0396 BIOLOGICAL EFFECTS OF MICROWAVE RADIATION ON THE TESTES OF SWISS MICE. *(E.)* Varma, M. M. (Bio-Environ. Eng. Sci. Res. Lab., Howard Univ., Washington, D. C.) and E. A. Traboulay. *ONR Rep.* Contract N0014-73-A-0346 Rep., 1974, 10p.

The biological effects of MW radiation on testicular tissue of 55- to 65-day-old Swiss mice was studied at 1.7 and 3.0 GHz. The power density and exposure time varied. At 1.7 GHz and a power density of 10 mW/cm^2 for 100-min exposures, severe changes in morphology were observed. The number of cells in the seminiferous tubules was reduced and the tubules showed sloughing of degenerating germinal cells in the lumen, which appeared as a coagulated mass of fused spermatids. At the same frequency, exposure to 50 mW/cm^2 for 30-40 min altered spermiogenesis: the lumens were empty with complete disintegration of spermatids, sertoli cells, and the connective tissue which surrounds the seminiferous tubules. Injuries at 3.0 GHz were minimal. (12 references)

0397 PROBLEMS OF PROTECTION AGAINST NONIONIZING RADIATION. *(Fr.)* Jammet, H. (Dep. Prot., At. Energ. Comm., Fontenay-aux-Roses, France). *Proc. Int. Cong. Int. Radia. Prot. Assoc.*, Washington, D. C., Sept. 9-10, 1973, 26p.

The physical properties, uses, possible occupational and non-occupational exposures, and the biological and physiological effects and health hazards of nonionizing radiation are reviewed. Microwaves produce heat in the irradiated organism by exciting certain vibration and rotation levels in atoms. The nonthermal effects of MW radiation on the body are of secondary importance. The MW-generated temperature increment of the body is a function of the energy content of the absorbed MWs, of the heat conduction capacity, and heat transfer capacity of the irradiated tissue. MWs absorbed by the body produce local hyperthermia or even burns, and are most dangerous for tissues with low degree of vascularization, such as the crystalline lens, which becomes opacified after a certain exposure time. Fatigability, somnolence, or insomnia; headache, sensorial disorders, emotional instability; increased neuromuscular excitability, anorexia, nausea, disorders of the cardiac rhythm; vagotonic crises, changes in lipothymic status, adrenal insufficiency, thyroidal hyperfunction; as well as ionic, electrophoretic and cytological changes of the blood, such as, anemia, lymphopenia, and polynucleosis were demonstrated in subjects exposed to low-intensity MW radiation. Broadcast waves are too weak to produce any biological effect in the organism even during occupational exposure. While there are no criteria for a maximum allowable radiation dose, and there has been no uniform standard established, the maximum allowable dose is usually set at 10 mW/cm^2 for relatively prolonged occupational exposure, and at 1 mW/cm^2 for continuous exposure. Certain countries, such as the USSR, have adopted limits ranging from 1 to 0.01 mW/cm^2, depending on the exposure time, on the basis of the nonthermal, functional effect of MW radiation. The development of closed systems with minimized radiation leak, the designation of no-access safety zones around high-power, open radiation sources, and minimization of the number of persons occupationally exposed to radiation are the most important measures in radiation protection. Goggles and protective clothing may be necessary in special cases for individual protection. (No references)

0398 TEST PROCEDURES FOR MEASUREMENT OF THE LEVEL OF RF ENERGY FROM VARIOUS DEVICES. *(E.)* *Fed. Commun. Comm. Rep.* No. FCC/OCE T74-01, NTIS: PB-236 994, 1970-1974, 22p.

Procedures used by the Federal Communication Commission's Laboratory in type approval testing of devices emitting RF energy are presented. The procedures cover: (1) wireless microphones operating in the 88-108 MHz band and auditory training transmitters operating in the 72-76 MHz band; (2) microwave ovens; (3) Class I TV devices; and (4) a radio control for a door opener. Manufacturers are urged to employ these procedures to increase their likelihood of receiving a grant for type approval. The procedures should also be used to test subsequent production of a type approved device to assure that all such devices continue to comply with the applicable regulations. (No references)

0399 AN EXAMINATION OF REGENERATING HEPATIC TISSUE SUBJECTED TO RADIO FREQUENCY IRRADIATION. *(E.)* McLees, B. D. (U.S. Naval Med. Res. Inst., Bethesda, Md.), E. D. Finch and M. L. Albright. *J. Appl. Physiol.* 32(1):78-85, 1972.

The effects of both pulsed and CW irradiation on mitotic activity and chromosomal aberrations in regenerating liver of partially hepatectomized Sprague-Dawley rats were investigated. Power absorption by the animals was 1.2-1.3 mW/g, or slightly below the threshold required for a rise in body temperature. Peak mitotic activity occurred 32-36 hr after partial hepatectomy. In both the CW and pulsed experiments, there was no significant difference between sham-irradiated and experimental animals in mitotic index values or percent of mitotic aberrations. The aberrations occurred primarily in the anaphase and telophase stages of cell divisions; the most common forms were bridging and fragmentation. No evidence for cellular damage at the histologic or ultrastructural level was found. In particular, there was no evidence of hepatocyte swelling, erythrocyte accumulation, or swelling of mitochondria from liver and kidney. The relationship of these results to similar studies in the literature and to radiation safety requirements is discussed. The exposure levels used in this study may represent the upper limit to which humans can be safely exposed. (44 references)

0400 RISKS AND DAMAGES DUE TO OCCUPATIONAL EXPOSURE TO ELECTROMAGNETIC FIELDS. *(It.)* Molteni, G. (Luigi Devote Clin. Occup. Dis., Univ. Milan, Italy). *Med Lavoro* 65(1-2):25-29, 1974.

Biological effects of, and health hazards due to, occupational exposure to MW radiation are reviewed. MW radiation exerts mainly thermal effect on the organism, and its biological thermal effect is essentially determined by the rate of absorption and the depth of penetration of EM waves. The absorption rate is a function of the water content of the body and the dielectric constant of the tissues. The depth of penetration is directly correlated with the presence of adipose tissue. The quantity of the heat absorbed is a function of the heat dispersion capacity of the body. The sensitivity of the organs is determined by the water content, the presence of adipose tissue, the degree of vascularization of the tissues, as well as of the mitotic index and of the degree of cell differentiation. Crystalline lenses, having a low degree of vascularization, and low heat dissipation capacity, as well as the testes and the nerve tissues, especially the hypothalamus, are the most sensitive organs with respect to MW radiation. MW-induced hyperthermia of the testes results in a reduction of the androgen production by the interstitial tissue. Hyperthermia of the hypothalamus may also result in a reduced androgen production due to hypofunction of the hypothalamus with resulting reduction of the gonadotropin production. The nonthermal effects of EM radiation include the demodulating effect, and the EM and molecular effects, the latter of which are of little significance for the human body. EM waves are able to orient electrically charged particles over 15 microns in diameter, and to exert a catalytic effect on certain chemical and enzymatic reactions within a narrow frequency band. EM waves were found to modify the amplitude and frequency of EEG and ECG waves. (6 references)

0401 INFLUENCE OF LOW-INTENSITY MICROWAVES ON THE ACID-BASE BALANCE IN EXPERIMENTAL ANIMALS. *(Rus.)* Shaposhnikov, Yu. G. (Dep. Surg., Cent. Inst. Postgrad. Train. Phys., Moscow, USSR) and I. F. Yares'ko. *Eksp. Khir. Anesteziol.* (6):60-61, 1974.

Guinea pigs were exposed to low-intensity MW radiation (5 mW/cm^2, wavelength 12.6 cm) 1 hr daily for 4 months to study the effect of such radiation exposure on the acid-base balance of the organism. The low-intensity radiation caused a persistent, strongly compensated shift in the acid-base balance, which manifested itself in a reduction of the carbon dioxide partial pressure in the plasma (37 ± 1.03 mm mercury), and of the total carbon dioxide level (22.6 ± 0.7 mEq/l), while the pH value was within the physiological range with 7.39. The significant decrease in the plasma carbon dioxide concentration was a result of hyperventilation, which is a specific adaptive reaction of the irradiated animals to low-intensity radiation. The tendency toward metabolic acidosis in the treated animals represents a compensatory factor in response to the reduced plasma carbon dioxide level. (6 references)

0402 VARIABLE FREQUENCY EXPOSURE SYSTEM FOR SMALL BIOLOGICAL SPECIMENS. *(E.)* McRee, D. (Natl. Inst. Environ. Hlth. Sci., Research Triangle Park, N. C.), P. Walsh, and R. Mathew. *Rev. Sci. Instrum.*, 46(3):253-256, 1975.

A variable frequency system referred to as the log-periodic-parabolic reflector system for exposure of small biological specimens has been developed. This system provides continuous wave and modulated EM radiation from 1-10 GHz with a variable power density from 0-20 mW/cm^2. The field at 61 cm from the irradiator assembly has a uniformity of ±10% over a 6 cm circle. The variable frequency sources are sweep oscillators with octave bands of 1-2, 2-4, 4-8, and 8-12.4 GHz which produce at least a 20 mW output throughout the entire frequency range. The function generator (range 0.0005 Hz to 5 MHz) and pen modulator provide the capability of pulse, square wave, sine wave, triangle wave or ramp function modulation. The forward and reflected power can be monitored at any given frequency and the system can be adjusted to provide maximum irradiated power. The MW field produced at the specimen location 61 cm from the illuminator enclosure is a planewave type field with a horizontal electrical field and vertical magnetic field. The shape of the MW field profiles may be changed by changing the antenna-to-reflector distance. The disadvantages of the system are its small uniform field size and power density availability at the specimen location. The primary advantages are (1) a wide range of frequencies with adequate power densities can be obtained economically; and (2) the planewave field is achieved at small distances from the illuminator permitting the entire system to be placed in a relatively small area. (12 references)

0403 BLOOD PROTEINS IN PERSONS EXPOSED LONGTERM TO 300 kHZ-300 MHz ELECTROMAGNETIC RADIATION. *(Pol.)* Pazderová, J. (Fac. Gen. Med., Charles Univ., Prague, Czechoslovakia), J. Pícková and V. Bryndová. *Pracov. Lék.* 26(8):292-295, 1974.

