0263 INFLUENCE OF MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON BIOLOGICAL OBJECTS.
(E.) Devyatkov, N. D. (no affil.). *Sov. Phys.-Usp.* 16(4):568-569, Jan.-Feb. 1974.

In the past decade experimental studies made in the USSR in the millimeter band at very low microwave energy flux densities (no more than a few milliwatts per square centimeter) produced highly interesting information on the effects of irradiation: a) the effect of irradiation depends strongly on the frequency of the microwaves; b) in certain power ranges, the effect of exposure depends weakly on variation of the power through several orders of magnitude; c) the effects depend significantly on duration of irradiation. It was also established that the vital activity of microorganisms is affected by millimeter-wave irradiation. The effect may be positive or negative, depending on the particular part of the band and the particular conditions of irradiation. A machine for irradiation of microorganisms and direct observation of their behavior during and after irradiation was designed around an MIS-51 comparison microscope. Various yeast cultures were irradiated to demonstrate the effect of millimeter-wave electromagnetic irradiation on cell division. Irradiation of a culture of *Rhodotorula rubra* for 15 hr at wavelengths 7.16, 7.17, 7.18 and 7.19 mm (10 experiments at each frequency) showed a sharp frequency dependence: cell division was stimulated at 7.18 mm and slightly depressed at the other wavelengths. Irradiation of a *Candida* culture caused a marked change in the nature of cell division as compared with controls; the irradiated cells exhibiting accelerated division. Irradiation elevated temperatures in some cultures by approximately 4 C. There have been only a few attempts to develop approximate hypotheses to account for the resonant effect of irradiation and some of its other properties. Further experimental and theoretical confirmations are needed to these interesting scientific problems. (No references)

0264 CERTAIN METHODOLOGICAL PROBLEMS AND RESULTS OF EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF MICROWAVES ON MICROORGANISMS AND ANIMALS.
(E.) Bazanova, E. B. (no affil.), A. K. Bryukhova, R. L. Vilenskaya, E. A. Gel'vich, M. B. Golant, N. S. Landau, V. M. Mel'nikova, N. P. Mikaelyan, G. M. Okhokhonina, L. A. Sevast'yanova, A. Z. Smolyanskaya and N. A. Sycheva (Gen. Ed.: N. D. Debyatkov). *Sov. Phys.-Usp.* 16(4):569-570, Jan.-Feb. 1974.

Findings related to research methodology problems and the results of exposure of certain biological objects to millimeter-band electromagnetic waves are presented. The effects of frequency, power flux density, exposure time, ambient temperature, and the identity of biological conditions were investigated in detail. Polarization was held constant, and all experiments were performed with continuous irradiation. It was established for a wide variety of microorganisms and tests that at a threshold power flux density of 0.01 mW/cm^2, effects vary weakly over several (2 and 5) orders of magnitude when a marked thermal effect, not produced by other heating sources, begins to make its appearance. The longer the time of irradiation, the stronger the observed effect, although saturation was noted after several hours. Effect of frequency on exposure is dependent on the acute resonant nature, and varies depending on the object and the test. Radiation of the fungus *Aspergillis aryazl* produced an increase in proteases with fibrinolytic activity. The original strain was irradiated at wavelength 6.6 mm, power flux density 0.1 mW/cm^2. Ten 2-hr doses were administered. Irradiation increased the proteolytic activity of the *aspergillis* by a factor of 1.5-2. The increase in fibrinolytic activity was not accompanied by an increase in biomass. Six months' observation verified that the effect was inherited. *Staphylococci* (strain 209) culture was irradiated repeatedly for 1 hr daily at 7.08 mm, power flux density 0.1 mw/cm^2. Over the course of multiple exposure, hemolytic activity, the ability to coagulate plasma, lecithinase activity, and gold pigment disappeared, in that order. In experiments on rabbits with 8 x 8 cm traumata on their backs infected with *staphylococci*, a decrease in the inoculability of the *staphylococci* was established after a series of daily radiation for 20 min, and healing time was reduced 20% compared to controls. Normal regeneration was observed on cytological examination of the secreta from the irradiated wounds. Peripheral blood showed moderate leukocytosis of neutrophilic nature, monocytosis and lymphopenia, indicating an augmented protective response of the organism. (No references)

0265 A STUDY OF THE EFFECTS OF MILLIMETER-BAND MICROWAVES ON THE BONE MARROW OF MICE.
(E.) Sevast'yanova, L. A. (no affil.) and R. L. Vilenskaya *Sov. Phys.-Usp.* 16(4):570-571, Jan.-Feb. 1974.

A decrease in the number of bone-marrow cells damaged by x-rays has been observed in previous studies when animals have been exposed to microwave fields. The present paper reports counts of mouse bone-marrow cells that remained undamaged by x-irradiation after prior irradiation with a microwave field in which the exposure time, power density of the field, and wavelength were varied. Counts of undamaged bone-marrow cells, normalized to the control (N/N_0), were plotted against power flux density (P) in the range from 1 to 75 mW/cm^2, for a constant 1-hr exposure time. X-ray dose was 700 rad. Preliminary microwave irradiation of the animals had no influence on N/N_0 up to a power flux density P = 10 mW/cm^2. This power density was then used for experiments in which the exposure times of the animals were varied. Microwave effects appeared at t = 30 min, and at 60 min N/N_0 reached 0.8. Further increase in time was not accompanied by any appreciable increase in the number of cells which remained undamaged by x-rays, indicating the optimum irradiation time to be 60 min. In experiments varying the wavelength of microwaves from 6.6 to 7.7 mm, undamaged-cell count rose from 0.5 to 0.85 at wavelengths of 6.7 and 6.82 mm, in the range 7.09-7.16 mm, and at 7.26 and 7.7 mm, while there was no protective effect at the other wave lengths studied. This behavior of the $N/N_0(\lambda)$ relationship suggests a resonant mechanism for the action of the microwave field. (5 references)

0266 EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON THE FUNCTIONAL ACTIVITY OF CERTAIN GENETIC ELEMENTS OF BACTERIAL CELLS. *(E.)* Smolyanskaya, A. Z. (no affil.) and R. L. Vilenskaya. *Sov. Phys.-Usp.* 16(4):571-572, Jan.-Feb. 1974.

The effects of millimeter waves on intracellular systems responsible for lethal synthesis in bacteria; i. e., colicin, were investigated. The activity of colicin synthesis in colicinogenic strains *E. coli* C600 (E_1) and *E. coli* K12S, sensitive to the colicin of the former, was determined by the lacunae method, in which the numbers of individual colicin-synthesizing bacteria are counted and evaluated with the aid of the induction coefficient determined by the ratio of lacuna formation frequencies in experiments and controls. The number of cells that synthesized colicin increased by an average of 300% on irradiation at wavelengths 5.8, 6.5, and 7.1 mm; 6.15 and 6.57 mm showed no effect, indicating that the regulation of functional activity in certain (in this case of extrachromosomic) genetic elements of bacterial cells may also be induced by microwaves. The behavior of the induction coefficient of colicin synthesis as a function of wavelength was investigated in greater detail in the range 6.50-6.59 mm. Results indicate that colicin synthesis is a resonant function of wavelength. The statistical significance ($P < 0.001$) of the differences between the comparison indicators in the control and experimental systems was demonstrated on statistical reduction of the results of repeated experiments (from 15 to 25 at each point). The effect was directly dependent on irradiation time. Irradiation for 30 min at 20 C had no influence on colicin synthesis; synthesizing increased by a factor of 1.5-2 after 1 hr, reaching a maximum at 2 hr. At 37 C, synthesis was induced by 30-min radiation. Variation of the power flux density through a factor of 100, from 0.01 to 1.00 mW/cm^2, had no influence on the induction coefficient. A reduction of the power to 0.01 mW/cm^2 resulted in a sharp decrease in the biological effect, indicating likely nonthermal effects of millimeter waves, since thermal effects depend primarily on flux intensity. Unlike other agents (both physical and chemical) which induce colicin synthesis by disintegrating DNA or blocking its synthesis, millimeter-band radiation is a fundamentally new agent that disturbs the functional regulatory mechanism of genetic elements in the cell, and extrachromosomic elements in particular, without causing direct damage to the DNA molecule. (2 references)

0267 EFFECTS OF MILLIMETER-BAND RADIO WAVES ON CERTAIN PROPERTIES OF BACTERIA. *(E.)* Kondrat'eva, V. F. (no affil.), E. N. Chistyakova, I. F. Shmakova, N. B. Ivanova and A. A. Treskunov. *Sov. Phys.-Usp.* 16(4):572-573, Jan.-Feb. 1974.

The influence of millimeter-band radio waves on sporogenesis, antigenic and proteolytic properties of bacteria was investigated. Three strains of *Cl. sporogenes*, two of *Cl. histolyticum* (anaerobic spore bacteria), and three strains of *Bact. prodigiosum* (an aerobic bacterium) were used. Each strain was irradiated 20 times at wavelength 7.20 mm for 3 hr. After irradiation, *sporogenes* and *histolyticum* shrank to half the size of controls, seldom appeared in pairs and chains, and showed a strong and consistent decrease in spore-forming ability. Two cultures lost their ability to form spores altogether without recovery after a year and 20 subculturings. There were changes in growth formations and color. The antigenic properties of bacteria were affected. Irradiated *sporogenes* and *histolyticum* cultures began to agglutinate at titers 1/2 to 1/4 those of controls. There was no change in the saccharolytic activity of bacteria, but proteolytic activity declined. The irradiated bacteria were slower to react on milk and fragments of meat, indicating a change in protein metabolism. Rabbits and white mice were inoculated with *histolyticum* cultures and observed for six days. Animals inoculated with unirradiated cultures perished during the first four days to a maximum dilution of 1:8. Of the eight rabbits inoculated with the irradiated cultures, one perished at the 1:8 dilution, and the rest after administration of undiluted or 1:2 diluted cultures. The survivability of bacteria irradiated at microwave lengths between 7.1 and 7.20 mm was diminished at all wavelengths, the strongest effect observed from the 7.15 mm wavelength. (No references)

0268 EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC WAVES ON CERTAIN ASPECTS OF PROTEIN METABOLISM IN BACTERIA. *(E.)* Manoĭlov, S. E. (no affil.), E. N. Chistyakova, V. F. Kondrat'eva and M. A. Strelkova. *Sov. Phys.-Usp.* 16(4):573-574, Jan.-Feb. 1974.

