 C at an average depth of 0.80 cm in muscle and at 433.92 MHz it was 11.4 C at a depth of 0.70 cm. While the round field applicator had the better depth of penetration (3.9 cm *vs* 2.9 cm), there was no practical difference in effective muscle heating with the two applicators. The effective depth of muscle heating was 2.9 cm with the 915 MHz applicator and 2.8 cm at 433.92 MHz. It is noted that 915 MHz is an approved frequency in diathermy units in the United States whereas 433.92 MHz is not. (9 references)

0146 EXPOSURE OF Gallus domesticus TO VARIOUS ELECTROMAGNETIC FIELDS. *(E.)* Giarola, A. J. (Dept. Electr. Eng., Texas A&M U., College Station), W. F. Kreuger, R. C. Fanguy, and A. Shrekenhamer. *Proc Microwave Power Symp*, May 29-31, 1974, p B2-3/1-B2-3/7.

Egg production of *Gallus domesticus* hens was reduced 3.0-33.7% from continuous exposure to continuous wave low-level electromagnetic fields at 2.435 GHz and 915 Mhz, and to electric magnetic fields at 60 Hz. Fertility and hatchability of exposed birds were not significantly reduced when compared with controls. No macroscopic abnormalities attributable to treatments were noted in hatched chicks or in dead embryos. Hens exposed to fields at 2.43 GHz may produce eggs with poorer shell quality, as measured by specific gravity of the egg. (1 reference)

0147 OVICIDAL EFFECTS OF ELECTROMAGNETIC ENERGY AT 2.45 GHZ ON EGGS Diabrotica undecimpunctata howardi Barber. *(E.)* Fanslow, G. E. (Dept. Electr. Eng., Iowa State U., Ames), J. J. Tollefson, and J. C. Owens. *Proc Microwave Power Symp*, May 29-31, 1974, p B2-1/1-B2-1/4.

Eggs of southern corn rootworm, *(Diabrotica undecimpunctata howardi Barber)* were exposed to electromagnetic energy at 2.45 GHz in slotted waveguide applicators to determine ovicidal threshold levels. Ovicidal levels at transmitted power levels of 250-2000 W and exposure time up to 8 sec are presented. Infrared measurements of temperature changes (e.g., 60 C at 1 kW, 0.8 sec pulse) and estimates of the heating produced at the microwave levels used, suggest that the ovicidal mechanism is primarily thermal. (No references)

0148 POSSIBLE MECHANISMS FOR THE BIOMOLECULAR ABSORPTION OF MICROWAVE RADIATION WITH FUNCTIONAL IMPLICATIONS. *(E.)* Rabinowitz, J. (New York U. Med. Ctr., N.Y.). *IEEE Trans Microwave Theory Techn* MT21(12):850-851, 1973.

A theoretical analysis of several possible modes of molecular absorption of microwave radiation suggests that interference with some stereospecific biomolecular process may result from excitation of constrained motional states of molecular segments. Absorption of a microwave photon by the molecular segment would increase its rotational energy, leading to changes in noncovalent chemical structure but leaving the covalent molecular structure unchanged. In the interior of large molecules, the infrequency of collisions will increase the probability of multiple excitations and resultant structural changes. (5 references)

0149 EFFECTS OF NON-IONIZING RADIATIONS ON THE TRANSFORMING ABILITY OF E. coli DNA. *(E.)* Ranade, S. S. (Dept. Chem. Technol., U. Bombay, India), N. G. Avadhani and D. V. Rege. *Photochem Photobiol* 19(2):103-108, 1974.

A transformation system in *Escherichia coli* was used to verify the extent of the lesions caused by ultraviolet (UV) and ionizing radiations. DNA inactivated at 280 nm UV could be reactivated to some extent by exposing the transforming DNA solutions at 240 nm. Reactivation at 240 nm was dose-dependent and reached saturation at about 370 J/m^2. The possibility of 240 nm reactivation was demonstrated using more than one *E. coli* strain as donor, and as recipient. Transforming DNA inactivated by ionizing radiations (^{90}Sr beta rays and ^{60}Co gamma rays) was not reactivable. Low doses of beta rays (240 rad), however, reactivated the DNA inactivated by 280 nm UV to a slight but significant extent. The extent of reactivation by beta rays depended on the degree of initial 280 nm UV damage; in this respect, beta reactivation resembled 240 nm UV reactivation. It is suggested that UV and beta rays reactivate 280 nm UV damage by a parallel mechanism, i.e. de-dimerization of pyridine photoproducts though at different efficiencies. (25 references)

0150 RESONANCE ABSORPTION OF MICROWAVES BY THE HUMAN SKULL. *(E.)* Joines, W. T. (Dept. Electr. Eng., Duke U., Durham, N.C.) and R. J.

Spiegel. *IEEE Trans Bio-Med Eng* BME-21(1):46-48, 1974.