The total blood serum protein and protein spectrum were examined in 153 technicians at television (TV) broadcasting stations, shortwave (SW) and medium-wave (MW) radio stations. The mean period of exposure at the individual transmitters amounts to 10, 14, and 17 years; the mean intensity of the EMF was 4.9, 15.6, and 7.0 V/m. All the individual values and also the mean blood proteins and their fractions were within the physiologic limits in the entire group. Comparison with a control group of 100 members disclosed the following differences in the mean values at 5% level of significance: Decrease of the albumin-globulin quotient in persons exposed to MW, conditional on the decrease of albumins and increase of alpha 1 and beta globulins. Decrease of beta globulins in persons exposed to SW, and decrease of gamma globulins in those exposed to TV. The total blood proteins were higher in the latter two groups. The deviations, determined statistically, can be considered to be an expression of the reaction by organisms to longterm EM radiation of low intensity, but they are too negligible to be considered pathological. (17 references)

SOURCE: Proceedings of the International Symposium on Biologic Effects and Health Hazards of Microwave Radiation, Warsaw, Poland, October 15-18, 1973.

0404 WHO CONCERN AND ACTIVITIES RELATED TO HEALTH IMPLICATIONS OF MICROWAVE RADIATION. *(E.)* Dieterich, B. H. (Div. Environ. Hlth, WHO, Geneva, Switzerland). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. xii-xiii.

The International Symposium on Biologic Effects and Health Hazards of Microwave Radiation was organized within the framework of the problems which man has had to face in terms of his physical environment, both old environmental hazards and new ones brought about by the progress of science and technology. WHO is concerned about the health implications of the growing use of devices producing nonionizing radiation. A need for national and international public health programs reflecting the rapid technical development of these devices is apparent. Internationally agreed criteria and standards of exposure are needed. The review and evaluation of existing knowledge made by this Symposium will aid WHO in suggesting priorities and reviewing long-term programs on MW radiation. This Symposium is regarded as a step forward in the joint effort undertaken by scientists in various countries and WHO to bring together scientific achievements in different parts of the world and to establish recommendations which should ultimately lead to the control of potential radiation hazards. (No references)

0405 U. S. PUBLIC HEALTH SERVICE CONCERN AND ACTIVITIES RELATED TO HEALTH IMPLICATIONS OF MICROWAVE RADIATION. *(E.)* Villforth, J. C. (Bur. Radiol. Hlth., HEW). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. xiii-xvi.

Man is exposed to increasing numbers of devices emitting RF and MW radiation. The manufacturing processes have far exceeded the development of instruments to detect radiation and biological research to determine somatic or genetic risks. The Bureau of Radiological Health of the U. S. Public Health Service is required by law to conduct research into the health effects of electronic products radiation and to establish and enforce standards of performance for electronic products that will assure that the public health and safety are protected. In addition, the EPA has general authority to develop guides and recommendations and the Occupational Safety and Health Administration is charged with protection of workers from occupational insults, including MWs. Some activities of the Bureau of Radiological Health include: (1) study of effects of MW ovens as they are the most immediate public health problem in the United States, (2) epidemiologic studies, (3) pathologic studies, (4) metabolic studies, (5) genetic studies, and (6) dosimetric studies. Technical problems indicate a general hardware problem associated with nonionizing radiation investigations. These force the Bureau into R & D activities to produce necessary product evaluation information from which dosimetry systems can be developed to assess deleterious biological effects of exposure to radiation. (No references)

0406 RAPID WARMING FROM HYPOTHERMIA BY MICROWAVES. *(E.)* Baillie, H. D. (Crumpsall Hosp., Manchester, U.K.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 15-21.

A microwave (MW) method for producing rapid warming from hypothermia in rats was developed to investigate the physiological responses to rapid warming, and perhaps contribute to research on the nonthermal effects of MWs. Wistar rats weighing 200-250 g, under general anesthesia, were used. Overheating of extremities was prevented by converting the animal's body to a uniform geometric shape by immersing it in a water jacket during exposure. Twelve control rats were cooled to 18 C and warmed to normal body temperature using water spray. All other rats were cooled by water spray and warmed by MWs in a 3 m x 1 m x 1 m cavity energized at 2.5 GHz by three water cooled magnetrons rated at 1.5 kW, giving the cavity a dielectric heating power of 4.5 kW, under optimal conditions. The frequency of the MWs corresponded to a freespace wavelength of 12.4 cm when measured with a coaxial wavemeter. Three groups of 12 rats each were warmed from 18 C to 38 C at power settings of 1/3, 2/3, and full power; for 60, 40, and 20 sec, resp. Control rats all survived; the mean cooling time was 20 min and the mean warming time 30 min. Three deaths occurred in rats warmed at full power, and two among those warmed at 2/3 power. All rats warmed at 1/3 power survived, indicating that warming rate of 20 C in 60 sec is the safe limit of MW warming under experimental conditions. During 3-mon observation period all survivors behaved normally, and offspring were apparently normal. The surface area of a 216 g rat was estimated to be 225 cm^2. While it was impossible to measure the field strength of the MWs used in these experiments in terms of mW/cm^2, it is suggested that the nonreflected part of the field incident on the animal had a power density functionally equivalent to 1100 mW/cm^2, based on the estimated surface area. (5 references)

0407 MAIN DIRECTIONS AND RESULTS OF RESEARCH CONDUCTED IN THE USSR ON THE BIOLOGIC EFFECTS OF MICROWAVES. *(E.)* Gordon, Z. V. (Labor Order Red Banner Inst. Sci. Res. Ind. Hyg. Occup. Dis., USSR Acad. Med. Sci., Moscow), A. V. Roscin and M. S. Byckov. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 22-35.

Research programs in the USSR use three approaches; i.e., hygienic, clinical, and experimental studies, to investigate the biological effects of a whole range of radiofrequencies, and particularly of MWs. Hygienic studies in factories have demonstrated the pronounced intermittent character of the MW irradiation regime to which workers are exposed; experimental studies have shown that intermittent radiation results in more pronounced biologic effects than steady irradiation under conditions of equal strength and time parameters. Based on long-term (20 yr) observations of exposed workers, the biologic effects of MW irradiation become more se-

vere with increasing duration of work accompanied by irradiation at low intensities (less than 1 mW/cm^2). Early USSR experimental studies on MW bioeffects were concerned with high intensities and were limited to establishing minimal lethal doses, thermal action, and effects such as cataract formation and changes in blood pressure. Subsequent studies have focused on changes in functions (general indicators, nervous system, cardiovascular system, biochemical changes, reproductive function, and nonspecific reactivity) in animals irradiated with MWs of nonthermogenic intensity. Statistically significant results of these experiments are summarized in a table showing, for each investigated function, radiation intensity, type of experiment, duration of each irradiation, animal species, and character of the changes. The results show the MW radiation (intensity, 10 mW/cm^2), when acting for long time periods, constitutes a pathogenic factor (morphologic lesions in the nervous system, changes in reproductive function, and some borderline conditions; e.g., lowered endurance, lag in weight gain). Irradiation at a lower intensity (1 mW/cm^2) is also medically significant according to a number of indicators; even at intensities as low as 250-500 $\mu W/cm^2$, certain biologic effects occur, including definite pathologic effects on reproductive functions. Investigations of the primary mechanisms of the biological action of MWs are also discussed. (32 references)

0408 PHARMACOLOGIC EFFECTS OF A PULSED MICROWAVE FIELD. *(E.)* Servantie, B. (Mil. Hosp. Postgrad. Stud., Sainte Anne, Toulon-Naval, France), G. Bertharion, R. Joly, A. M. Servantie, J. Etienne, P. Dreyfus and P. Escoubet. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 36-45.

The effects of prolonged MW exposure on laboratory animals were studied using albino CD-1 mice of the Charles River strain. To look for biologic effects other than thermal, low mean power densities were used. The field effect on sensitivity to pentetrazol was studied by exposing the mice to MWs for 8, 15, 20, 27, and 36 days. At the end of this period 50 mg/kg pentetrazol was administered i.p. to each mouse and the time interval between injection and beginning of the convulsive fit was measured. Mortality was determined at the end. All irradiated mice except the 8-day group differed significantly from the control population. After 15 days, exposure delays appearance of the fit, but for longer exposures the onset of the fit is hastened. The differences in mortality between exposed animals and controls appears after 15 days and increases for longer exposures. Studies performed using curare-like drugs resulted in a hypothesis of the way a MW field acts. The experiments were performed on intact animals using Gallamin or suxamethonium; on *in situ* neuromuscular preparations using Pancuronium; and on isolated neuromuscular preparations consisting of removed left-half diaphragms and left phrenic nerve in baths containing decamethonium, suxamethonium, tubocurarin, and diallylnoxiferin, after 10-15 days of irradiation. It was found that preparations from irradiated animals are paralyzed less and recover sooner than those from normal rats. This experiment led the authors to localize the action of the MW field to the level of the neuromuscular synapse with the field modifying the enzymatic mechanism by a decrease in the quantity of enzyme or a modification of the enzyme itself. They conclude that the MW field creates a decrease in the binding energy between the drug molecule and enzyme molecule, explaining the difference in susceptibility between normal and irradiated animals. (3 references)

0409 MICROWAVE IRRADIATION AND ENDOCRINE FUNCTIONS. *(E.)* Mikolajczyk, H. J. (Inst. Occup. Med., Lódź, Poland). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 46-51.

The literature on MW radiation and endrocrinological changes is reviewed. Since the question of whether there is general or selective reactivity of the endocrine system in an organism exposed to MWs has not been answered, the effect of MWs on endocrine function should be studied with carefully controlled investigations and experimental procedures for the following reasons: electromagnetic energy is transformed into heat within living tissues and may therefore affect pituitary-thyroid functions; it may be an environmental stress factor regulated by the pituitary-adrenocortical system; the heating may affect the pituitary-gonadal system; and MW radiation may modify activation of acetylcholine and adrenaline. (19 references)

0410 BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHz RANGE. *(E.)* Kalada, T. V. (Inst. Ind. Hyg. Occup. Dis., Leningrad, USSR), P. P. Fukalova and N. N. Goncarova. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 52-57.