Material from an investigation of the effects of millimeter radio waves on certain aspects of the protein metabolism of anaerobic and aerobic bacteria and on fungi, whose protein metabolisms exhibit qualitative differences, are reported. *Cl. sporogenes, Cl. histolyticum* (anaerobes); *B. prodigiosum, Staphylococcus aureaus* (aerobes); and *Act. norsie, Pen nigricans* (fungi) were studied. The microbes were irradiated at wavelengths of 7.2 and 7.6 mm by a backward-wave-tube source at an average power flux density of 4-5 mW/cm^2 in the radiation incident on the object. Equal numbers of irradiated and unirradiated microorganisms were introduced into the nutrient medium, and the free amino acid contents were determined by Baudet's method in this medium after one day of growth. All data were calculated as percentages of the amino acid contents in the nutrient medium after unirradiated microorganisms had been cultivated in it. A series of experiments also investigated the effects of different wavelengths (7.2 and 7.6 mm) on the *Staphylococcus*, and the protein metabolism of individual amino acids in the various microbes after irradiation at 7.2 mm. Qualitative and quantitative differences in the effects of different wavelengths were found. Wavelengths also acted variably on amino acids with acidic or alkaline properties. "Acidic"

amino acids increased after growth of microbes irradiated at 7.2 mm, with no difference at 7.6 mm. "Alkaline" acids decreased during growth of bacteria irradiated at 7.2 mm and increased at 7.6 mm. Changes in the contents of "acidic" and "alkaline" amino acids were also observed after irradiation of aerobes, anaerobes, and fungi at 7.2 mm. Findings indicate that millimeter band microwaves have a definite influence on the protein metabolism of bacteria, manifested either in the form of activation or inactivation of proteolytic enzymes or in a change in activity of enzymes participating in the metabolism of the individual amino acids. (3 references)

0269 REACTIONS OF LIVING ORGANISMS TO EXPOSURE TO MILLIMETER-BAND ELECTROMAGNETIC WAVES. *(E.)* Zalyubovskaya, N. P. (no affil.). *Sov. Phys.-Usp.* 16(4):574-576, Jan.-Feb. 1974.

The reactions of organisms in various stages of evolutionary development (viruses, microbes, insects, birds, and mammals) were studied. Exposure of microorganisms (*Staphylococcus, Streptococcus, E. coli,* typhoid bacillus) to mm waves lowered their survival rates by 60% and more, affected the morphological, culturing, and biochemical properties; increased their sensitivity to antibiotics; and modified their antigenic properties. The infective activity of irradiated viruses was lowered. The biological effects depended on wavelength and exposure time; bactericidal action was most pronounced at 6.5 mm. Irradiation of adult male and female *Drosophila* for 15-60 min resulted only in lessened fertility dependent on the wavelength of the radiation and duration. Prolonged exposure (3-5 hr) at 6.5 mm resulted in significant changes including lessened viability, fertility, and mutations in the second generation. Seven-day-old chick embryos were irradiated with millimeter waves 5 times for 30 min. None perished and there was no weight loss, but the incubation period was lengthened by 2-3 days, and hatched chicks were somewhat retarded in development, especially when irradiation had been at 6.5 mm. Irradiated chicks lagged behind controls in weight through observations up to 50 days. Irradiation of white rats and mice over 40-50 days for 10-15 min was not lethal, but physical and behavioral changes were noted. Food and drink were refused for some time; hair on shaved skin areas failed to grow back; and biopsies showed atrophy of the Malpighian layer, sclerosis of derma, and abnormalities in the outer layer of skin and underlying muscle. Blood coagulation rate was higher after irradiation (68.2 ± 1.5 sec in the control, 35.0 ± 1.3 sec after irradiation at 6.5 mm; $p<0.01$). Hemoglobin content decreased, and blood-serum albumin was lower. Total nucleic acids and albumins were decreased in liver and spleen, and irradiated animals showed lower resistance to infection; antibody (agglutinin) and blood lysozyme levels were half those of controls. The studies suggest that the action of millimeter waves is a general biological one not limited by phylogenetic differences between organisms, the effects being dependent on wavelength and exposure time. (No references)

0270 EFFECTS OF MILLIMETER-BAND ELECTROMAGNETIC WAVES IN THE CELL AND CERTAIN STRUCTURAL ELEMENTS OF THE CELL. *(E.)* Kiselev, R. I. (no affil.) and N. P. Zalyubovskaya. *Sov. Phys.-Usp.* 16(4):576-577, Jan.-Feb. 1974.

The basic criteria for evaluation of millimeter-wave effects on cells were morphological and biochemical indicators, survival rates, and changes in antigenic, culturing, and virulence properties of the irradiated objects. Irradiation resulted in damage to the cell membrane, degeneration of protoplasm, and an increase in the cells and nuclei, and nucleic acid and albumin contents. It is possible that by affecting cell metabolism microwaves influence synthetic processes. The number of viable cells decreased after irradiation at various wavelengths, 6.50 mm showing more conspicuous biological activity. This wavelength also produced significant changes in hemolytic stability of red blood cells (erythroctyes), indicating functional and structural changes. Changes in nucleic acid and albumin contents also occurred in nuclei and mitochondria separated from liver cells. Millimeter-wave irradiation of viruses (adenoviruses, measles virus, vesicular stomatitis virus, and others) resulted in reduction of virus particles by a factor of 2-3. Lowered infectious activity of adenoviruses and measles virus was manifested in a delay of the cytopathogenic effect on tissue culture. The infectious activity in tissue cultures treated with DNA irradiated at 6.50 mm appeared between 15 and 16 days, as compared to untreated at 10 days, and corresponded morphologically to a manifestation of the whole virus, indicating a loss of infectious activity but not of transforming activity as shown in the later appearance of the cytopathogenic effect. The influence of microwave irradiation on the cellular genome was judged from the increase in latent-phage and colicin productive activity after irradiation of lysogenic and colicinogenic microbe strains. After irradiation of the latter at 6.50, colicin titer increased, and increased production of phage particles was observed in lysogenic microbe strains; the latter significant at 5.9, 6.1, 6.50, and 7.5 mm; $p<0.01$. The data indicate a possible use of millimeter-band electromagnetic waves toward controlled modification of viruses and microbes. (No references)

0271 OUTLOOK FOR STUDY OF THE MECHANISMS OF THE NONTHERMAL EFFECTS OF MILLIMETER- AND SUB-MILLIMETER-BAND ELECTROMAGNETIC RADIATION ON BIOLOGICALLY ACTIVE COMPOUNDS. *(E.)* Gaĭduk, V. I. (no affil.), Yu. I. Khurgin and V. A. Kudryashova. *Sov. Phys.-Usp.* 16(4):577-578, Jan.-Feb. 1974.

Aqueous solutions of hemoglobin (Hb) were irradiated at millimeter band wavelengths around 7.35 mm for 5 hr at a radiation intensity of 1 mW/cm^2 and temperatures 37-40 C. After exposures, the percentage acid hydrolysis of the Hb (splitting off of heme) was lower than that in the control; i.e., there was increased strength in the bond between heme and protein after irradiation. This can be interpreted as an increase in the stability of the Hb to the transition (during irradiation) from the active *oxy* form to the inactive *met* form, since the rate of acid hydrolysis of *oxy*-Hb is much lower than that for *met*-Hb. These changes may be explained by either of two hypotheses: 1) A single molecular group in the active center, distal histidine E7, essential to the Hb function, may be responsible; the energy of the histidine oscillation and its average position with respect to the iron atom being changed under the influence of microwaves; or 2) The action of microwaves is transferred to the histidine as a result of excitation of vibrations of the macromolecule as a single entity--the "protein-machine" hypothesis. Microwave irradiation may assist in determining which, if either, theory is applicable, and be useful for resonance control of biological processes such as the addition of oxygen to Hb, in order to regulate enzyme reactions and study the properties of biopolymers; e.g., their catalytic activity. The use of physicochemical methods to indicate microwave exposure is also promising. There is the possibility of developing a microwave method for measuring the degree of hydration of biopolymers in solution at different temperatures (NMR and microcalorimetric measurements yield the amount of free water when frozen solutions are melted). The proposed method would yield information on the interaction of amino acids and other biologically active compounds with water, and could be used to construct a theory of resonant microwave effects on biopolymers. In addition, direct determination of the hydration number would be helpful to understanding the nature of the reactivity of organic compounds in the liquid phase and certain specific properties of macromolecules determined by their interaction with the aqueous medium. (12 references)

0272 REMARKS ON TWO POSSIBLE MECHANISMS OF THE EFFECT OF MICROWAVES ON HEMOGLOBIN. *(E.)*

Chernavskii, D. S. (no affil.). *Sov. Phys.-Usp.* 16 (4):578-579, Jan.-Feb. 1974.

The direct action of microwaves on histidine, and on the molecule as a whole, with excitation of elastic oscillations of the entire structure of the protein, may be regarded as two aspects of the same mechanism, rather than alternatives. It might be appropriate to recall the hypothesis of the role of elastic deformation in enzymatic catalysis. These elastic deformations in the enzyme-protein may be thought of as a "spring" which at the proper time transfers energy into the active center, where the substrate molecule is located. Estimates have indicated that the dimensions of the "spring" would indicate a system of a size which has a natural vibration frequency of the same order of magnitude as the resonance frequency in the spectrum of the microwave effect. The conclusion that a preferred frequency exists follows from the hypothesis that the deformations are elastic in nature. The "protein machine" concept indicates that the one generalized degree of freedom that encompasses the entire molecule and is characterized by a common frequency should be preferred in the macromolecule. The vibration frequencies of the several parts of the machine that participate in the ensymatic event (in particular the histidine radical) are the same as the common frequency. The direct action of microwaves in the histidine in hemoglobin should cause the entire "machine" to oscillate; the two mechanisms representing different aspects of the same mechanism. The highly important question as to the influence of temperature on oscillation, which may, in fact, not be particulary strong, requires special attention. In classical physics there are many examples of the excitation and survival of low-frequency vibrations against a background of higher-frequency thermal vibrations. The protein macromolecule is sufficiently massive and "classical." The experimental trend in millimeter-band effects of microwaves may cast light on many fundamental problems of enzymatic catalysis. *(2 references)*

0273 AUGMENTATION OF BONE REPAIR BY INDUCTIVELY COUPLED ELECTROMAGNETIC FIELDS. *(E.)*

Bassett, C. A. L. (Coll. Phys. Surgs., Columbia Univ., N.Y.), R. J. Pawluk and A. A. Pilla. *Science* 184:575-577, May 1974.