A computer program was developed to calculate relative microwave absorption and distribution of electric field intensity in homogeneous and inhomogenous (multilayered) models of the human skull. To cover a range of skull sizes, calculations were made for spheres of 7 and 10 cm radius. At frequencies in the 0.1-3 GHz range, the results for the multilayered model show pronounced resonance absorption effects that are not present in the homogeneous model. Of particular interest is a broad relative absorption peak near 2.1 GHz. Since the multilayered sphere corresponds to skin, fat, bone, dura, cerebrospinal fluid, and brain and thus represents a closer approach to reality, the leakage from microwave ovens operating at 2.45 GHz may be a greater hazard to human health than is now recognized. (9 references)

0151 THE EFFECT OF DISPERSION ON THE THERMAL CONDUCTIVITY OF DIELECTRICS CONTAINING RESONANT SCATTERING CENTRES. *(E.)* de Goer, A. M. (Ctr. Nuclear Studies, Grenoble, France) and L. J. Challis. *Solid State Commun* 13(7):745-748, 1973.

The effects of dispersion on the thermal conductivity of a dielectric containing randomly placed resonant scattering are considered. It is shown that dispersive effects are negligible for small concentrations of strongly coupled ions such as Cr^{2+} ions in MgO but can be important for concentrated (> 1%) systems of weakly coupled ions. (10 references)

0152 EMPIRICAL STUDIES OF CARDIAC PACEMAKER INTERFERENCE. *(E.)* Mitchell, J. C. (USAF Sch. Aerospace Med., Brooks Air Force Base, Texas), W. D. Hurt, W. H. Walters III, and J. K. Miller. *Aerosp Med* 45(2):189-195, 1974.

The relative susceptibility of cardiac pacemakers to electromagnetic radiation interference was tested at several representative radar sites in the U.S. The 21 pacemakers, of different types and manufacturer, were evaluated in a free-field configuration as well as in a saline solution phantom (implantation stimulation). Test results are presented for five frequency bands between 260 and 6000 MHz. Many pacemakers skipped one or two beats when the main beam of the radars scanned past the point of closest approach. This effect, observed regularly for some pacemakers at distances of a mile or more from the radars, might result in a pacemaker patient losing a normal heartbeat every 10-12 sec (about 5-6 beats/min). Although this interference is not considered a threat to life, the effect could be serious at closer distances-depending on the particular pacemaker in use, the state of the patient's health, and the activity in which he is involved. (8 references)

0153 OVERVIEW OF DEPARTMENT OF DEFENSE ELECTROMAGNETIC RADIATION HAZARDS STANDARDIZATION PROGRAM. *(E.)* Caine, S. (Naval Electronic Systems Command, Washington, D. C.). *IEEE Int Electromagnetic Compatibility Symp , N.Y.* June 20-22, p 127-131, 1973.

High-intensity electromagnetic radiation can cause premature activation of sensitive electro-explosive devices contained in ordnance and weapons systems, ignite flammable fuel-air mixtures, cause possible biological injury to personnel, and trigger or damage solid state electronic circuitry. In 1972, the scope of the Department of Defense Electromagnetic Compatility Standardization Program was expanded to develop criteria and documentation to preclude electromagnetic radiation hazards to weapon systems, ordnance, and military personnel. Another electromagnetic radiation hazards problem is primarily civilian and concerns electric blasting caps. These devices may be exposed to many commerical sources of electromagnetic energy, including mobile and fixed radio communications and TV transmitters, radar and navigation transmitters, geophysical survey equipment, and industrial heaters. A safety guide (ANSI C95.4-1971) approved by the American National Standards C95 Committee on Radio Frequency Radiation Hazards contains recommended distances between blasting caps and civilian transmitters. A draft of a blasting cap standard will be submitted to the committee in 6-9 months. (2 references)

0154 PRESERVATION STUDIES ON CANINE KIDNEYS RECOVERED FROM THE DEEP FROZEN STATE BY MICROWAVE THAWING. *(E.)* Rajotte, R. V. (MRC Transplantation Group, U. Alberta, Edmonton, Canada), J. B. Dossetor, W. A. Geoffrey Voss and C. R. Stiller. *Proc IEEE* 62(1):76-85, 1974.

Uniform heating of frozen canine kidneys (-79 to 23 $\pm$ 10 C) was achieved using a microwave heating system at 2450 MHz. The kidneys contained the cryoprotective agent dimethyl sulfoxide; uniform cooling was obtained a 1 C/min, with fluorocarbon perfusion down to -40 C. Slow environmental cooling was used from -40 to -79 C, the temperature at which the organs were stored for up to five days. After microwave thawing at 2 to 4 C/sec, temperature differences were $\leq$10 C, provided the initial kidney perfusion was complete and uniform. For comparison these microwave heating rates were also applied to organs immediately after perfusion cooling to +4 C. Microfil injection and histological studies of thawed and reimplanted kidneys have shown some preserved capillary blood vessels, but frozen-thawed kidneys have not functioned. Viability tests-oxygen and *p*-amino-hippurate uptake-were performed on kidney slices recovered from -79 or -196 C by the same methods. *p*-Amino-hippurate uptake did not survive kidney slice thawing despite the well-preserved light microscope structure of the slices. A traveling-wave thawing system may be suitable for controlled testing of human organs. (39 references)

0155 MICROWAVE OVEN TECHNIQUES FOR BIOLOGICAL SOLIDS DETERMINATION OF WASTEWATER SAMPLES. *(E.)* Carter, J. L. (Dept. Environ. Eng., Marquette U., Milwaukee, Wis.). D. A. Fleischfresser, and T. K. Ishii. *Proc Microwave Power Symp*, May 29-31, 1974, p A3-2/1-A3-2/4.

An industrial microwave oven was used to evaluate variables necessary to optimize the microwave drying of wastewater samples for biological solids