Clinical observation of a large group of workers exposed to UHF EM radiation (40-200 MHz) for more than 5 yr indicates that systematic, prolonged exposure leads to disturbances in neurovegetative regulatory functions (52%), often expressed in vegeto-asthenic and neurasthenic syndromes (14%); circulatory pathology, including hypertension, mycardiodystrophy, cardiosclerosis (24%); changes in the gastrointestinal tract (chronic gastritis 12%, ulcers 2%); and impairment of oxygenation of heart muscle (42 out of 50 patients with negative histories). Levels of loosely protein-bound cholesterol and total cholesterol were elevated, and the ratio of phospholipids lowered. Lowered osmotic resistance of leukocytes and lowered phagocytic reaction were more frequent than in controls. Changes in threshold of heat perception, reflex responses to stimuli, and hypertension were also observed. The intensity of these disturbances was related to the length of occupational exposure, indicating causal and perhaps cumulative effects. A clearcut relationship between reaction and intensity of exposure was also found. Phasic changes

in the neurovegetative and circulatory systems were observed, indicating adaptive responses. These responses are regarded as transient states with the potential for becoming pathologic since repeated irradiation led to serious functional disturbances. The influence of thermogenic and athermal levels of EM fields on CNS, EEG conditioned reflexes, hemodynamics, biochemical and immunobiologic function, and the morphologic picture of animals (unspecified) was also evaluated in acute and chronic experiments (5-8 mon irradiation). Results indicate a definite dependence of biologic effects on the length of irradiation and the intensity, frequency and components of the EM field. The studies establish general biologic trends in the reactions of organisms, elucidate some aspects of pathogenesis of functional deviations, and indicate their cumulative character. (17 references)

0411 THE CHARACTERISTICS OF BIOLOGIC EFFECTS OF MICROWAVES COMBINED WITH THE ACTION OF SOFT X-RAY IRRADIATION AND HEAT. *(E.)* Nikonova, K. V. (Labor Order Red Banner Inst. Sci. Res. Ind. Hyg. Occup. Dis., USSR Acad. Med. Sci., Moscow) and I. P. Sokolova. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 58-66.

The biologic effects of combined 10 cm MWs and x-ray irradiation with E_{ef} = 13 x 5 keV were studied in mice. Following exposure to a single dose of 2500 r x-rays and 15-min daily irradiations with 40 mW/cm^2 MWs for 6 weeks, mice developed radiation sickness manifest by changes in body weight, low leukocyte count in peripheral blood, progressive skin lesions, and decreased weight of the testes. The testicular lesions were more severe, death rate higher, loss of body weight more marked, skin lesions occurred earlier and were more evident, and decline in peripheral blood leukocytes was more pronounced than resulted from x-rays or MWs applied singly. Studies of the effects of the combined action of 1 mW/cm^2 for 1 hr/day and 24 r/week revealed that the role of MWs becomes more conspicuous with a change to low intensities. Changes in weight and in peripheral blood (decreased leukocyte and erythrocyte counts and increased reticulocyte numbers) were analagous to those accompanying isolated MW irradiation. Also related to the action of MWs was a marked hyperplasia of reticuloendothelial elements in the liver and spleen, of lymphoid elements in the lungs, and of microglia in the brain; manifestations of irritation of the receptor apparatus; and a decrease in ribonucleoproteins of the epidermis. X-ray irradiation determined the lowered weight of the testicles and increased vascular permeability. Immunologic functions (phagocytic and digestive functions of neutrophils, bactericidal properties of plasma) over a 6-mon period revealed changes attributable to either MWs or x-rays with intensity indistinguishable from those resulting from exposure to either factor alone. Studies of the combined action of MWs and high air temperature clearly evidence synergism. Significant changes in arterial pressure of animals so exposed emphasize the need for study of the regulatory and adaptive systems of organisms. (17 references)

0412 INFLUENCE OF MICROWAVE RADIATION ON THE HEMATOPOIETIC SYSTEM. *(E.)* Czerski, P. (Natl. Res. Inst. Mother Child, Warsaw, Poland), E. Paprocka-Słonka, M. Siekierzyński and A. Stolarska. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 67-74.

Results of investigations of MW effects in the lymphocytic and red cell systems are reported. In the first series of experiments, 3 groups of rabbits were exposed to 2950 MHz pulsed (1200 MHz, 1 μsec) or CW MWs at 3 mW/cm^2, 2 hr/day for a total of 74 or 158 hr; a 4th group served as controls. After irradiation, ^{59}Fe citrate-labeled blood samples were withdrawn from all groups for hematologic and radioactivity determinations. Calculations of ferrokinetic indices demonstrated significant differences. The 74-hr exposure to pulsed MWs induced much more pronounced effects than did CW MWs of the same duration; the differences were highly significant. In contrast, 158-hr exposure to CW MWs induced effects similar to those of pulsed MWs of half that duration. The second series of experiments concerned the effects of MW exposure of guinea pigs at various times of the day on the circadian rhythm of bone marrow cells. No marked differences were seen in the circadian rhythm of recognizable precursors of granulocytes and erythroblasts. In cells belonging to the stem cell category (early erythroblasts, myeloblasts, hemopoietic stem cells, and probably lymphocytes), a distinct change in amplitude and phase of the circadian rhythm of cellular divisions was noted in animals irradiated in the morning or evening, as compared with one another and controls. Syngeneic mice were subjected to a single MW exposure (a.m. or p.m.) and examined for 3 days beginning 24 hr after exposure. Results indicated that MWs induce a disturbance in the amplitude and phase of the mitotic rhythm of cells of the stem cell category. The reaction of the lymphocytic system was quantitated by determining the serum hemagglutin level and the number of antibody producing cells in lymph node homogenates of mice irradiated for 6 or 12 weeks and immunized with sheep RBC. Significant differences between controls and irradiated groups indicated that MW exposure affected the lymphocytic systems of immunocompetent cells. (14 references)

0413 HARMFUL EFFECTS OF MICROWAVE RADIATION ON THE BONE MARROW. *(E.)* Yagi, K. (Dep. Intern. Med., Tokyo Med. Coll., Japan), R. Ueyama, S. Kurohane, N. Hiramine, H. Ito and S. Umehara. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 75-88.

The possibility that MW radiation might result in aplastic bone marrow was investigated by irradiating young white male rabbits with a 2450 MHz (12 cm) continuous MW generator. Irradiation sessions (power density 1.3 mW/cm^2) lasted 30 min, repeated 5 times/day for 7 consecutive days. Histologic and macroscopic changes in the irradiated bone marrow, changes in body weight, tissue temperature, and peripheral blood were examined over a 6-week period. Macroscopically, the color of the bone marrow changed from red to yellowish red in the first 3 weeks, and then to gray in the last 2 weeks of the observation period. In the first 3-4

days, plasma-like substances (exudate) developed around bone marrow fat cells and in the center of the parenchyma. Over the next 3 days, the exudate increased gradually in the parenchyma and surrounding fat cells; and completely filled the sinuses. A marked increase in the exudate was accompanied by the disappearance of fat cells in week 2, marked destruction and decrease of the parenchymal cells starting at week 3, and distinct sinus wall thickening and plasmatastis in the sinus in weeks 5-6. Fat cells reappeared during week 4, but the destruction of the parenchyma cells continued. Complete aplastic bone marrow was seen in 5 of 7 cases in the 5th week, and in 6 of 9 in the 6th week. Fibrosis, present in the 3rd week, was not observed in bone marrow obtained in weeks 5-6. Histochemical studies indicated that the exudate contained neutral and acid mucopolysaccharides, apparently derived from the serum due to an inflammation of the bone marrow. The average decrement of body weight in the exposed animals was 0.4 kg. Femoral tissue temperature rose to 39 C within the first 5 min of irradiation and maintained a level of 42 C during the next 30 min. Peripheral blood changes included a marked decrease in small lymphocytes at the end of irradiation and a 900% increase in large lymphocytes. Animals treated with hydrocortisone (4 mg/kg/day for 6 weeks) did not develop aplastic bone marrow. The results demonstrate that MWs can have a harmful effect on bone marrow and suggest that aplastic anemia may be caused by inflammation of the bone marrow rather than by stem cell failure. (12 references)

0414 EFFECTS OF MICROWAVES ON THE CELL METABOLISM OF THE RETICULO-HISTOCYTIC SYSTEM. *(E.)* Miro, L. (Lab. Biol. Phys., Fac. Med. Montpellier, Nimes, France), R. Loubière and A. Pfister. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 89-97.

Long-term exposure to low levels of MW radiation is known to produce subjective and objective disorders in humans. To find the source of these disorders, mice, rats, and rabbits were exposed to 450 hr of continuous MW irradiation at 7 mW/cm^2 mean power density. No modification of their behavior or appearance was noted. Autopsy revealed no macroscopic or microscopic alterations of their organs, but a hyperplasia of the spleen and liver was noted, indicating possible stimulation of the reticulo-histocytic system. A systematic study of the liver, spleen, and thymus cell metabolism of 40 male Swiss mice exposed to MWs was undertaken. The mice were paired and divided into 2 groups: the experimental group was continuously exposed to MW radiation for 145 hr while the control group was kept under the same conditions in another room. No difference in behavior between control and experimental animals was noted and weight curves showed no modification. After exposure all animals were injected i.p. with a methionine ^{35}S solution in a dose of 2.5 $\mu Ci/g$. Fifteen hr after injection, the mice were decapitated and an autopsy was performed. For the germinative centers and lymphoid zone of the spleen, liver, and thymus there was a highly significant ($p < 0.001$) increase in the rate of incorporation of tagged amino acid in the experimental group. This increased radioactivity is in conformity with a real increase in protein synthesis by hepatic, thymic, and splenic cells and is not a simple slowing down of the protein metabolism rate. Thus, continuous exposure of mice to MW radiation for 160 hr induced a great increase in protein synthesis in the liver, thymus and spleen. Further experiments are necessary to confirm or invalidate this effect on the reticulo-histocytic system. (No references)

0415 ARE MICROWAVES TERATOGENIC? *(E.)* Rugh, R. (Bur. Radiol. Hlth., U.S. Pub. Hlth. Serv., Rockville, Md.), E. I. Ginns, H. S. Ho and W. M. Leach. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 98-107.

Pregnant CF_1 white mice were exposed for 15 min on gestation day 8.5 to a constant exposure rate of 2450 MHz radiation (forward power of 7.37 W). A waveguide apparatus was used so that the integral dose rate to the animals could be determined under stable controlled environmental temperature (25 C) and relative humidity (50%). Most pregnancies were terminated at 18 days to determine the teratogenic effect of MWs on whole litters. Doses to pregnancies that yielded 100% normal offspring ranged from 2.4-7.8 cal/g, with the frequency of normal litters decreasing with an increase in average dose; doses that yielded 100% abnormal offspring were observed beginning at 5.8 cal/g. Microwave-induced teratogenesis was seen among litters exposed to average doses in the 2-8 cal/g range. The teratogenic effects detectable by direct observation included gross hemorrhage, exencephaly, stunting, fetal resorptions, and fetal death. The possibility of subtle and microscopically observable effects, in addition to gross anomalies, is suggested. The results indicate a linear relation exists between the MW dose and fetal effects; there was no evidence of a threshold effect. The variability of the incidence of anomalies within litters indicates that cause and effect relations are not well enough established and understood to permit prediction of MW effects either in the mouse or in other species. (6 references)

0416 THE USE OF CONDITIONED REFLEXES TO STUDY MICROWAVE EFFECTS ON THE CENTRAL NERVOUS SYSTEM. *(E.)* Lobanova, E. A. (Labor Order Red Banner Inst. Sci. Res. Ind. Hyg. Occup. Dis., USSR Acad. Med. Sci., Moscow). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 109-118.