The effects of electromagnetic fields on bone repair in 43 adult beagles were investigated. Pulsing, magnetic fields produced by air-gap, rectangular coils were used to induce dynamic, orthogonal, voltage fields in bone and soft tissue. The basic coil, 215 by 3 cm, internal dimensions, allowed a homogeneous voltage field on 1.5 to 2 cm of bone, placed in a plane parallel to the inside coil edge. Bilateral, transverse, fibular osteotomies were performed 3.5 to 4.5 cm distal to the proximal fibular head. Two different, pulse-shaping, circuit designs were applied. In the first group of 22 animals, a pulse of 1 msec duration repeating at 1 Hz (1P, 1 Hz), produced a peak voltage field of 2 mV/cm in bone. In the second group of 21 animals, a circuit was used with a pulse of 15 μsec duration repeating at 65 Hz (10P, 65 Hz) and producing a peak of 20 mV/cm in bone. In the first series employing the 1P, 1 Hz circuits, 20 animals were available for study at 28 days. In 10, the stimulated leg produced larger load values than the contralateral control. The remaining 10 had greater load values associated with the unstimulated side. The mean load values revealed no statistically significant difference. Thirteen animals bearing 10P, 65 Hz at pulse 15 μsec (pulse varied on remainder) were available for analysis 28 days after operation; 10 demonstrated higher load values (greater stiffness)

in the treated legs, with percentage increases in load far larger than those produced by the inactive legs in this or the first series. Three animals had a greater load value associated with the control leg. The findings are significant by the sign test P <.07. The active values were also statistically significant when grouped by size of deformity and compared with controls. The studies demonstrate that low-frequency, low-intensity, external pulsing electromagnetic fields can be inductively coupled to tissue to achieve an increase in the tempo of a repair response. (17 references)

0274 POSSIBILITIES FOR CONTROLLING INSECTS WITH MICROWAVES AND LOWER FREQUENCY RF ENERGY. *(E.)* Nelson, S. O. (Agric. Res. Serv., USDA, Univ. Nebraska, Lincoln) and L. E. Stetson. *IEEE Trans. Microwave Theory Tech.* MTT-22(12):1303-1305, Dec. 1974.

Insects that infest grain, cereal products, wood, seed and other stored products can be controlled through dielectric heating by microwave or lower radio frequency (RF) energy. The principles applicable to the control of stored-product insects with RF energy, and general research findings on this topic, are reviewed. Data are presented on the frequency dependence of the dielectric constant and dielectric loss factor of insects and grain, and use of such information is discussed in relation to RF treatment of infested products to control insects. Experimental data that confirm the usefulness of information on dielectric properties are presented. These data show that RF treatment at 39 MHz is much more effective for controlling adult rice weevils in wheat than is treatment at 2450 MHz. Complete insect mortality was obtained with much lower grain temperatures, indicating that a higher degree of differential heating was obtained in the lower frequency range than was obtained at microwave frequencies. Some aspects of practical application are also considered. (19 references)

0275 EXPOSURE OF BACTERIA TO 2450 MHz MICROWAVE RADIATION. *(E.)* Hamrick, P. E. (Natl. Inst. Environ. Hlth Sci., Research Triangle Park, N. C.) *J. Microwave Power* 8(3):227-233, 1973.

Four strains of *Escherichia coli* and one strain of *Pseudomonas aeruginosa* were exposed to continuous 2450 MHz microwave radiation in a system designed to give uniform field of continuous wave radiation at the sample holder with no more than 10% variation in power density over a 6 inch diameter. Samples were exposed for 12 hr at an intensity of 60 mW/cm^2. The growth curves of control and exposed bacteria were compared for this 12-hr period. No effect on cell replication rate was detected that could not be explained as a result of temperature variation. These findings do not imply that bacteria exposed to radiation at other frequencies will not exhibit changes in growth rate; or that 2450 MHz microwave radiation will not affect other biological systems, since studies on chick embryo indicate that differentiating tissues may be affected by low-level radiation. The fact that rapidly growing and dividing bacteria are not affected, whereas differentiating tissues are, should be important in discovering how microwave radiation interacts with biological material. (12 references)

0276 ORIENTATION AND FREQUENCY EFFECTS ON WHOLE ANIMAL ABSORPTION OF MICROWAVES--LETHALITY EXPERIMENTS. *(E.)* Hawkins, T. D. (Dept. Microwave Res., Walt. Reed Army Inst. Res., Washington, D. C.), J. Schrot, J. Sharp and O. P. Gandhi. *Proc. Int. Microwave Symp.*, June 12-14, 1974.

In recent experiments with rats and biological phantom and salinefilled prolate spheroidal bodies, radio frequency (RF) absorption was found to depend strongly upon the polarization and frequency of electromagnetic fields. Power deposition more than an order of magnitude greater was observed at resonance for waves polarized along the long dimension of the body. This paper describes the time to convulsion measured on 100 and 400 g rats, and 25 g mice exposed to microwave radiation at 985, 1700, and 2450 MHz with electric and magnetic fields along the lengths of the animals, resp. The presented data are based on observations on 198 animals, 33 at each frequency in each of two orientations. In each case, as expected, radiation polarized along the long dimension (â) was more lethal than that along the shorter dimensions. The most dramatic results were observed on mice that convulsed at 985 MHz in the $\vec{E} \| \hat{a}$ orientation with an average time of 500 seconds as compared to no visible effects on such animals for up to 7200 seconds at $\vec{H} \| \hat{a}$ radiation exposure. This is ascribed to the resonance effect described previously. For 100 and 400 g rats, the resonance frequencies are predicted to be on the order of 550 and 325 MHz, resp., much lower than the lowest observation frequency of 985 MHz. Further experiments are in progress to define the mechanisms involved. (No references)

0277 CARDIAC PACEMAKER EMC IN PERSPECTIVE. *(E.)* Miller, D. A. (IIT Research Institute, Chicago, Ill.). *Proc. IEEE Electromagnetic Compatibility Symp.*, June 20-23, 1973.

The susceptibility of cardiac pacemakers to electromagnetic interference has been investigated by both engineers considering electrical phenomena and by physicians deeply concerned with clinical impact. This summary reviews the significant work done so far in each field, and designates seven areas which need to be considered in future work to give a perspective

on cardiac pacemaker EMC: (1) the clinical significance of cardiac pacemaker interference susceptibility, (2) the response of different types of pacemakers to various interference situations, (3) various coupling mechanisms in the pacemaker, (4) test methods, (5) the role of animal tests, (6) the role of clinical studies, and (7) the requirements for standards development. A distinguished panel of six persons from medical, instrumentation and technical fields has been assembled to address these areas. (10 references)

0278 NERVE IN EXCITABLE STATE IN MICROWAVE FIELD. *(E.)* Kamal, A. K. (Electron. Comm. Eng. Dept., Univ. of Roorkee, UP, India), S. C. Gupta and S. Gupta. *Med. Biol. Eng.* 12(6):827-830, Nov. 1974.

The electrical conductivity of squid axon membrane was calculated in the excitable state under microwave radiation at frequencies from 100 kHz to 100 MHz. Since the conductivity of excited squid axon increases with the strength of stimulus, with the result that ionic currents such as sodium and potassium also increase, the behavior of ionic currents of nerve in excitable state was predicted theoretically in the presence of microwave fields, and an electronic model was proposed and used to find the behavior of nerve membrane. The curves of various ionic currents and membrane conductances were plotted for the squid, to show the various effects of microwave radiation fields. From the curves it is clear that, as the applied radiation frequency increases, currents also increase, due to the conductivity modulation of the membrane. (5 references)

0279 AGRICULTURAL MICROWAVE APPLICATIONS RESEARCH. *(E.)* Nelson, S. O. (Agric. Res. Serv., Univ. Nebraska, Lincoln). *IMPI Newsletter* 2(3):19-21, Aug. 1974.

Research on the use of radiofrequency (RF) energy to help solve agricultural problems conducted jointly by the USDA and the University of Nebraska, at Lincoln, is reviewed. Experiments have dealt with the possibility of using RF to dry grain, control stored-grain insects, improve seed germination and carotene retention in alfalfa, control loose smut in barley, improve the nutritional quality of soy beans, and non-destructively measure moisture content. The need for information on the dielectric properties of materials exposed to RF electric fields required the development of techniques, apparatus, and measurement methods over a wide range of frequencies. Experiments in recent years have included treatments at 2.45 GHz, and several microwave systems have been assembled. As is true with other potential RF and microwave power applications, economic factors have hampered the adoption of RF processes for commercial use. Studies are continuing to determine whether the efficiency of RF applications to agriculture can be substantially improved. (1 references)

0280 MICROWAVE EMISSIONS IN THE AIR: ARE THEY A BIOLOGICAL TIME BOMB? *(E.)* Anonymous. *Med. World News* 15(29):22-23, Aug. 2, 1974.

With microwave ovens, radio and TV transmitters, radar dishes, medical diathermy machines, and other sources of non-ionizing radiation broadcasting unprecedented quantities of electromagnetic emissions through the air, there is a growing worry that some more subtle nonthermal effect may be occurring from this radiation. This article briefly reports the recurring expressions of concern with the possible dangers from uncontrolled exposure and the need to determine the effectiveness of present "safe exposure limits." The work of Drs. Przemyslaw Czerski and Maksymilian Siekierzynski, of Warsaw's National Research Institute of Mother and Child, and their concern with the still unexplored effects of microwave exposure on children, the aged, sick, pregnant women, and the general public is mentioned. Differences in national limitations and standards, the Office of Telecommunications Policy report and call for extended research, and Dr. Zorach Glaser's reported biological phenomena are also described. (No references)

0281 THE CIRCADIAN PERIODICITY OF MAN AS AN INDEX FOR THE BIOLOGIC ACTION OF ELECTROMAGNETIC FIELDS. *(Ger.)* Wever, R. (Max Planck Inst., Behav. Physiol., Seewiesen, West Germany). *Z. Phys. Med.* 2(6):439-471, 1971.