The effect of MWs on the function of higher compartments of the CNS was investigated in a series of experiments on rabbits and rats. Experiments were first performed on rabbits irradiated 4 months with cm MWs at an intensity of 10 mW/cm^2 for 60 min/day; following irradiation conditioned motor-food

reflexes were studied for 2 months. The action of MWs during the first month of irradiation led to an inhibition of conditioned reflexes, as apparent from a prolongation of the latent period of the reflexes to positive signals and, in a number of cases, even the lack of conditioned reflexes. These changes were found more frequently in the first half of the stereotype, preceding application of the differentiating signal. The active inhibition was somewhat intensified. The shifts in neurodynamics were preserved during the 2nd and 3rd mon of exposure. In the course of the 4th mon, all indicators of conditioned reflex activity underwent marked changes. Following termination of radiation, normalization of conditioned reflexes took place only after 2 mon. Outbred nonstock rats exposed to the same radiation regime became lethargic after their first exposure. Early MW-induced effects on conditioned motor-food reflexes consisted of a significant increase in latent periods, frequent lack of reflexes to positive conditioning stimuli and sight of food, the presence of phase phenomena, deepening of differential inhibition, and a resultant pronounced inhibition. Inbred K-M rats, which have more excitable CNS, appeared more resistant than outbred rats to the action of MWs; however, starvation led to a deterioration of conditioned reflexes in the inbred rats, and slightly facilitated the activity in the outbred rats. Chronic irradiation of rats with pulsed 10 cm waves of 10 mW/cm^2 intensity induced pronounced changes in reflexes; the same waves at 1 mW/cm^2 intensity did not. Irradiation for 15-min at 10 mW/cm^2 did not significantly influence CNS excitability, while 1 mW/cm^2 irradiation for 15 min somewhat increased it. Further studies revealed that the expression of CNS changes depended on the level of food motivation. Changes in conditioned reflexes indicates functional changes in the higher compartments of the CNS; the possible mechanisms of these functional changes are discussed. (26 references)

0417 PHARMACOLOGIC ANALYSIS OF MICROWAVE EFFECTS ON THE CENTRAL NERVOUS SYSTEM IN EXPERIMENTAL ANIMALS. Barański, S. (Mil. Inst. Aviat. Med., Warsaw, Poland) and Z. Edelwejn. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 119-127.

The effects of chronic exposure to nonthermal levels of MWs on the activity of the CNS of experimental animals were analyzed. During the studies drugs stimulating or inhibiting the function of the CNS at different levels were used. Male, 1-yr old rabbits weighing 3.0 kg were divided into 3 groups of 15 and administered i.v. chloropromazine (4 mg/kg), 1% solution penetracole (3 mg/kg), and an aqueous solution of phenobarbitone (40 mg/kg), resp. Unirradiated controls received the same treatment as experimental animals which had previously been exposed to chronic irradiation of pulse-modulated 10 cm MWs at power density 7 mW/cm^2 for 3 hr per day for a total of approximately 200 hr. EEG recordings of the motor, sensory and visual cortex regions were made after irradiation and after the administration of drugs; the evoked potential of the visual cortex was also investigated by retinal stimulation by a flash of light 700 lux density and 1 c/s frequency, emitted by a stroboscope. The effects of irradiation were detected in all EEG parameters, with a high degree of desynchronization of the EEG pattern. Chloropromazine produced EEG synchronization in both irradiated and control animals; pentetrazole produced rapid onset in irradiated animals; and desynchronization of EEG was marked after phenobarbitone. All main components of evoked visual potentials were also markedly changed by irradiation. Desynchronization of EEG pattern was probably due to activation of the ascending part of the mesencephalic reticular formation. The differences in evoked visual cortical potentials were dependent, partially, on the functional state of afferent systems transmitting specific or nonspecific impulses. (17 references)

0418 A QUANTITATIVE ELECTROENCEPHALOGRAPHIC STUDY OF THE ACUTE EFFECTS OF X-BAND MICROWAVES IN RABBITS. *(E.)* Goldstein, L. (Dep. Psychiatr., Rutgers Med. Sch., Piscataway, N. J.) and Z. Sisko. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 128-133.

Adult male New Zealand rabbits equipped with intracranial electrodes above the sensory-motor cortex, and trained to sit quietly in an anechoic chamber, were exposed 5 min to MW radiation at 9.3 GHz, with power densities varying from 0.7 to 4.8 mW/cm^2, CW. Radiation was beamed at the heads, with the antenna 45 cm away. The rabbits were pretreated with a sedative dose (4mg/kg in a 0.1 ml/kg volume, i.v.) of pentobarbital in order to create conditions permitting the detection and measurement of EEG, and the behavioral manifestations of arousal and hyperarousal. Although there were no behavior and/or EEG changes during exposure, in a number of experiments, following a latent period of 3 to 12 min, sudden arousal occurred which lasted on the average 3 min, with desynchronization of EEG activity and clearcut behavioral excitation, observed through remote control TV monitors. In most cases, 2 or 3 successive periods of arousal occurred interspersed with reversals of electrical activity and behavior to sedation activity. In most experiments, the alternation of periods of arousal and sedation was separated by intervals of 3 to 10 min. Duration of arousal was related to power density, 240 ± 75 sec for 1.44 mW/cm^2, and 768 ± 78 sec for 2.88 mW/cm^2 (9 experiments in each case, total exposure time 5 min). In a few cases there was a constant waxing and waning of both EEG and behavior between sedation and arousal. Alternation of periods of arousal and sedation has been previously described following acute administration of stable free-radical compounds. It is possible that MW exposure produces or enhances the formation of free-radicals from naturally occurring compounds in the brain. The effects did not occur when the relative ambient humidity was above 40%, perhaps because transmission of waves was impaired in rabbits whose long hairs are known to absorb water. (2 references)

0419 PSYCHOGENIC STRESSORS ARE POTENT MEDIATORS OF THE THERMAL RESPONSE TO MICROWAVE IRRADIATION. *(E.)* Justesen, D. R. (VA Hosp., Kansas

City, Mo.), D. M. Levinson, and L. R. Justesen. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 134-140.

A quantitative measure of the ability of small mammals to detect MW energy at low rms-density is studied using Evoked Thermocolonic Response (ET_cR), a parameter experimentally developed by the authors. This response is an elevation of colonic temperature as a reaction to various stimuli. The female albino Sprague-Dawley rat was used to compare ET_cR's evoked by peripheral sensory perception and by MW radiation. A study was made to determine whether small doses of MW energy and a mildly adversive stimulus (faradic stimulation of the feet) would evoke comparable ET_cR's and be additive in nature. 2.45 GHz magnetron-generated MW energy was injected into a cavity holding the rats. Measurements were made at 0, 360, and 1800 mJ/g total E doses, with faradic currents of 0, 50, and 60 μA-rms applied to the feet. Both irradiation and foot shock were found to be reliable triggers of the ET_cR. There was no interaction between the two, but simply an additive effect with respect to magnitude of the ET_cR. A second study was done using rats treated with sodium pentobarbital (35mg/kg i.p.), a hypnotic, resulting in little or no ET_cR, demonstrating that the quickening of nervous activity leading to a rise in core temperature will not occur without the perception of an alien stimulus. (10 references)

0420 SOME EFFECTS OF VARIOUS PULSED FIELDS ON ANIMALS WITH AUDIOGENIC EPILEPSY. *(E.)* Stverak, I. (Inst. Aviat. Med., Prague, Czechoslovakia), K. Marha and G. Pafkova. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 141-144.

The significantly greater biological effectiveness of PW as compared to CW at equal frequency and average power density raises the question of whether the greater effect is caused by the actual modulation of the EM field in normally used sources. To investigate the problem, the effects of a pulsed EM field were compared with the effects of a pulsed ES field, the interfering influence of the high-frequency carrier component being excluded. Forty rats with congenital audiogenic epilepsy were used in both situations (24 were irradiated, 16 served as controls). In order to create the types of pulsed energy required, generators were developed and the values of the field carefully calculated so that in both cases the amount of effective energy was equal. The characteristics of generators of ES pulses were approximately: pulse width 10 μsec, amplitude 800 V, pulse repetition 762.2 Hz. The generator of pulsed EM waves emitted waves at 2850 MHz, pulse duration 2.7 μsec and repetition frequencies 357 Hz. At the place of exposure the average power density amounted to 30 mW/cm^2. Irradiation occurred over a period of 10 weeks. Indicators of the effect of both pulsed fields were changes in sensibility; i.e., the length of the latency period and the sensitivity to the stimulus releasing the onset of convulsions. Homogeneity of biologic material was ascertained by using one-half of each animal litter and the control group, and excepting irradiation, handling in the same way as the experimental group. Change in the onset of the cramp reaction was studied not only in animals directly irradiated, but also in the first and second filial generation. Results obtained from the pulsed ES field showed that irradiation led to prolongation of the interval from the beginning of sound stimulation to the onset of seizures. A higher number of null reactions also occurred. In all cases of EM radiation the mean time preceding the onset of seizures was longer in irradiated than in control animals; the null reaction occurring in approximately 70% of the irradiated group and 20% of controls. Results obtained at the 6th week were significant at the 5% level; the remaining differences were statistically insignificant. The next stage of the study will examine the effects of CW fields. (4 references)

0421 INTERACTION OF ELECTROMAGNETIC FIELDS AND LIVING SYSTEMS. *(E.)* Romero-Sierra, C. (Dep. Anat., Queen's Univ., Kingston, Canada), J. A. Tanner and J. Bigu del Blanco. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 145-151.