Under natural conditions biological periodicity is synchronized to 24 hr by environmental periodicities depending on the rotation of the earth; e.g., the natural light/dark cycle. In studies of autonomous circadian periodicity in 19 human subjects, internal desynchronization was observed with different periods in activity and in basic functions (e.g., in rectal temperature) over several weeks. Two experimental rooms were used, differing only in that the right room was shielded against electric and magnetic fields. The results from the two experimental rooms showed remarkable and statistically significant differences. In the subjects, unaware of the differences between the rooms, the period of activity ranged between 17 and 65 hr, without the subjects perceiving these abnormalities. It was hypothesized that the natural electromagnetic fields, which penetrated the left room, but not the right, accelerated the free running rhythm, reduced interindividual differences, and prevented internal desynchronization. The hypothesis was tested by equipping the right room, in addition to the shielding, with facilities for introducing various electric and magnetic fields. In preliminary experiments static electric and magnetic

fields proved insufficient. However, a weak electric field, alternating with a frequency of 10 cps, proved as effective as natural fields in significantly shortening the period of human circadian rhythms, reducing the interindividual differences, and preventing internal desynchronization. As was predicted by a mathematical model, additional parameters of the autonomous rhythm were also affected. In other experiments during which the artificial 10 cps field was switched on and off periodically it was found to act as a weak "zeitgeber," confirming the hypothesis that weak electromagnetic fields influence human circadian rhythms. (30 references)

0282 FIFTH SUPPLEMENT TO BIBLIOGRAPHY OF REPORTED BIOLOGICAL PHENOMENA ("EFFECTS") AND CLINICAL MANIFESTATIONS ATTRIBUTED TO MICROWAVE AND RADIO-FREQUENCY RADIATION. *(E.)* Glaser, Z. R. (Electromag. Rad. Proj. Off., Bur. of Med. and Surg., Washington, D. C.). *Med. Res. Dev. Command Report*, AD 784-007/7, July 1974.

This report is the fifth supplementary "up-dated" bibliographic listing to Naval Medical Research Institute Research Report No. 2, completed in 1971 by the author, and available in revised form, with Supplements 1 through 3, from NTIS as AD 750-271. The revised report contains more than 2300 literature citations, and includes as a first chapter, an outline of the effects which have been attributed to radio frequency and microwave radiation. Almost 500 additional references are contained in the latest supplement to this bibliography of the world literature. Particular attention has been paid to the effects of non-ionizing radiation on man at the radio and microwave frequencies. Citations are arranged alphabetically by the author (where possible), and contain as much information as possible to assure effective retrieval of the original documents. Soviet and East European literature is included in detail, and a final section lists pertinent national and international technical meetings with presentations and authors. Supplement No. 4, completed in June 1973, is available from NTIS as AD 770-621.

0283 BIOLOGICAL EFFECTS OF MICROWAVES: A BIBLIOGRAPHY WITH ABSTRACTS. *(E.)* Harrison, E. A. (Natl. Tech. Inf. Serv., Springfield, Va.). *Natl. Tech. Inf. Serv.*, WIN-73-070, Oct. 1973.

This bibliography contains 76 selected abstracts of research reports covering the biological effects on man and animals that can result from exposure to microwaves. The bibliography was prepared from NTIS's online interactive bibliographic retrieval system consisting of more than 360,000 records of documents dating from 1964 through September 1973. The documents were submitted by all major departments and agencies within the federal government, as well as leading private organizations or individuals with federal grants and contracts. Each citation indicates the availability of the document and, when available from NTIS, quotes the price. A special order form is included.

0284 CONTINUOUS MONITOR OF DANGEROUS LEVELS OF MICROWAVE POWER. *(E.)* Hannah, S. (Dept. Electr. Electron. Eng., Univ. Newcastle-upon-Tyne, U.K.). *Electron. Lett.* 10(14):274-276, July 1974.

A small-size instrument which can be carried in a pocket, similar to the well-known x-ray photographic monitor, is needed continuously to monitor dangerous maximum and average levels of microwave power. This paper reports the development of such a device. By solving Maxwell's field equations for a plane wave normally incident on an isolated thin conducting film, it was found that such a film can be made to exhibit a maximum absorption of 50% of the incident power over a broad frequency range, if its skin resistivity is made equal to half the intrinsic impedance of free space. Usable germanium (Ge) films were produced having skin resistivities within 4% of their desired value by depositing Ge on to a heated glass substrate. The resulting Ge film is 3 μm thick with conductivity of $1.75 \times 10^{3}\Omega^{-1}m^{-1}$. Sensors were produced with a free Ge surface area of 2.3×1 cm^2 on differing-thickness glass substrates of 3×1 cm^2 size. Contact resistances are of the order of a few ohms, and the skin resistivities between 196 and 192 $\Omega/\square$. Testing determined that the sensor is capable of reliably monitoring power levels from 1 mW/cm^2 to 1 W/cm^2 without deterioration. A signal processing circuit which is compact, light-weight and of low power consumption was also developed and an instantaneous display is obtained by driving light-emitting diodes from the ten outputs of a decade counter. This display can be switched on by hand or switched on automatically when a certain danger level is reached. An acoustic signal can also be activated if desired. Integrated exposure level is obtained by the use of either a 'log E' silver cell at the input to the counter, or by a piece of photographic film placed alongside a light-emitting diode, which is activated by the counter input. (3 references)

0285 INTERACTION OF A 2450 MHz MICROWAVE FIELD WITH THERMOCOUPLES AND THERMISTORS. *(E.)* McRee, D. I. (Natl. Inst. Environ. Hlth. Sci., Research Triangle Park, N. C.) and F. T. Pendergrass. *Health Phys.* 25 (August):180-182, 1973.

Research data on biological effects of microwave radiation is of limited value for establishing safe exposure levels because of lack of accurate dosimetry. The amount of energy absorbed by a biological speci-

men is usually measured by thermistors or thermocouples, but erroneous measurements may result from interactions of the incoming microwave field with the devices. This paper presents experimental results illustrating these interaction problems, and provides suggestions for eliminating them. The interaction of the microwave field with shielded and unshielded thermistors and thermocouples was evaluated. The devices were placed in a zone irradiated by a 2450 MHz, continuous wave microwave field. Both devices were connected to a strip-chart recorder, placed in the field in two different geometrical orientations, with power levels at sensing areas set at 100 mW/cm^2. Time-temperature profiles for thermistors, shielded or unshielded, were almost the same. Temperature rise was a real one, due to the heating of the absorber. Orientation of the thermistor leads to the electric field had no effect. Unshielded thermocouples were unsatisfactory because of interaction effects of microwave fields with leads. To eliminate these effects the leads were placed inside a 1/8 in. copper braided shield, grounded at the recorder ground terminal and extended to 1 in. from the thermocouple tip. Time-temperature profiles were similar to thermistor profiles, but the spread in the data was greater. Higher temperatures resulted when thermocouples were oriented parallel to the electrical field, indicating some small amount of interaction. Proper shielding and grounding of all components, selection of detectors which are less sensitive to electromagnetic fields, and high resistance and shielded leads oriented perpendicular to the field reduce the possibility of erroneous measurement. (3 references)

0286 FURTHER EXPERIMENTS SEEKING EVIDENCE OF NONTHERMAL BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. *(E.)* Lindauer, G. A. (Emerson Electric, St. Louis, Mo.), L. M. Lie, G. W. Skewes and F. J. Rosenbaum. *IEEE Trans. Microwave Theory Tech.* MTT-22(8):790-793, Aug. 1974.

Experiments undertaken to verify and augment earlier observations on teratological damage inflicted upon the darkling beetle *Tenebrio molitor* by low power microwave irradiation are reported. Individual experimental parameters--duty cycle, orientation, pupa age, power level, and total absorbed energy--were varied in a phenomenological approach to elucidate mechanisms by which teratological damage is realized. One- to two-day-old pupae (nominally, 3/16-in diameter x 5/8-in length) were mounted for irradiation in styrofoam blocks, then inserted along the center line of X-band waveguides with their anterior portions towards the power source. The waveguide was terminated in a matched load. The pupae were irradiated at 9 GHz, then placed for the duration of pupation in individual numbered vials in a darkened chamber at 21 C. The emergent adults were categorized for gross morphological defects in ignorance of whether a particular insect was from the irradiated or control group. The incidence of abnormality increased more than three-fold with irradiation, while death rate remained essentially unchanged. The data do not reveal statistically significant evidence for the dependence of teratological damage on duty cycle, orientation, pupa age, or irradiation intensity. The incidence of damage does depend on the amount of energy absorbed by the pupa, which may depend on age when irradiated. Experiments conducted to date have not shown the incidence of damage to be dependent on whether the microwave power is pulsed or continuous wave, but only a small range of pulse repetition frequencies was used. (10 references)

0287 ACCELERATION OF FRACTURE REPAIR BY ELECTROMAGNETIC FIELDS. A SURGICALLY NONINVASIVE METHOD. *(E.)* Bassett, C. A. L. (Coll. Phys. Surg., Columbia Univ., N.Y.), R. J. Pawluk and A. A. Pilla. *Ann NY A Sci.* 28:242-262, 1974.

The effects of external electromagnetic coils on repair of fibular osteotomies were investigated in the beagle. The osteotomies were flanked medially and laterally by coils driven by 1-P 1-Hz or 10-P 65-Hz circuits. *In vitro* experiments showed that the level of induced voltage at the osteotomy site was 2 mV/cm for the 1-P 1-Hz circuits and 20 mV/cm for the 10-P 65-Hz circuits. In *in vivo* experiments, cantilever load values were computed for each of 3 deformations (0.025, 0.050, and 0.075 in.) in fibulae stimulated by pulsed 1-Hz or 65-Hz fields. At each deformation, stimulated values for the 10-P 65-Hz circuits were significantly higher than values for unpowered control circiuts. Values for animals exposed to the 1-P 1-Hz circuits were not statistically significant. Specimens in the 10-P 65-Hz series were characterized not only by a small mass of callus on the 28th postoperative day, but also by fibroosseous or osseous tissue that united the osteotomized ends of the fibula. Newly formed tissue was aligned parallel to the long axis of the bone. Cartilage, when present, displayed advanced endochondral-like ossification. The results indicate that the major effects of electromagnetic field stimulation were exerted on architectural and maturation aspects of the reparative process; i.e., the healing process was accelerated. Controlled application of the 10-P 65-Hz induced wave form to human fractures appears justified. (45 references)

0288 MICROWAVE HALL MOBILITY MEASUREMENTS ON HEAVY BEEF HEART MITOCHONDRIA. *(E.)* Eley, D. D. (Med. Sch., Univ. Nottingham, U.K.), R. J. Mayer and R. Pethig. *Bioenergetics* 4:187-200, 1973.

At an applied field of 1.21 tesla, heavy beef heart mitochondria (HBHM) yielded initial microwave Hall mobility values at least 6 times greater than values for bovine serum albumin at similar resistivity values. The Hall signal was markedly reduced by cyanide, suggesting that the signal from untreated HBHM originated in the cytochrome oxidase part of the

respiratory chain. Measurements on completely or partially purified respiratory complexes confirmed that Hall mobility was greatest for cytochrome oxidase. Smaller Hall signals were given by NADH-cytochrome c reductase and succinate coenzyme Q reductase. Prolonged exposure to 9.2 GHz (60 mW) irreversibily damaged the electron transport pathway (as measured by Hall signal) of cytochrome oxidase. This was accompanied by complete loss of capacity to oxidize ferrocytochrome c. Such changes did not occur with HBHM or with the other respiratory complexes. To determine whether the reduction in the Hall signal of cytochrome oxidase with time in the microwave cavity was due to oxidation or denaturation by microwave power, experiments were performed with fully reduced and oxidized cytochrome oxidase. The results indicated that the decay in Hall signals from cytochrome oxidase was due to irreversible denaturation. A semiconductor model for mitochondria is outlined. (45 references)

0289 STANDARDS FOR PROTECTION OF PERSONNEL AGAINST NON-IONIZING RADIATION. *(E.)* Michaelson, S. M. (Sch. Med. Dent., Univ. Rochester, N.Y.) *Am Ind Hyg Assoc J.* 35(12):766-784, 1974.

The biomedical effects of non-ionizing radiant energies must be realistically assessed not only to avoid undue exposure of workers or the general public, but to ensure that research, development, and beneficial utilization of these energies will not be restricted. Areas of disagreement on the potential hazards of non-ionizing radiation exist especially in relation to radiofrequency and microwaves (1 to 1 X 10^5mm). According to the best evidence available, the most important, if not the only, effect of microwave absorption in the mammal is the conversion of the absorbed energy into heat. The ANSI standard of 10 mW/cm^2 is roughly a factor of 10 below thresholds of damage by thermal effects, assuming exposure of 0.25 hr or more. Eastern European reports of nonthermal microwave effects on the central nervous system, following exposure to less than 10 mW/cm^2, have not been confirmed in the West. Department of Defense investigations and studies of workers exposed to microwaves for 15-20 yr suggest that the ANSI standard is sufficient. Proposals to adjust the standard to the temperature-humidity index ignore the ability of the body to adjust to considerable fluctuations in ambient temperature and humidity with little or no strain. Research into the biological effects of non-ionizing radiation must be fostered to avoid overly restrictive and unrealistic standards. (61 references)

0290 APPLICATIONS OF MICROWAVE THAWING TO THE RECOVERY OF DEEP FROZEN CELLS AND ORGANS: A REVIEW. *(E.)* Voss, W. A. G. (Surg. Med. Res. Inst., Univ. Alberta, Edmonton, Canada), R. V. Rajotte and J. B. Dossetor. *J. Microwave Power* 9(3):181-194, 1974.

Two resonant microwave systems operating at 2450 MHz were applied to thawing of deep-frozen adult canine kidneys, fetal mouse hearts, and tissue culture cells. The electrical activity of fetal BALB-c mouse hearts, recovered from -196 C by microwave heating at 200 C/min, survived in a high percentage of cases. The hearts were taken from 17- to 19-day-old embryos, frozen in 5 ml samples of Minimum Essential Medium with 25 mm Hepes buffer, 10% dimethyl sulfoxide, and 10% fetal calf serum. Electrical activity, monitored for up to 35 days after s. c. implantation in sygeneic adult mice, did not differ from that of control implants. Overall survival for frozen, thawed, and implanted hearts was 67% (37/55) between 6-10 days and 59% (32/54) at more than 30 days. Survival of Chinese hamster cells was good following rapid microwave thawing at 100-250 C/min (from -79 to + 10 C). Uniform thawing of adult frozen canine kidneys from -79 C was obtained at rates between 100-300 C/min. Heating could be controlled to an end point of 23 C with a variation across the organ of <± 12 C, providing prior perfusion of the organ was complete. Although subsequent functional success has not yet been achieved with frozen thawed kidneys, area of well-preserved glomeruli and capillaries were observed, indicating blood was being perfused. Histologic examination of normal or frozen kidney slices has been difficult and unreliable. (38 references)

0291 AN INTERNATIONAL PROGRAM FOR MICROWAVE EXPOSURE PROTECTION. *(E.)* Michaelson, S. M. (Sch. Med. Dent., Univ. Rochester, N.Y.) and M. J. Suess. *IEEE Trans. Microwave Theory Tech.* MTT 22(12):1301-1302, 1974.

In the developed countries there has been a remarkable increase in the number of processes and devices that utilize or emit microwaves. Such devices are used in all sectors of our society for military, industrial, telecommunications, medical, and consumer applications. Because of the world-wide implications of the rapidly developing technology and associated health-safety considerations, development and implementation of a program for international cooperation in the use and protective measures related to microwave/radiofrequency (MW/RF) exposure is required. Activity in this respect has been initiated by the Regional Office for Europe of the World Health Organization (WHO/EURO) which has developed a sector program concerned with the health effects of non-ionizing radiation (NIR) as part of its long-term program in environmental pollution control (see CL 0228). To implement this program, several steps have been taken with participation by scientists and administrators from several countries. These activities have engendered plans and proposals for facilitating exchange and evaluation of information on the biologic and health effects of microwave radiation and in focusing attention on those areas in which additional information and new approaches are needed. (28 references)

0292 HOT SPOTS GENERATED IN CONDUCTING SPHERES BY ELECTROMAGNETIC WAVES AND BIOLOGICAL IMPLICATIONS. *(E.)* Kritikos, H. N. (Moore Sch. Electr. Eng., Univ. Pennsylvania, Philadelphia) and H. P. Schwan. *IEEE Trans. Biomed. Eng.* BMT-19 (1):53-58, 1972.

The distribution of the heating potential generated by an incident electromagnetic plane wave on a conducting sphere simulating the human head was investigated. It was found that for a sphere of 10-cm radius having the same electrical characteristics as those of biological tissues, no hot spots are generated inside. While at lower frequencies the heating is relatively uniform with some polarization effects, for frequencies above 1000 MHz only skin heating takes place. For a sphere of the same size but of conductivity of σ=10 mmho/cm (which for f>1000 is lower than that of biological tissues) hot spots occur inside for f>1000 MHz. Intense hot spots also occur inside spheres of radius 5 cm having the same electrical characteristics as those of biological tissues in the frequency region of 250 MHz<f<2800 MHz. (10 references)

0293 A LIMITED MICROWAVE DIATHERMY FIELD SURVEY. *(E.)* Kantor, G. (Bur. Radiol. Hlth., Div. Electron. Prod., Rockville, Md.) and P. S. Ruggera. *DHEW Publ. (FDA)* 75-8018, Dec. 1974, 23p.

In a field survey of 5 treatment facilities and 1 educational institution, field patterns were obtained from 7 microwave diathermy machines using a total of 20 applicators. These patterns were compared with those generated in the Electromagnetic Branch Laboratory under anechoic conditions. Operator routine, frequency of use of microwave diathermy, and equipment type and maintenance are reviewed. Average applicator patterns, measured with a Narda 8300 probe, varied from 0.2 mW/cm^2 for a 4" hemisphere to 8.4 mW/cm^2 for a 22" by 5" corner reflector. Aperture leakage was 2.5 mW/cm^2 and 3.2 mW/cm^2, resp., for applicators with a 6" hemisphere and applicators with a 6 3/4" by 5 1/2" corner reflector. Leakage from other units was less than 0.5 mW/cm^2. In all cases leakage from the generator-module was less than 0.5 mW/cm^2. Malfunctioning equipment was observed and therapists and instructors had a limited understanding of electromagnetic radiation despite their awareness of the harmful effect of high-level microwave exposure. In general, operators relied on the recommendations contained in the manufacturer's manual. (3 references)

0294 ELECTROMAGNETIC FIELDS INDUCED INSIDE ARBITRARILY SHAPED BIOLOGICAL BODIES. *(E.)* Livesay, D. E. (Dept. Electr. Eng. Systems Sci., Michigan State Univ., East Lansing) and K. M. Chen. *IEEE Trans. Microwave Theory Tech.* MTT-22(12):1273-1280, 1974.

A theoretical method was developed to determine the electromagnetic field induced inside heterogeneous biological bodies of irregular shape. A tensor integral equation for the electric field inside the body was derived and solved numerically for various biological models. These models include a small dielectric cube illuminated by plane waves of varying intensity; a thin layer of conducting medium illuminated by a plane wave of 300 MHz; a tissue block comprising a fat layer and a muscle layer, illuminated by a 100-MHz plane wave; homogeneous and inhomogeneous muscle cylinders exposed to a 2.45-GHz plane wave; and homogeneous and inhomogenous fat cylinders exposed to a 2.45-GHz plane wave. (10 references)

0295 FIRST REPORT OF I. M. P. I. SUB-COMMITTEE ON THE BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. *Int. Microwave Power Inst. Report,* May 25, 1971.

The purpose and program of the International Micro-Wave Power Institute (IMPI) Subcommittee on the Biological Effects of Microwave Radiation, formed in 1970, are outlined. *Subcommittee activities* include compilation of an international list of references on the biological effects of microwave radiation, to be obtained and maintained through the MEDLARS (Medical Literature Analysis and Retrieval System) of the U.S. National Library of Medicine. The list will extend back to January 1964, and will be updated at 6-month intervals. Information on entries in the list is available to IMPI members from the MEDLARS computer printout and a punch card system. Of the journals currently publishing work on the biological effects of electromagnetic radiation, 89 are in English and 119 in other languages. Other ongoing Subcommittee activities are related to an international register of workers conducting studies on the bioeffects of microwave radiation, the yearly incidence of relevant publications, collecting abstracts and leading articles on the subject, the response to the Simple Language Summary project, problems of indexing and abstracting interdisciplinary journals, and problems of experimental design in the biology-microwave interdiscipline. (No references)

0296 A MICROWAVE DOSIMETRY SYSTEM FOR MEASURED SAMPLED INTEGRAL-DOSE RATE. *(E.)* Christman, C. L. (Bur. Radiol. Hlth., Div. Biol. Effects, Rockville, Md.), H. S. Ho and S. Yarrow. *IEEE Trans. Microwave Theory Tech.* MTT-22(12):1267-1272, 1974.