Basic phenomena underlying electromagnetic (EM) interaction with living systems are reviewed, and a conceptual viewpoint of the emerging laws that govern such interactions is presented. Past experimental findings on interaction effects are summarized, and the extremely complex wave and nonwave effects are diagrammed. Microwave (MW) field intensity ranges corresponding to identifiable biological effects are: nonthermal, 1 μW-100 μW; thermal, nonheating, 100 μW-10 mW; and heating, 10 mW and above. Thermal, nonheating effects are identified with changes in temperature and heat balance not attributable to the direct conversion of MW energy to heat in tissue. Irradiation intensities below 100 $\mu W/cm^2$ are considered nonthermal for both pulsed and continuous waves. At a power level of 10 mW/cm^2, the energy transformed into heat in the body is roughly equal to the heat loss per square centimeter of body surface. On this basis, power levels between 100 μW and 10 mW are nonheating although thermal mechanisms may be involved. The interaction between EM fields and living systems is dependent on the characteristics of the radiation, the environment, and the biological receptors. In light of the strong EM interaction between glial and neuronal cells, the emerging laws of interaction between EM fields and organisms appear to be: (1) EM fields imposed on a living system modify the EM interaction that exists between glial and neuronal cells inside a nervous structure; (2) To predict the consequences of interaction, all the parameters (radiation, environment, biological receptors) must be quantified and integrated; (3) EM fields trigger a set of interactive biophysical phenomena; and (4) The unstable sequence of events thus triggered may be stabilized at the level of the cell, tissue, organ or organism affected. It is noted that a period of captivity introduces a discontinuity in birds' spatial and temporal perception of the minute gradients in temperature, humidity and EM field, creat-

ing disorientation when released. The same concept can be applied to other migratory species such as fish. (49 references)

0422 PRINCIPLES OF INTERACTION OF MICROWAVE FIELDS AT THE CELLULAR AND MOLECULAR LEVEL. *(E.)* Schwan, H. P. (Dep. Bioeng., Univ. Pennsylvania, Philadelphia). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 152-159.

The present state of knowledge of the electrical properties of tissues and other biological systems is summarized. Three relaxation regions α, β, γ of the dielectric constant exist at low, medium, and very high frequencies. Inhomogeneous structure is responsible for β-dispersion and permanent dipole rotation for γ- and β tail-dispersion; α-dispersion is least clarified but involves both counter ion relaxation and electrophoretic relaxation. The characteristic frequencies vary from one biological object to another. Thus, blood cells display a weak α-dispersion centered around 2 kHz, while muscle displays a very strong one near 0.1 kHz. The β-dispersion of blood is near 3 MHz, that of muscle tissue is near 0.1 MHz. Dispersion characteristics of certain biologic materials are tabulated, including electrolytes, biologic macromolecules, amino acids, proteins, nucleic acids, protein-free cells, and charged and excited membranes. Unresolved problems include the origin of β-dispersion; the application of the theory of counter ion relaxation to macromolecules and cells; protein, amino acid, and nucleic acid data *versus* concentration; and the origin of α-dispersion in membranes. The electric data available to date do not support the concept that MWs may induce resonance effects which might cause irreversible damage. In addition, there is no evidence of the existence of nonthermal effects at the molecular or cellular level. While electric properties provide insight into the mode of interaction of alternating fields, they cannot readily reveal the mechanic effects that may be imparted. Forces evoked by alternating fields (field-evoked forces, dielectrophoresis, electromechanical effects) deserve consideration; they may be responsible for the phenomenon of "hearing" pulsed fields and, hence, some of the behavioral effects reported in the 1-10 mW/cm^2 range. (8 references)

0423 INTERACTION BETWEEN MICROWAVE AND MILLIMETER-WAVE ELECTROMAGNETIC FIELDS AND BIOLOGIC SYSTEMS: MOLECULAR MECHANISMS. *(E.)* Illinger, K. H. (Dep. Chem., Tufts Univ., Medford, Mass.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 160-172.

The interaction between EM radiation and the molecular components of biologic systems is analyzed to delimit the possible coupling mechanisms with EMF which may lead to an alteration of the energetics and/or dynamics of the molecular system. Subjects treated include the quasilattice vibration mechanism of MW absorption in poly-(α-benzyl-L-glutamate) (PBLG) and dielectric saturation in PBLG and other biopolymer systems in MW fields. Appendices contain a theoretical analysis of the time-evolution of the energy of a molecule in the presence of collisional perturbation by other molecules and of perturbation by an EM field; a discussion of the natural background of nonionizing radiation in the biosphere; a description of molecular dynamics in the presence of EM field perturbation; a brief summary of RF and MW absorption in biopolymers; and a short review of field-stimulated proton shift in the hydrogen bonds of biopolymers. The natural EM background in the biosphere at MW- and RF-frequencies is orders of magnitude below the power levels associated with technological and/or scientific applications. In contrast, the natural background of VLF, ELF, and zero-frequency (static) fields in the biosphere is one of the same order of magnitude as certain technical applications. Irreversible effects arising from the perturbation of rotational diffusion in biological fluids by external EMF in the RF and centimeter-wave region, at normal *in vivo* temperatures, have a low probability at field strength below saturation levels. The existence of quasilattice vibrations in extended biopolymeric structures (e.g., the alpha-helix) indicates the possibility of damped resonant interactions between millimeter-wave and far-infrared EMF and biologic systems. Irreversible saturation effects in biological fluids are expected only at (static) field strengths of the order of kV/cm in the helix-coil transitions of certain biopolymers and in micelle-random-Zwitterion transitions. Proton shifts induced by MW EMF, and hence *possible associated genetic-code alterations*, are improbable for systems such as DNA. (56 references)

0424 EFFECTS OF MICROWAVE IRRADIATION IN VITRO ON CELL MEMBRANE PERMEABILITY. *(E.)* Barański, S. (Mil. Inst. Aviat. Med., Warsaw, Poland), S. Szmigielski and J. Moneta. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 173-177.

Erythrocytes were isolated from heparinized (50 I.U./ml) rabbit venous blood, saline washed, and suspended in clean saline containing no potassium, to form a 10% suspension. They were then exposed to continuous EM waves of 10 cm at 1, 5 and 10 mW/cm^2 power densities for 15, 30, 60, 120 and 180 min. No increase in temperature was observed. The erythrocytes were centrifuged and the concentration of potassium and hemoglobin in the supernatants measured. Osmotic resistance of the cells was also determined. Rabbit granulocytes isolated from the peritoneal cavity 8 hr after infusion of 0.5% glycogen and suspended in heparinized saline were also exposed to continued 10-cm waves at 1 or 5 mW/cm^2 for 15, 30 and 60 min. The granulocytes were stained with 0.1% nigrosin and observation of cell viability was made using a phase-contrast microscope. After centrifugation of the remaining suspensions at 15,000 rpm at 4 C for 20 min the activities of acid and alkaline phosphatase, catalase and lysozyme were determined in the supernatants using biochemical techniques. Irradiation at 1 mW/cm^2 for 15 and 30 min resulted

in an efflux of potassium from the erythrocytes. Increased permeability of membranes to hemoglobin appeared at 60 min, and total hemolysis and lowered osmotic resistance appeared at 120 and 180 min of irradiation. A marked increase in the percentage of dead granulocytes was observed after irradiation at 5 mW/cm^2. After 60-min irradiation at this power density 80% of the granulocytes showed diffuse staining. In suspensions irradiated at 1 mW/cm^2 only 20% were stained, the last figure being close to the value observed in controls. Injury of isolated rabbit granulocytes was observed after 20 min of irradiation, measured by the activity of acid phosphatase and lysozyme in the supernatants. Activity of alkaline phosphatase and catalase was seen only after 120 and 180 min. Marked morphological changes were also observed in stained cells under phase-contrast microscopy after the two longest periods of irradiation. (18 references)

0425 ASSESSING MICROWAVES AS A HAZARD TO THE EYE--PROGRESS AND PROBLEMS. *(E.)* Carpenter, R. L. (Bur. Radiol. Hlth., Winchester, Mass.). E. S. Ferri and G. J. Hagan. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 178-185.

At any given output of a particular MW source, the minimal single exposure period required to induce opacity formation of the lenses of the eye can be determined. These minimal exposure periods yield a curve showing time and power thresholds for induction of lens opacities by single irradiations of the eye. This curve is also useful for identifying specific time and power combinations which constitute subthreshold exposures. Experiments which tested the effect of subthreshold exposures repeated at regular intervals demonstrated that irradiation which apparently does not damage the lens when experienced only once may cause lasting damage when repeated daily or weekly. Non-anesthesized New Zealand white rabbits were irradiated 2 inches from a dipole antenna at 2.45 GHz, CW, one hr a day for 20 days. This was defined as chronic irradiation and the lowest power level which would consistently cause development of lens opacities was sought. Opacities developed in 4/10 experiments at 100-110 mW/cm^2, but an increase to 120 mW/cm^2 resulted in opacities in 8/10 rabbits. One hr exposure at this level was found to be subthreshold in 7 experiments. Tests were also performed to study how the MW field is perturbed by the body of a rabbit. In a free field condition the power distribution in a planewave resembled concentric circles of decreasing power density. The rabbit was placed with its right eye in the center of the field and the resulting planewave distribution became a haphazard pattern of irregular zones of differing power densities. The power density at the position of the eye was reduced about 40%. Many other factors disturb the field, leading to the conclusion that power density should be reported only as a measurement in the field where the experiment is to be conducted in the absence of all perturbing factors including the experimental animal. (27 references)

0426 EXPERIMENTAL MICROWAVE OCULAR EFFECTS. *(E.)* Appleton, B. (Walter Reed Army Med. Cent., Washington, D. C.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 186-188.

Albino rabbits were exposed to MW radiation of the eyes under varying experimental conditions including number and duration of exposures, wavelength, power level, duty cycle, and head only *vs* whole body exposures. Similar experiments using dogs were also started. If the front or one side of the rabbit was irradiated, the lethal power level was between 25 mW/cm^2 and 50 mW/cm^2, but if the body was shielded or if only the head was exposed, the threshold for ocular damage was around 300 mW/cm^2, giving little support to the hypothesis that repeated subthreshold exposures cause significant cumulative damage. Exposure to power levels one order of magnitude below cataractogenic levels was an extremely noxious stimulus causing the animal to struggle violently to remove itself from the field. In experiments using dogs, similarity with respect to MW ocular effect between the two experimental models was indicated. (No references)

0427 THE EFFECTS OF MICROWAVES ON HUMAN LYMPHOCYTE CULTURES. *(E.)* Stodolnik-Barańska, W. (Inst. Biostruct., Med. Acad. Warsaw, Poland). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 189-195.

The effects of exposure to MW radiation on human lymphocytes cultured *in vitro* with and without addition of phytohemagglutinin (PHA) was studied. Lymphocyte cultures were exposed in a thermostatic (37 C) chamber at 7 mW/cm^2 or 20 mW/cm^2 to 2950 MHz pulsed MWs. At 20 mW/cm^2, MW exposure induced changes in the mitotic index which depended on exposure time: at 10 and 15 min exposures slight differences were noticed compared to controls; after 20 and 40 min exposure, significant differences were seen. Similar results were obtained at 7 mW/cm^2 after 3-4 hr. Exposure also induced changes in numbers and structures of chromosomes, the degree of change depending on duration of exposure. The most usual finding was changes in chromosomal morphology suggesting changes in spiralization. Irradiation of lymphocytes without PHA addition induced the appearance of blastoid forms and macrophage-like cells. The results suggest that MWs may have mutagenic effects, and also indicate that exposure may induce changes in interphasic nuclei. MWs are the only agents known to be capable of inducing lymphoblastoid transformations. This phenomenon could be used to investigate the mechanism operative in blastic transformation of lymphocytes. (13 references)

0428 MICROWAVE THAWING OF CELLS AND ORGANS. Voss, W. A. G. (Surg. Med. Res. Inst. Univ. Alberta, Canada). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 196-201.

Microwaves may provide a method of controlling the rate and uniformity of heating deep-frozen materials such as might be developed for recovery of human organs from storage banks. Large MW insults at 2450 MHz have been applied to deep-frozen adult kidneys, fetal mouse hearts and tissue culture cells causing controlled temperature changes at rates up to 500 C/min from -196 C to 23 ± 12 C. Two resonant MW systems of 10 and 17 cubic inches, similar in design to conventional MW ovens, were used for heating a number of biological samples, ranging in volumes from 2 to 100 ml. The methods used and results obtained are presented. The electrical activity of fetal mouse hearts taken from 17-19 day-old embryos and recovered from -196 C by MW heating survived in a high percentage of cases. Electrical activity was observed for up to 35 days after implantation of these hearts in the ear of syngeneic adult mice. MW heating at 2450 MHz seems to give rise to faster resumption of electrical activity and a higher survival rate compared to conventional water bath heating. Tissue culture cells also withstood rapid thawing in a resonant MW system operating at very high, near breakdown, field strengths. Uniform MW thawing of adult canine kidneys was obtained at rates between 100 and 300 C/min. Although subsequent functional success was not achieved with the kidneys, areas of viable tissue with vascular integrity were observed. (12 references)

0429 QUANTITATION OF INDUCED ELECTROMAGNETIC FIELD PATTERNS IN TISSUE AND ASSOCIATED BIOLOGIC EFFECTS. *(E.)* Guy, A. W. (Univ. Washington Sch. Med., Seattle). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, pp. 203-216, 1974.

A quantitative description of EMF within tissues and an understanding of the relation between these fields and the thermodynamics of the biologic system are desirable in formulating exposure standards. U.S. safety guides that allow a maximum human exposure level of 10 mW/cm^2 incident power are partially based on limiting the average absorbed power density to the average resting value of the metabolic rate. Safety guides, however, cannot be specified in terms of absorbed power density; they are more conveniently expressed in terms of an incident PFD expressed in units of mW/cm^2 or, for the case of stationary or quasi-stationary fields, in terms of electric field strength E, in V/m, or magnetic field strength H, in A/m. Nevertheless, none of these field quantities measured exterior to a subject can be classified as hazardous, nonhazardous, thermal, or nonthermal without sufficient knowledge of exposure conditions, frequency, subject size, and subject geometry to determine the actual absorbed power density in the subject. Both thermal effects and pearl-chain formation, which depends on a sustained force across internal tissue or cell interfaces, are related to average power absorption and not to the peak absorbed power from modulated or pulsed EMF. The relation between frequency, body size, and absorbed power can be understood by considering spherical tissue layers exposed to a plane EM wave. From 1 MHz to 20 MHz, absorption varies as the square of the frequency, due primarily to the magnetically induced fields. In this range, the maximum power absorption density is 10^{-5} to 10^{-2} W/kg per mW/cm^2 incident power. From 100 to 1000 MHz, internal reflections are significant for a man-size sphere and the average absorption attains a maximum of 2×10^{-2} W/kg per mW/cm^2 incident power at 200 MHz, which remains relatively constant with frequency up to 10 GHz. The maximum absorption density increases with frequency above 1000 MHz, approaching that produced by nonpenetrating radiation. Thermograms are presented which clearly show hot spots in a phantom cat brain exposed to a 918 MHz aperture source and the unpredictable absorption peaks that occur in the body and tail of a phantom rat exposed to the same frequency. An experimental protocol is outlined to eliminate misinterpreting highly localized thermal effects as nonthermal or low-level effects. (12 references)

0430 SOME RECENT DEVELOPMENTS IN THE CHARACTERIZATION AND MEASUREMENT OF HAZARDOUS ELECTROMAGNETIC FIELDS. *(E.)* Bowman, R. R. (Electromagnetic Div., NBS, Boulder, Colo.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 217-227.

The magnitude of power density [S] is often not a meaningful measure of the intensity of complicated EMF and is a poor index of potential hazards even in the MW band. In contrast, the electric field strength, defined as the Hermitian magnitude [E] of the field, is a meaningful measure of the strengths of fields having reactive near-field components, multipath components, and arbitrary polarization. Three recently developed instruments for measuring [E] in complicated fields are discussed with respect to their capabilities and limitations for measurement of either fields external to subjects or fields unperturbed by subjects. Tabulated characteristics include frequency range (GHz) for $\pm$ 1 dB response for single planewaves, upper frequency (GHz) limit for spatial resolution of complicated fields, and field levels measurable (given in terms of [E] and equivalent planewave [S]). The first instrument is a broadband, isotropic sensor based on a Golay cell. The sensor consists of a pair of thin-walled air-filled spheres connected by tubes to a sensitive differential pressure transducer. The field-sensing sphere is coated with a high-resistivity film; the noncoated sphere provides compensation for changes in ambient temperature or pressure. The sensor will have an essentially constant response (average of $[E]^2$) for single planewave fields with wavelengths either long or short compared with the field-sensing sphere. The sensor can withstand fields of 1 W/cm^2 average level; the peak density overload is not known. A second type of broadband, isotropic field sensor consists of three orthogonal dipoles with diode detectors connected between the arms of the dipoles. The readout of the instrument is calibrated to display $1/4\ \varepsilon[E]^2$. For wavelengths up to two or three times the length (8 mm) of the dipoles, the probe can be calibrated to measure single planewave fields or to provide some sort of average reading for multipath fields; the instrument will not accurately measure multifrequency fields. Another isotropic, wideband field sensor comprises three orthogonal lossy elements made from thin-

film thermocouples. Outputs from the elements are summed to provide a signal proportional to $[E]^2$; the instrument can be calibrated to read in units of mW/cm^2. (10 references)

0431 METHODS OF CALIBRATING MICROWAVE HAZARD METERS. *(E.)* Baird, R. C. (Electromagnetics Div., NBS, Boulder, Colo.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 228-236.

Existing calibration methods for MW hazard meters require that a known field intensity be established through measurement, calculation, or a combination of both. The device under test is placed in the "standard" field and the meter indication is compared with the known field value. Three different approaches to producing the "standard" calibrating field are described: the free-space standard method, guided wave methods, and the standard probe method. The basic concepts, advantages and limitations, and attainable accuracies of each method are reviewed. The free-space standard field method can be used for calibrating antennas as well as power meters. NBS uses standard gain horns above 2.6 GHz to establish 10 mW/cm^2 fields to an accuracy of ± 0.5 dB, including multipath effects. Below 2.6 GHz an open-ended waveguide is used as the radiating element. Present accuracy down to 0.9 GHz is ± 0.6 dB; transmitter powers of 35 W or less are required to produce a 10 mW/cm^2 field. Guided wave methods require considerably less power and space but are useful only for frequencies below 1 or 2 GHz, since the device being calibrated must be small compared to the guide dimension. One waveguide system operates at 400-600 MHz with an estimated uncertainty in the field intensity of ± 12%; another operates at 2450 MHz with an accuracy to within ± 6-7%. The standard probe method is the simplest and may prove to be the best method of calibrating hazard meters for general use. An accurately calibrated probe is used as a "transfer standard"; i.e., the probe determines the field intensity over a particular region in space (or in a guided system) produced by an arbitrary transmitting antenna. The probe to be calibrated is then placed in the same location in the field and the meter reading compared with the known value of the field. Dipole-diode type probes may ultimately serve as such a transfer standard. (21 references)

0432 METHODS OF MICROWAVE FIELD QUANTIFICATION FOR BIOLOGIC STUDIES. *(E.)* Smith, R. B. (Sch. Electr. Electron. Eng., Univ. Bradford, U.K.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 237-239.

Priorities placed on establishing standards for safe exposure of personnel working in the vicinity of high-power radiofrequency sources have created new emphasis on the development of instrumentation for monitoring microwave (MW) power density. This report describes a monitoring bolometer, developed at the Univ. of Surrey, based on the classical gas thermometer. Two thin-walled silica spheres are placed in a radome coated to reflect infrared radiation and transparent to microwave radiation. The spheres are air-filled and connected by narrow-diameter tube to a capacitive differential-pressure transducer. One sphere is coated with resistive films and absorbs MW energy. The other is not coated and provides ambient temperature compensation. The pressure difference due to the absorption of energy by the resistive film and subsequent heating of air in the coated cylinder is converted into a change in capacitance at the pressure transducer. A special transformer ratio bridge converts the capacitance change into an out-of-balance voltage which is linearly related to temperature rise in the coated sphere and thus to the power absorbed. The final temperature of the coated sphere is dependent on the heat loss mechanisms within the radome. The thermal time constant was found to be dependent on the silica substrate and was about 8 sec for 63% of the final temperature. The use of an electronic differentiation circuit reduced the effective time constant of the instrument to less than one second. A major part of the research was devoted to measuring the frequency-dependent absorption coefficient of the coated spheres, which was found to be a function of sphere diameter and surface resistivity. (2 references)

0433 RADIATION HAZARDS FROM MICROWAVE SOURCES WITH MOBILE ANTENNAS: CERTAIN TECHNICAL PROBLEMS. *(E.)* Frank, Z. (Inst. Aviat. Med., Prague, Czechoslovakia). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 240-242.