An interface was developed to allow measurement of sampled integral-dose rate, defined as the change in the integral dose during a particular time interval divided by that interval, absorbed by test animals during exposure in a waveguide to 2450-MHz continuous

wave microwave energy. Irradiation data for 12 CFl mice show that the sampled integral-dose rate varies with time due to movement of the animals. Comparative exposures performed on a dead mouse, anesthetized mice, and mice in small tubes demonstrated that variations in the sampled integral-dose rate are reduced when animal movement is limited. The variation in sampled integral-dose rate for anesthetized animals was approximately the same as that for the dead animal. The variation for animals in small tubes was greater than that for anesthetized animals, although it was significantly less than the variation observed for animals restricted to a volume in the waveguide. If the integral dose absorbed by the animal is the only factor determining the biological effect of microwaves, animal movement will not affect measurements of integral dose. However, if the biological effect is dependent on the integral-dose rate, animal movement may affect experimental results. The distribution of absorbed microwave energy may also vary with movement. Variations of integral-dose rate and the distributed-dose rate may need to be quantified if these variables affect the biological outcome of microwave radiation. (7 references)

0297 MICROWAVE SELECTIVE BRAIN HEATING. *(E.)* Lin, J. C. (Univ. Washington Sch. Med. Seattle), A. W. Guy and G. H. Kraft. *J. Microwave Power* 8(3/4):275-286, 1973.

Maximum absorbed microwave power/unit mass internal distribution were calculated for homogeneous spheres simulating human and animal heads, assuming an incident power density of 1 mW/cm^2. Theoretically, hot spots occurred for spheres with radius between 2-8 cm at 918 MHz and between 0.9-5 cm at 2450 MHz. Distribution of absorbed power, as well as peak absorbed power, differed according to size and frequency. At 2450 MHz maximum heating was at the center for a 3-cm brain compared with the proximal portion for a 7-cm brain. At 918 MHz maximum heating occurred near the center for both 3-cm and 7-cm brains. Thermographic recordings made on spherical brain models were in close agreement with theoretical predictions. In selective brain heating (915 MHz) experiments, cats were exposed to 380, 190, and 95 mW/cm^2 at 90, 180, and 360 sec, resp. A temperature of 43 C was attained in 90 sec without tissue damage at any power density, thus suggesting the possibility of using microwave differential hyperthermia as an adjunct for combination therapy in brain cancer. (13 references)

0298 RESEARCH NEEDS FOR ESTABLISHING A RADIO FREQUENCY ELECTROMAGNETIC RADIATION SAFETY STANDARD. *(E.)* Johnson, C. C. (Inst. Biomed. Eng., Univ. Utah, Salt Lake City). *J. Microwave Power* 8(3/4):367-388, 1973.

The presence of radiofrequency electromagnetic radiation in the environment was negligible prior to World War II. Now man is being subjected to appreciable levels of this form of radiation due to the rapidly expanding use of radar, television, industrial and medical heating units, communication systems, and many other related devices. In 1966 the American National Standards Institute (ANSI) published a document "Safety Level of Electromagnetic Radiation with Respect to Personnel," establishing an incident power density safety level of 10 mW/cm^2 from 10 MHz-100 GHz for periods greater than 0.1 hr. This standard was formulated primarily from research results on tissue heating considerations. The safety level in the USSR and Eastern European countries is 10 $\mu W/cm^2$ based on research relating to central nervous system and behavioral effects. This fundamental difference of 1000 to 1 in the safety standard is due in part to both a different emphasis and standards philosophy. In view of the need for a scientifically sound standard and to clarify conflicting research data, ANSI Subcommittee C95.4 was directed to prepare a report on research needs for establishing an improved radiofrequency safety standard. This paper, based on the subcommittee report, contains recommendations for research in the following areas: biological effects, field variables, dosimetry and instrumentation, protocols for biological studies, extrapolation to man, effects of elevated temperature and environmental conditions, and population groupings. The importance of conducting research in groups is emphasized. Priority is assigned to research on the biological effects of long-term, low-level exposures and to the development of instrumentation that will improve knowledge of electric field and absorbed power distribution in biological specimens. (55 references)

0299 MICROWAVE CHARACTERISTICS OF HUMAN TUMOR CELLS. *(E.)* Stamm, M. E. (Univ. California Sch. Med., Los Angeles), W. D. Winters, D. L. Morton, and S. L. Warren. *Oncology* 29(4):294-301, 1974.

Microwave energy transmitted between 76-86 GHz was used to identify differences between human tumor cells and autologous normal cells grown in tissue culture. An interferometer configuration enabled the microwaves to be divided into a tumor beam and a normal beam; energy from the normal beam was continuously subtracted from that of the tumor beam. When both samples were of the same material; i.e., normal *versus* normal, and the same thickness, a nul response was detected. In the case of normal *versus* tumor specimens, their two-characteristic spectra were automatically subtracted, resulting in the differential transmission spectra of the two materials. After samples were grouped according to spectral type, histological analysis showed that the tumors consisted of 1 carcinoma, 2 melanomas, and 6 sarcomas. Each spectral type corresponded to a specfic type of malignancy. Comparative microwave analysis of

primary tumor, metastatic tumor and normal cells from the same patient may provide data correlated with immunologic information such as levels of tumor-associated antigen in cells during *in vitro* culture. (2 references)

0300 ELECTROMAGNETIC FIELDS IN A HOMOGENEOUS MODEL OF MAN. Barber, P. W. (Dept. Electr. Bioeng., Univ. Utah, Salt Lake City).). *Proc. 1974 USNC/URSI-IEEE Meeting*, Oct. 14-17, 1974.

The Extended Boundary Condition Method used to solve electromagnetic scattering problems is applied to the calculation of internal fields in a prolate spheroid which has been illuminated by a plane electromagnetic wave. The electrical parameters of the model were chosen to approximate a homogeneous distribution of muscle tissue. The problem is solved on a spherical basis, which results in a set of equations for the coefficients of expansion of the internal field in terms of the incident field coefficients. Solution of the system of equations required evaluation of a set of integrals over the surface of the spheroid, and a matrix inversion. Once the coefficients were obtained, the fields were calculated throughout the interior volume. Internal power density was calculated for different characteristics of the model, and for various orientations of the incident field. The technique can also be used to calculate the power deposition in small animal models. The capability to make calculations for both man-sized bodies and small animals will make it possible to extrapolate data obtained from animal experiments to man's body configuration, useful in determining an electromagnetic radiation safety level and in medical diagnosis and therapy. The technique can also be used to compute internal power density levels for *in vitro* tissue preparations. (No references)

0301 ELECTROMAGNETIC FIELD MEASUREMENTS FOR BIOEFFECTS EXPERIMENTS AND THE CONTROL OF POTENTIAL HAZARDS. Bowman, R. R. (Natl. Bur. Stands., Boulder, Colo.). *Proc. 1974 USNC/URSI-IEEE Meeting*, Oct. 14-17, 1974.

The measurement of potentially hazardous electromagnetic (EM) fields is difficult because of complicated field configurations. Though it has long been realized that instruments designed to measure simple planewave fields are not adequate, more suitable instruments have not been available until the last few years. Since the power density S of complicated fields often has little meaning as a hazard index, these new instruments measure the Hermitian magnitude $E \equiv (E_x^2 + E_y^2 + E_z^2)^{\frac{1}{2}}$, or some derived quantity such as the electric field energy density $U_E = \frac{1}{4} \epsilon_o E^2$. The new instruments, as presently designed, respond to E^2 and the field sensors are essentially independent of their orientation in the field, regardless of the complexity of the field. Further development of this type of instrument is expected to allow direct measurements of electric fields inside subjects and phantoms. The capability to measure internal fields is important for determining the internal exposure of subjects in bioeffects experiments and for developing phantom "dosimeters." (No references)

0302 MEASUREMENT OF POWER ABSORBED IN THE TISSUE OF MAN AND ANIMALS EXPOSED TO ELECTROMAGNETIC FIELDS. Guy, A. W. (Univ. Washington, Seattle). *Proc. 1974 USNC/URSI-IEEE Meeting*, Oct. 14-17, 1974.

Absorbed power may be quantified by: 1) theoretical calculations based on the particular source and geometric shape of the exposed object, 2) measurement of the fields within the tissues by field sensing probes, 3) indirect point-by-point measurement of the absorbed power by rate of change of temperature increase in the tissue under exposure, and 4) indirect thermographic measurement of the absorbed power by rate of change of two dimensional temperature patterns in sectioned phantom models of the tissues or in the actual tissues of sacrificed animals. In the first method, shape and sources are restricted to specific configurations. Specimens may be contained in cylindrical, disk-shaped or spherical containers and exposed to plane fields or waveguide fields so that total absorbed power or absorbed density distribution may be calculated from the incident fields, measured by standard means. Direct measurement in tissue by field sensing probes is difficult, and though such probes are under development, no satisfactory instruments are available at this time. The most straight-forward method of determining power absorption is measuring the rate of change of temperature rise at the site, and converting it to power absorption density and electric field strength from the known thermal and electrical properties of the tissues. This must be done without metallic probes or wires, and with sufficient applied power levels to provide rapid temperature rise. Thermistors or thermocouples with small diameter, high resistance lead wires may be satisfactory, or dielectric guides which allow metallic probes to be withdrawn and reinserted before and after irradiation. New dielectric fiber optic probes are promising for continuous monitoring. All methods require information on the thermal and electrical properties of the tissues. Development of internal field measurement instrumentation should be of high priority. (No references)

0303 THE EFFECT OF 2450 MEGAHERTZ MICROWAVE RADIATION ON LIVER ADENOSINE TRIPHOSPHATE (ATP). *(E.)* Albert, E. N. (Sch. Med., George Washington Univ., Washington, D. C.), G. McCullars and M. Shore. *J. Microwave Power* 9(3):205-211, 1974.

This investigation was designed to explore the effects of microwaves on the adenosine triphosphate levels of liver hepatocytes. Chinese hamster littermates were irradiated with 2450 MHz microwave radiation at a power density of 50 mW/cm^2 for 30 minutes to 4.5 hours over a period of 1 to 21 days. The animals were sacrificed immediately after the last exposure. Adenosine triphosphate levels per gram weight of tissue were measured by using luciferin firefly extract. It was found that, under these conditions, there was no significant difference between control and experimental animals, when littermates were used in each of the above groups. (16 references)

0304 THE INFLUENCE OF ELECTROMAGNETIC WAVES IN THE COURSE OF AN INFECTION WITH NEW CASTLE DISEASE VIRUS IN CHICK EMBRYO TRACHEAL ORGAN CULTURE. *(Ger.)* Henneberg, G. (Dept. Virology, Robt. Koch Inst., Berlin Mun. Brd. Hlth., Germany), S. Heller and H. Jordanski. *Zbt. Bakt. Hyg., I. Abt. Orig.* A226, p. 17-25, 1974.