In considering hygienic conditions in a given locality MW sources, such as radar installations whose main function is to emit energy into the environment, should be observed. The general practice is to measure the intensity of the irradiated field; however, real conditions during field measurements of MW intensity differ significantly from those of calibrating standards and anechoic chambers. It is therefore necessary to determine the maximum intensity values considering radiation emitted simultaneously from all independent sources. In order to compute data for hygienic evaluation, one must use an orderly sequence of theoretical analysis, real measurements, analysis of the existing situation, and of all factors influencing the distribution of power density from the equipment used. The derived formulae may then be used to predict hygienic conditions for new installations. (6 references)

0434 RESONANCE METHOD FOR THE DETERMINATION OF THE COMPLEX DIELECTRIC CONSTANT OF BIOLOGIC MATERIALS IN THE MICROWAVE BAND. *(E.)* Piotrowski, M. (Mil. Inst. Hyg. Epidemiol., Warsaw, Poland). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 243-253.

The problem of measuring the complex dielectric constant of biologic materials in EM fields was solved by the resonance method. The examined substance was

placed in a cuvette, the dimensions of which were smaller than the inner dimensions of the measuring cavity. Losses in the wall of the cuvette and its geometry were taken into consideration. The electrodynamic aspect of the task was reduced to the solution of the internal electrodynamic problem for the case of an isotropic medium described by a continuous function of dielectric permittivity of a nonhermitian symmetry. The metrologic aspect was based on experimental determinations of the resonance frequency and the Q factor of the resonator with and without a sample, and establishing interrelations linking these quantities with certain physical parameters of the resonator and the examined material. An original solution to the problem of selfvibrations of the resonator was obtained using Galerkin's method. An analytical procedure and the use of quasi-H_{onp} modes are needed for the dielectric measurement of lossy samples concentrically placed in the resonator and cuvettes, and not completely filling the cavity. There are no restrictions on size or on the material parameters of the tested substances (for isotropic media with magnetic permeability equal to vacuum permeability $\mu_o = 1$). These characteristics allow the choice of convenient samples and ensure obtaining the selected sensitivity for predicted values of ε_2 and ε_1 The most critical parameter is the inside diameter of the cuvette. Procedures for determining the permittivity ε_2' and ε_2'' from f (ε', ε'') and Qd (ε', ε'') can be carried out separately. Measurements of the dielectric constants of a number of substances including distilled water, γ-globulin, and human blood (Na tartrate) were carried out in a resonator tuneable to the X band with a field distribution H_{011}. In the range of measured values $\varepsilon_2' = (40 + 60)$ and $\varepsilon_2'' = (20 + 35)$, the error does not exceed 0.5%. The full error in determining ε_2' and ε_2'' (5 + 10)% is mainly due to the measuring technique used. (14 references)

0435 MICROWAVE REFLECTION AND DIFFRACTION BY MAN. Beischer, D. E. (Naval Aerospace Med. Res. Lab., Pensacola, Fla.) and V. R. Reno. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 254-259.

Valuable information for evaluating the biological effects of MW radiation may be gained from measurements of reflected, scattered and transmitted radiation. MW field perturbations were measured in immediate proximity to an illuminated human subject in an indoor range to assure close environmental control. A 4.8 m parabolic reflector was used to collimate a beam illuminating an experimental stage (3.6 m x 3 m x 2.4 m). Power measurements were taken by an NBS isotropic sensor in which three orthogonal dipoles are combined to measure the power density. The studies were conducted at 1 and 3 GHz CW, at power densities of not more than 50 $\mu W/cm^2$ in vertically and horizontally polarized fields. The interference patterns of a human being show a standing wave on the illuminated side and a pronounced shadow on the opposite side. Both the spatial standing wave and the radial diffraction field around man resemble the field perturbations demonstrated theoretically and experimentally around a conducting circular cylinder. A comparison between diffraction patterns around a cylinder and a conducting mannequin allow for estimating the significance of the shape of the subject. The studies indicate that power measurements made in the vicinity of man may be subject to wide errors if standing waves and shadows are not taken into consideration; the design and positioning of personnel MW dosimeters should be influenced by these facts. It is also apparent that one man can considerably modify the MW field incident on his neighbor, an important consideration in multiple exposure of men and animals. Reflection and transmission measurements will permit a new approach to the estimation of absorbed energy in different-sized parts of the human body. (2 references)

0436 CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS *(E.)* Sadcikova, M. N. (USSR Acad. Med. Sci., Moscow. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 261-267.

Microwave or radiowave sickness has been identified as a distinct occupational disease following prolonged work involving exposure to MWs. Changes take place in the function of the nervous, cardiovascular, and other systems leading to a characteristic complex of symptoms. The health status of 2 groups of workers involved with radio equipment emitting radiation in the MW range was observed and compared to controls. The first group was exposed to a power density of up to a few mW/cm^2 while the second group was exposed to a much lower intensity. Both groups significantly differed from controls in frequency of such complaints as heaviness of the head, drowsiness during the day, tiredness, irritability, anxiety, light sleep at night, and partial loss of memory. In both groups the frequency of asthenic and autonomic vascular disturbances of a hyperreactive character (expressed dermographism, hyperhidrosis, arterial hypertension) related to age and employment depended directly on the duration of professional contact. It was found that a complex of symptoms corresponding to MW sickness was diagnosed only in those patients of the first group who began work under very unfavorable conditions. Microwave sickness was characterized by various autonomic vascular disturbances with crises of cerebral and coronary vascular insufficiency and asthenic symptoms. Three stages (initial, moderately advanced, and advanced) in the development of the illness were distinguished with asthenic, astheno-autonomic with vascular dysfunction of hypertonic type, and hypothalmic clinical syndromes. Of those patients suffering from MW sickness, despite repeated therapeutic courses and temporary withdrawal from work, upon returning to previous working conditions symptoms increased in severity. Cessation of work involving irradiation frequently resulted in stabilization of the processes or recovery if withdrawal took place in the initial stage of the illness. (24 references)

0437 NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES. *(E.)* Klímková-Deutschová, E. (Neurol. Clin., Charles Univ., Prague, Czechoslo-

vakia). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 268-272.

Data on 352 persons occupationally exposed to nonionizing radiation from 29 places of work were analyzed with respect to clinical, biochemical and bioelectric signs, age, and the characteristics of the exposure to EM radiation. Symptoms such as headache, fatigue and excitability were found most frequently in workers exposed to radiation in the cm waveband. Age had no significant relationship to symptomatology. There were slight disturbances in enzyme function including a slight increase in fasting blood sugar. Fatigue, paralleled by a reduction in vigilance and pathological changes in the EEG, was found to be localized in the mesodiencephalic region. This activity was found particularly in persons exposed to high levels of radiation from a pulsed field. These analyses concentrated on fine regulatory mechanisms which are disturbed before organic changes can occur. This determination is important for the application of preventive measures such as excluding from work involving nonionizing radiation persons liable to paroxysmal activity of the CNS and certain people with pseudoneurasthenic syndrome or motor system disturbances. (No references)

0438 A STUDY OF THE HEALTH STATUS OF MICROWAVE WORKERS. *(E.)* Siekierzyński, M. (Inst. Postgrad. Stud., Mil. Med. Acad., Warsaw, Poland). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 273-280.

The health status of 841 men (ages 20-45 yrs) who were occupationally exposed to irradiation with pulsed MWs of various frequencies was studied. The men were divided into two groups according to exposure levels: those exposed during working hours at power densities above 2 W/m^2 and those exposed at power densities below 2 W/m^2. They were divided into subgroups based on age and duration of employment and were examined for eye changes, functional disturbances, and all other causes for unfitness for work taken together. No statistically significant correlation was found between parameters examined and duration of employment in the two groups, while there was an obvious existing correlation between some parameters and age. Thus within the groups as well as between groups of persons occupationally exposed to various power densities of MW radiation, no correlation is indicated between degree of exposure or duration of employment and incidence of analyzed health disturbances. (2 references)

0439 BLOOD PROTEINS IN PERSONNEL OF TELEVISION AND RADIO TRANSMITTING STATIONS. *(E.)* Pasderová, J. (Res. Inst. Telecommun., Prague, Czechoslovakia), J. Picková, and V. Bryndová. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 281-288.

Previous studies have indicated that no changes in health status due to EM radiation have been observed except modification of the blood protein ratio. These investigations were repeated on radio and TV technicians who have worked at least 5 years in their profession. The levels of blood proteins and their fractions were within physiologic limits, but statistically significant differences were found between mean values for the exposed *vs* control groups. Total protein level was higher in people operating medium wave transmitters. The albumino-globulin quotient decreased in radio technicians, and gamma-globulin decreased in TV technicians. The findings confirmed previously reported data on evidence of blood protein changes, but differs from previous reports in that no evidence of gamma-globulin elevation was found. No pathologic findings were revealed, and the mean differences between exposed and control groups are considered to be a general response of the organism to the stress of EM radiation. (9 references).

0440 THE BIOLOGIC ACTION AND HYGIENIC SIGNIFICANCE OF ELECTROMAGNETIC FIELDS OF SUPERHIGH AND ULTRAHIGH FREQUENCIES IN DENSELY POPULATED AREAS. *(E.)* Dumanskij, J. D. (A. N. Marzeev Kiev Sci. Res. Inst. Gen. Public Hyg., USSR) and M. G. Šandala. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 289-293.

Hygienists have begun studying the effect of UHF and SHF energy in densely inhabited areas. At the sites of TV, radar, radioastronomy and radiometerology sources, the intensity of electromagnetic energy is much higher than the earth's background and penetrates buildings located in the vicinity. Twenty-eight rabbits and 128 white rats were used in investigations of biologic effects for the UHF range and 100 white rats and 32 rabbits were used in the SHF range. The animals were irradiated for 8-12 hr daily for 120 days. Turning on the EM field elicited changes in the CNS as the animals appeared excited. Certain periodic changes appeared in the conditioned reflex activities of the animals; this was connected with development of inhibitions related to impairment of nervous reactivity and leading to pathologic stagnation and inertia. Previously observed changes in bioelectric activity of the brain cortex were confirmed. EM fields impaired biochemical mechanisms which ensure the normal course of nervous processes; resulted in increased weight of the adrenals, reduction in their ascorbic acid content, and increased secretion of ketosteroids in the urine; and increased the ability of the thyroid gland to concentrate radioactive iodine. Electromagnetic energy caused changes in the composition of the blood including decrease in leukocytes, eosinophils, reticulocytes, erythrocytes and hemoglobin. An increase in the RNA and DNA contents of spleen and liver was induced. Thus, prolonged exposure of low intensity EM energy in the UHF and SHF ranges resulted in appreciable changes in the general status of the organism, conditioned reflex activity, bioelectric activity

of the brain cortex, various biochemical parameters, blood composition and morphologic structures of tissues and organs of the exposed animals. The biologically active intensities were 0.06-10 $\mu W/cm^2$ for UHF and 5-20 $\mu W/cm^2$ for SHF ranges. (No references)

0441 SELECTED CASES OF MICROWAVE CATARACT IN MAN ASSOCIATED WITH CONCOMITANT ANNOTATED PATHOLOGIES. *(E.)* Zaret, M. M. (Zaret Foundation, Inc., Scarsdale, N.Y.). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 294-301.

The term microwave cataract is defined, its pathogenic evolution described, and the differential diagnostic features distinguishing it from all other types of cataract are presented. The role of microwaves as a secondary, contributory or synergistic factor is not discussed. Six case histories, selected from more than 50 cases, are presented. Each case having exhibited characteristic posterior capsular opacification following a known exposure to microwaves, and an absence of other demonstrable cataractogenic etiology, is considered as having primary microwave cataractogenic etiology. Histories and ophthalmologic findings depict acute, subacute or chronic forms of microwave cataract. The covert nature of usual exposures, characteristic latency, slow evolution and subsequent insidious onset of symptoms are discussed. Concomitant ophthalmologic and generalized pathological findings are described and compared to similar findings reported in the scientific literature as being related to microwave exposure. The additional ophthalmological findings consist of: (1) hydrops of the lens, keratoconjunctivitis, iridocyclitis and chorioretinitis, which can develop immediately following irradiation; (2) keratopathy, glaucoma, synchiae,, retinal degeneration, melanomata and capsule exfoliation, which can develop later; and (3) after long periods of latency, corneal endothelial dystrophy and lenticular nuclear sclerosis, which are indicative of premature aging. Non-ophthalmological findings observed in this group include mental illness; cardiac, vascular, hormonal and arthritic disease; testicular malignancy and a rare, bizarre CNS degeneration in a child fathered by one of the patients. The protean nature of microwaves and its potential contributory role as a pathogenic agent are discussed. (No references)

0442 RETINAL CHANGES IN MICROWAVE WORKERS. *(E.)* Tengroth, B. (Dep. Ophthalmol., Univ. Gothenburg, Sweden) and E. Aurell. *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 302-305.

Retinal changes in people occupationally exposed to MWs have not been reported in the literature. However, in an electronic industry working with radar equipment, during periodic checking on the eyes of personnel the frequency of significant lens opacities in a group of younger workers and retinal lesions in the paramacular and macular regions had been noted. An epidemiologic study on 98 workers in a similar industry was performed to determine the significance of these findings. Sixty-eight workers had been exposed to MWs for a length of time; they were divided by type of exposure into persons testing radar equipment and measuring MW radiation from different klystrons and persons from experimental laboratories. Thirty persons also exposed were used as controls. All personnel were examined by eye specialists to determine refraction and visual acuity, to study the optic media by corneal microscope and slit lamp in comple mydriasis, and to study the retina by ophthalmoscope. The number of lens opacities even at younger ages was high among exposed workers. Retinal lesions were also of high frequency. Dividing the exposed personnel by task indicated a concentration of lens and retinal lesions among testing personnel. This group is more apt to be exposed to higher power levels, indicating that maximum permanent exposure (MPE) of 10 mW/cm^2 may be too high. Similar retinal lesions have been observed in subsequent studies done in Poland, confirming these preliminary observations. Further experimental and theoretical work needs to be done to determine whether such lesions are due to nonthermal effects. (7 references)

0443 ASSESSMENT OF LENS TRANSLUCENCY IN JUVENILES, MICROWAVE WORKERS AND AGE-MATCHED GROUPS. *(E.)* Zydecki, S. (Inst. Postgrad. Stud., Mil. Med. Acad., Warsaw, Poland). *Biologic Effects and Health Hazards of Microwave Radiation*, Polish Med. Publishers: Poland, 1974, pp. 306-308.

Differing criteria used for lens translucency have led to controversy on the effects of occupational exposure to MW radiation on the eye. The reported study examined 3000 individuals of both sexes, divided into 3 groups of 1000 each. Group A was further divided into 2 subgroups. A_1 contained 542 people exposed directly to MW radiation ranging between 0.1 mW/cm^2 and 1 mW/cm^2, approximately. During short periods of time the mean power density to which this group was exposed could reach up to 6 mW/cm^2. Group A_2 was made up of 458 individuals exposed to MWs at 0.01 mW/cm^2 or less. Both groups were exposed on the average 4 hr per day, the history of occupational exposure ranging from 1 to 15 yr. Group B comprised 1000 age-matched individuals not exposed to MWs; Group C included young people aged 5-17 yr. Groups B and C served as controls for Groups A_1 and A_2. Lens translucency was assessed using a 5-grade scale. Detailed analysis indicated that a close correlation exists between age and the grade of lens translucency, and that the frequency of inborn defects may be about 0.7%. Statistically significant differences in the frequency of various grades of lens translucency existed between Group A, B, and C; as were the differences between subgroups A_1 and A_2. Analysis demonstrated that duration of occupational exposure did not play a decisive role. Decrease in lens translucency depended upon power density levels. However long-term exposure to low doses (below cataractogenic levels) may tend to accelerate the normal aging process. (No references)

0444 MICROWAVES - A TOOL IN MEDICAL AND BIOLOGIC RESEARCH. *(E.)* Grant, E. H. (Phys. Dep., Queen Elizabeth Coll., London, U. K.). *Biologic Effects and Health Hazards of Microwave Radiation,* Polish Med. Publishers: Poland, 1974, pp. 309-316.

The degree of interaction of MWs with biologic tissue may be determined if the amount of energy which is reflected and the amount absorbed is known. This can be determined theoretically from the angle of incidence and the complex permittivity. The complex permittivity may be rigorously determined and it should be possible to construct a data base for the electrical properties of body tissues. In the MW region the electrical properties of water dominate those of all other biologic molecules present. The structure of this water immediately surrounding the biologic macromolecules is "bound" or "modified" and has different electrical properties than "pure" water. Once these electrical parameters are known they may be used in medical and biologic research such as the investigation of hyperbetalipoproteinemia, treatment of cancer and evaluation of the size and shape of biologic molecules in an aqueous environment. (28 references)

Summaries of Discussions, Session Reports and Recommendations

0445 SESSION A. GENERAL EFFECTS OF MICROWAVE RADIATION. *(E.)* Z. V. Gordon, T. V. Kalada, M. L. Shore and H. P. Schwan. *Biologic Effects and Health Hazards of Microwave Radiation,* Polish Med. Publishers: Poland, 1974, pp. 317-320.

Several papers during this session were devoted to the biologic effects of higher intensities of MW radiation. The majority were concerned with the biologic effects at intensities so low that thermal effects can be excluded. In these latter investigations the possibility exists that microthermal effects and nonthermal effects which are unclear at the present time might have occurred being responsible for the biologic changes observed. During the general discussion it was suggested that energy density flux levels of MW fields be divided into three ranges: (a) high intensities of 10 mW/cm^2 upwards (region of thermal effects); (b) the range of subtle effects from about 1-20 mW/cm^2 (possible effects of a microscopic or macroscopic nature); (c) intensities below 1 mW/cm^2 (region of nonthermal effects). The boundaries indicated are dependent on numerous variable factors such as animal size, threshold of warmth sensation, frequency, pulsing, etc. The intermediate range calls attention to the need for additional research on subtle effects and clarification of the underlying mechanisms. The following recommendations specific to the subject of this session were agreed upon: (1) More biophysical investigations are needed on mechanisms of MW interaction with complex microscopic and submicroscopic bystems (e.g., intermolecular mechanisms). Special attention should be made in determining the absorbed energy dose and its spatial distribution. (2) Threshold values at which biologic effects are induced should be determined. Combined effects of MW and other environmental factors and the effects induced at various MW frequency bands should be studied. (3) Biologic, medical and biophysical effects in the entire RF range should be conducted, with particular attention to their dependence on the physical characteristics of the EM field. (4) Cumulative effects, delayed effects, differential radiation sensitivity, effects related to cellular transformation, and carefully controlled human epidemologic studies are areas requiring further research.

0446 SESSION B. INFLUENCE OF MICROWAVE RADIATION ON THE NERVOUS SYSTEM AND BEHAVIOR. *(E.)* W. R. Adey, E. A. Lobanová, A. V. Rodcin and W. A. G. Voss. *Biologic Effects and Health Hazards of Microwave Radiation,* Polish Med. Publishers: Poland, 1974, pp. 321-323.

Discussions in this session emphasized difficulties in evaluating subtle physiological and behavioral effects during and following MW exposure in mammals. For example, natural factors such as growth and aging must be considered in long range tests, autonomic nervous reactions resembling field-induced changes must be ruled out, and difficulties involved with using inappropriate metal instrumentation must be solved. The question of thresholds for thermal effects within the crania with and without potential distortions of the EM field following implantation of inappropriate metal electrodes was repeatedly raised. There was much interest in problems of instrumentation in CNS studies, as recording of temperature during or immediately following irradiation of the brain would be important. Justesen presented his "evoked colonic temperature" to obviate the need for recording directly in the CNS, but this was not accepted by Soviet participants. In studying the effects of pulsed fields, Stverak, Marha, and Pavkova emphasized the significance of the envelope of the carrier wave in seizure induction, as these envelopes are potent in modifying conditioned reflexes and EEG rhythms. Romero-Sierra proposed schemes of tissue-interaction with MW fields. The data presented are important for setting up safe exposure limits to MW radiation. The session recommended that further investigation of MW effects on the nervous system should include: (1) investigation of the influence of MW exposure on behavior and conditioned reflex functions using various exposure regimes; (2) electrophysiologic investigations carried out during the exposure period; (3) investigations of effects of MWs on CNS metabolism; and (4) investigation of morphologic changes in the CNS following MW exposure.

0447 SESSION C. EFFECTS OF MICROWAVE RADIATION AT THE CELLULAR AND MOLECULAR LEVEL. *(E.)* E. H. Grant, K. H. Illinger, B. Servantie and S. Szmigielski. *Biologic Effects and Health Hazards of Microwave Radiation,* Polish Med. Publishers: Poland, 1974, pp. 324-326.

The size dependence of the pearl-chain effect was discussed. Inconsistencies between reported findings