The influence of electromagnetic waves from the range of infrared (λ=1-2μ) and cm-waves (λ=1.4 cm) on the course of an infection with Newcastle Disease Virus (NDV) in chick embryo tracheal organ cultures is the subject of this report. The decrease of destruction of the ciliated epithelium and its ciliary activity, respectively, after radiation was found to be statistically significant. The effect of radiation by red light of the suspended inoculum was increased by an additional radiation of the organ cultures with cm-waves. This phenomenon caused by infrared and cm-waves may also point to the importance of these wave lengths as bioclimatic factors. (6 references)

0305 THE EFFECTS OF DECIMETER WAVES ON CATECHOLAMINE METABOLISM IN THE TISSUES OF HEALTHY RABBITS. *(Rus.)* Maksimova, L. I. (Central Inst. Health Resorts, Physiotherapy, Moscow, USSR). *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (38):490-493, 1973.

The effects of electromagnetic radiation in the decimeter range on the catecholamine metabolism in tissue and plasma were investigated in 45 healthy male, 2.5-3.5 kg, rabbits exposed to 65 cm radiation at power densities of 110 mW/cm^2 and 380 mW/cm^2, for 12 six-minute daily sessions. The generator's active surface of 12.56 cm^2 was set against the D_{10} - L_4 region which corresponds to the plane of the adrenal glands. The animals were decapitated 24 hr and 20 days after the exposure. Studies were made of the blood, adrenal glands, cardiac muscle, pulmonary tissue and hypothalamus. Findings indicate that exposure of the adrenal glands at 110 mW/cm^2 stimulates the sympathetic part of the sympathetic-adrenal system: the adrenalin content in the glands tended to rise (P>0.05); noradrenalin content increased from 29.87 to 123.46 µg/g. In the cardiac muscle and blood the noradrenalin content rose from 1.19 to 1.49 µg/g and from 6.9 to 10.64 µg/g, resp. Adrenalin content rose from 0.05 to 0.09 µg/g in the hypothalamus. Dopa content in the hypothalamus increased from 0.01 to 0.15 µg/g. No change was observed in the pulmonary tissue. Studies of the catecholamine metabolism 20 days after the exposure revealed the noradrenalin content in the adrenal glands at 100.25 µg/g (normally 29.87 µg/g), while in the heart, hypothalamus and blood plasma it approached the norm. The adrenalin and dopa content in the hypothalamus remained elevated. Exposure at 380 mW/cm^2 produced substantial changes. In the adrenal glands the adrenalin content dropped by 47% to 137.6 µg/g (normally 258.78 µg/g), and dopa decreased from 25.11 to 10.82 µg/g. Noradrenalin, adrenalin and dopa tended to decrease in the cardiac muscle, while in the blood plasma the adrenalin content dropped from 6.16 to 3.71 µg/g and noradrenalin from 6.9 to 3.37 µg/g. The experiment indicated a strong depressing effect of exposure in the decimeter range at 380 mW/cm^2 power density on the sympathetic part of the sympathetic-adrenal system. (13 references)

0306 THE EFFECT OF UHF ELECTROMAGNETIC WAVES ON THE INDUCED POTENTIALS OF THE AUDITORY CENTERS AND THE PROSPECTS FOR INADEQUATE AUDITORY STIMULATION. *(Rus.)* Sagalovich, B. M. (Moscow Sci. Res. Inst. Ear, Nose, Throat, USSR) and G. G. Melkumova. *Vestn. Otorinolaringol.* (4):3-8, 1974.

The experiments, involving 25 rabbits and 20 albino rats exposed to 2050 MHz, 2500 MHz, and 3000 MHz at power densities ranging from 0.15 mW/cm^2 to 14 mW/cm^2, studied the feasibility of transmitting sound information directly to the auditory centers of the cerebral cortex bypassing the ear. Needle electrodes were introduced into the auditory zone of the cortex of immobilized animals. Measurements were made of induced potentials of the auditory zone in response to clicking sounds. The results show that the mean amplitude drop of induced potentials in rabbits exposed to 2050 MHz at power densities of 0.5 mW/cm^2, 0.25 mW/cm^2, and 7.0 mW/cm^2 was 38% before the exposure, 0% at the time of the exposure, and 10% after the exposure; in rats 30%, 10% and 37%, resp. Exposure to 2500 MHz at 1.0 mW/cm^2, 0.5 mW/cm^2 and 14 mW/cm^2 produced the drop of 27%, 30%, and 30%, resp., in rabbits; 45%, 46%, and 45% in rats. Pulse frequences were 2,000, 1,000 and 1,000 pulses per minute; duration: 18 µsec, 18 µsec and 500 µsec; coefficient of charge: 0.036, 0.018, 0.05. The change of frequency from 2050 mW to 2500 mW involved a substantial rise in the response threshold, while at 3000 mW there was no reaction of the auditory centers. Findings suggest that the observed phenomenon was of a sensory nature as the thermal effect of the exposure was avoided by employing the power density of 10 mW/cm^2

sparingly. The inhibitory effect of induced potentials by electromagnetic waves correlated with the duration of pulses and the coefficients of charge, rather than with the mean power densities. (19 references)

0307 THE EFFECT OF 2450 MHz MICROWAVE IRRADIATION ON THE GROWTH OF MICE. *(E.)* McAfee, R. D. (VA Hosp. New Orleans, La.), R. Braus, and J. Fleming. *J. Microwave Power* 8(1):111-116, 1973.

This study was conducted as a follow-up to previous research for which results were considered inaccurate or inconclusive. A correction is also made of the record of the authors' having confirmed experimentally a dielectric saturation effect which might cause denaturation of molecules in living material; no such confirmation was achieved. One hundred control and 96 experimental Swiss-Webster mice were used in the follow-up experiments. Experimental mice were irradiated daily for 2 min each hour at a power density of 10 mW/cm^2, and subsequently weighed over a 36-day period. Except for the 5th and 8th day, when mice were weighed *en masse*, mice were individually weighed to the nearest 0.1 g. Using data from the frequency distribution of mouse weights plotted on the initial, 18th, and 36th day of irradiation, the possibility of there being significant weight difference between groups of experimental and control mice was tested using "Student's" t test. No significant differences were found. (P values for all three days were much greater than 0.05.) (7 references)

0308 DIELECTRIC PROPERTIES OF MATERIAL FOR MICROWAVE PROCESSING--TABULATED. *(E.)* Tinga, W. R. (Dept. Electr. Eng., Univ. Alberta, Edmonton, Canada) and S. O. Nelson. *J. Microwave Power* 8(1):23-65, 1973.

A brief description is given of the dielectric dispersion and relaxation as a function of frequency and temperature. Important aspects of the behavior of dielectric mixtures with respect to frequency, temperature, and composition are summarized and referenced. In the tabulation, materials are classified as Agricultural, Biological, Foods, Forest Product, Leather, Rubber, and Soils and Minerals. The data tabulation entitled "Values for the Dielectric Constant, ε', and the Dielectric Loss Factor, ε'', of Materials Described at Indicated Temperatures, Moisture Contents and Frequencies," shows material description and frequency as the two basic variables and lists all other factors influencing the data as parameters. In many cases data are available at only a few frequencies, which results in many blank spaces in the table. On the other hand the table shows at a glance those frequency ranges where further data are necessary, and allows for updating as data become available. The frequency range is set between 10 kHz and 10 GHz, since most important dielectric dispersion phenomena lie within this frequency range. The biological section of the table includes data on: bovine serum albumin, bacteria, blood, red blood cell, bone and bone marrow, bovine eye lens, fat and fatty tissue, G-actin, hemoglobin, insects, liver, lung, muscle and skin. (82 references)

0309 EFFECT OF SUPERHIGH FREQUENCY ELECTROMAGNETIC ENERGY ON MUTAGENESIS. *(Rus.)* Danilenko, I. I. (no affil.), V. I. Mirutenko and V. I. Kudrenko. *Elektron. Obrabotka Materialov* (4):71-72, 1974.

Two-day-old cultures of a histidine-dependent strain of *Candida tropicalis*, D-2, were washed twice with physiological saline and allowed to stand for 24 hr before they were resuspended in a pH 6.0 phosphate buffer containing N-nitroso-N-methylurea (NMM; 1 mg/ml) or N-methyl-N-nitro-N-nitroguanidine (NMG; 0.25 mg/ml) at 32-33 C for 3 hr. These treated cells were then diluted and inoculated into either complete or minimal media to study their viability, morphological variability, and yield of revertants. After exposure to the mutagens for 1.5 hr, 2 ml samples of some cell suspensions were exposed to superhigh frequency (SHF) radiation (37,000 MHz, 1 mW) for 30 min at a minimal distance from a GZ-30B waveguide generator. The cells were then treated again with mutagen for a total of 3 hr. While SHF radiation alone had no effect on cell viability, NMM reduced it to 72 ± 8% and NMG to 21 ± 2% of control values. SHF + NMM had little effect on viability, but SHF + NMG reduced it to 18 ± 3% of control values. While only 8 ± 2% of control cells and 17 ± 3% of those exposed to SHF showed morphological variability, 41 ± 6% of those exposed to NMM and 34 ± 3% of those exposed to NMG showed variability. Morphological variability was present in 66 ± 6% of cells exposed to SHF + NMM and in 42 ± 3% of those exposed to SHF + NMG. The yield of revertants was significantly increased by all forms of treatment, but was particularly pronounced in those given combined treatment. It is suggested that SHF radiation might affect DNA polymerase, increasing the number of *his* + mutants and morphological variants. The lethal effect of SHF radiation was not due to heat production since no temperature increase was noted. The synergistic effect of SHF radiation + mutagen might be due to increased permeability of cell walls to mutagen. (8 references)

0310 NUTRITION AND IN VIVO ROTATIONAL MOTION: A MICROWAVE STUDY. *(E.)* Webb, S. J. (Physics Dept., Univ. S. Florida, Tampa) *Int. J. Quantum Chem.: Quantum Biology Symp.* (1):245-251, 1974.

Experiments conducted with mammalian cells revealed that microwave frequencies absorbed by normal cells are different from those absorbed by tumor cells, and that the frequencies all form a series separated by a constant frequency. Tissue cultures of normal baby hamster kidney (BHK), BHK tumor cells transformed by mouse sarcoma virus (MSV), and Ehrlich ascites cells, having different tumor producing capacities, were used along with tissue slices of "natural" human mammary and lung carcinoma. The cells and tissues were examined without any fixation processes. Following their exposure to a microwave field having a density of 50-100 mW/cm^2, the cells were cloned on agar media and implanted into susceptible animals to assess possible lethal effects. All the normal mammalian cells absorbed frequencies of MWs, between 50-90 GHz, which formed a series separated by 2.0 and 2.5 GHz, resp. The frequencies absorbed by tumor cells appeared to follow 2, and perhaps 3, series separated by 1.9, 2.3, and 2.7 GHz, resp. As a given strain of cell went from highly tumorgenic to nontumorgenic, the strength of attentuation in the 2.3- and 2.7-GHz series of frequencies absorbed decreased, and attentuation of frequencies in the 2.5-GHz series occurred or increased. The irradiation of both the BHK and Ehrlich tumor cells with each of two frequencies in the 2.3-GHz series resulted in a decrease in their tumorgenicity but not viability. The results indicate that an *in vivo* movement, possibly of water or other small molecules, in mammalian cells interacts with a set series of electromagnetic frequencies between 50 and 90 GHz and is quantized with only certain energy transition, from one quantum level to the next, allowable. The difference between normal and tumor cells seems to reside in their respective physical rather than chemical characteristics which determine *in vivo* motions and, hence, structural architecture. (30 references)

0311 EFFECTS OF ELECTROMAGNETIC ENERGY ON THE ENVIRONMENT--A SUMMARY REPORT. *(E.)* Cory, W. E. (Electron. Syst. Res., San Antonio, Tex.) and C. L. Frederick. *IEEE Trans. Aerospace Electron. Systems* AES-10(5):738-742, 1974.

The beneficial and potentially hazardous effects of electromagnetic (EM) radiation are reviewed. Included is a discussion of natural and man-made EM generators; the electrical nature of man; direct and indirect effects of EM on man; medical, industrial, agricultural, and telecommunication uses of EM technology; and their regulation by government agencies. Judgements on the beneficial *versus* harmful effects of EM energy can be based in part on evidence that the latter can destroy DNA in human cells, act selectively on the chemical structure of virus molecules, and affect chromosomes. Man-made generators that produce non-ionizing waves generate frequencies below 10^{15} Hz. These waves do not have sufficient energy to dislodge electrons from their orbits in atoms or produce ion pairs. The approximate frequency ranges are reported for EM effects and treatments. Illnesses caused by exposure to EM fields can be largely eliminated by adherence to exposure levels found to be safe. The health of persons with diseases not caused by EM energy may be greatly improved by proper therapeutic uses of energy. (6 references)

0312 A MICROWAVE DECOUPLED BRAIN-TEMPERATURE TRANSDUCER. *(E.)* Larsen, L. E. (Methodist Hosp., Houston, Tex.), R. A. Moore and J. Acevedo. *IEEE Trans Microwave Theory Tech.* MTT-22(4):438-444, 1974.

Bench tests of conventional temperature transducers in microwave environments have demonstrated artifacts responsible for errors of several degrees centigrade. These findings led to a program for development of systematic test procedures and the design of microwave integrated circiut (MIC) electrodes with artifact reduced to 0.1 C, the criterion for measurements in the anterior hypothalamus/preoptic area of the brain. Tests of a glass electrode implicated lead-wire coupling as the major factor in artifact production. The MIC electrode has 5-μm microline conductors, a thick-film thermistor, and 50-kΩ current-limiting resistors. For thermographic tests in a 50 mW/cm^2, continuous wave field at 2450 and 918 MHz, the needle was thermally isolated from the external conductive monofilament by means of a Teflon chassis. Temperature rise due to the presence of the electrode was below the limit of resolution of the thermograph for line scans taken at the electrode tip. (17 references)

0313 MICROWAVE RADIOMETRIC MEASUREMENTS OF THE TEMPERATURE INSIDE A BODY. *(E.)* Enander, B. (Div. Electromagnetic Theory, Royal Inst. Tech., Stockholm, Sweden) and G. Larson. *Electron. Lett.* 10(15):317, 1974.

Thermal radiation in the microwave region comes from a surface layer of a body with a depth that is the same magnitude as the depth of penetration--the distance where the planewave field decreases by a factor of e^{-1}. In order to measure this thermal radiation a radiometer of the type used in radioastronomy was built and temperatures inside a body were measured at 0.9 to 1.2 GHz. The radiometer, which is a broadband receiver, compares the noise from a matched termination at a known temperature with the noise from an antenna placed on the body. The theoretical accuracy of the system is about 0.1 C. By placing the antenna on a dissipative medium at a homogeneous temperature, the radiometer will measure the temperature, provided the antenna is matched to the medium. The antenna used was a small loop antenna designed to give a good match when placed on a human body or other dissipative medium with similar dielectric

properties. In experiments with humans, the antenna was placed on the surface of the body, together with a thermistor that measured the surface temperature. On most parts of the body, it was possible to get a good match to the antenna (v.s.w.r.<1.2). Radiometer temperatures were generally 1 C above thermistor temperatures, because the radiometer is also sensitive to depth temperatures, which are higher than surface temperatures. Measurements of this type may have applications in medicine for diagnostic purposes. (2 references)

0314 MICROWAVE SICKNESS: A NEW DISEASE? *(Ger.)* Werner, G. (Central Hosp. NVA, Bad Saarow, Germany) and G. Schubert. *Wissenschaftl. Z. Ernst Moritz Arndt Univ.* [*Med. Reihe*] 23(3/4):159-161, 1974.

The extent of microwave tissue damage depends upon the following factors: intensity; length of exposure; frequency; size, shape and water content of the biological object; the thermoregulatory condition of the tissue; and on environmental (especially meteorological) conditions. Acute and chronic forms of microwave damage can be distinguished. A classification of 3 degrees of severity of microwave damage is proposed for each form. Acute microwave damage: 1st degree--Acute crisis of the circulatory system and a thermoregulatory disturbance (at approximately 10 mW/cm^2); 2nd degree--Various syndromes depending on organs, especially parts of the brain, which are exposed (15-20 mW/cm^2); 3rd degree--Radiation shock. Chronic microwave exposure can result in disturbances or even changes in certain organs. Symptoms are varied, but a similarity to neurocirculatory imbalances can be detected. Chronic microwave damages can also be classified into 3 categories: 1st degree--Mild symptoms combined with hypertension. Symptoms recede after exposure is discontinued; 2nd degree--Hypotension fatigue, sexual potency disturbances, changes in the EEG and ECG. The critical intensity for possible damage to the testicles is 5 μW/cm^2; 3rd degree--Symptoms are the same as 2nd degree, only more severe, combined with trophic disturbances of the skin. All past experience emphasized the importance of prevention. (No references)

0315 TUMOR SYNCHRONISATION THROUGH MICROWAVES. *(Ger.)* Dietzel, F. (Ctr. Radiol., Justus Liebig Univ., Giessen, Germany). *Strahlentherapie* 148(5):531-542, 1974.

This study examines the applicability of high-frequency waves in the treatment of malignant tumors by influencing the replicative metabolism of the tumor. NMRI-mice (380) with solid Ehrlich neck tumors were exposed to a single dose of high-frequency radiation (461.04 megacycles), so that the intratumoral temperature after 4 minutes was 42 - 43 C. The rate of the replicative metabolism of the tumors was determined by measuring the incorporation rate of ^{32}P. Immediately following the exposure, the rate of ^{32}P incorporation sank to minimum. The rate of ^{32}P-incorporation reached a maximum 72 hr after exposure, overshooting the baseline considerably and resulting in "tumor-synchronisation". Microwave therapy alone, therefore, can retard tumor growth significantly, mainly by deactivating enzymes involved in DNA synthesis. Microwave therapy with present instruments seems possible for superficial and semi-deep tumors. Treatment of deeper tumors would require more power output, and the development of a method for measuring the proliferation rate, since the ^{32}P incorporation method only works for superficial tumors. (85 references)

0316 MICROWAVES FOR COOKING APPLIANCES. *(Ger.)* Schlumpf, K. (St. Gallen, Switz.). *Elektrizitätsverwertung* 47(12):408-410, 1972.

Many years of tests have shown that no radiation damage occurs at frequencies of 2400 - 2500 Hz, as long as the intensity of the scattered radiation does not exceed 10 mW/cm^2. New regulations will set the maximum permissible intensity of scattered radiation at 1 mW/cm^2. Safety is also ensured by a switch disconnecting the generator when the oven door is opened. In some countries the power source must be disconnected to gain access to the electrical part of the instrument. Since the intensity varies inversely with the square of the distance from the energy source, distance is also very important. An intensity of 1 mW/cm^2 at a distance of 5 cm would only be 0.004 mW/cm^2 at a distance of 76 cm. (No references)

0317 EFFECT OF COMBINED EXPOSURE TO MICROWAVES AND X-RAYS ON THE PERMEABILITY OF THE HISTOHEMATIC BARRIER. *(Ukr.)* Faitelberg-Blank, V. R. (Odessa Agric. Inst., USSR) and A. V. Orlova. *Dopovidi Akad. Nauk Ukrainsk. RSR (Ser B)* (8):741-745, 1974.

Male rats were exposed to 800 r of x-radiation alone or to the same dose of x-rays followed by electromagnetic radiation (EMR; wave length 12.3 cm, 30 W) for 10 or 20 min. After 1-15 days, animals were injected i.p. with $Na_2H^{32}PO_4$ (4.5 μCi/100 g body weight), sacrificed after 60 min, and incorporation of ^{32}P was significantly increased in relation to its incorporation in the blood. However, 3 days after exposure, incorporation of ^{32}P decreased, reaching a minimum after 10 days. After 15 days, incorporation of ^{32}P was still decreased in most of the tissues examined. In contrast, 1 day after exposure to x-rays and EMR incorporation of ^{32}P in the tissues decreased. However, at later periods, ^{32}P incorporation, and thus permeability of the histohematic barrier, returned to normal values in rats exposed to both x-rays and EMR. These findings confirm those of other investi-