considerable vigilance as it is believed that factors disrupting the emotional state may influence primate performance. Selection of RF parameters was based on known energy deposition and wave penetration factors, and on reports of emotional, behavioral, and neurophysiologic effects to low-power level RF exposures at specific frequencies and modulations. Tracking performance under RF will be contrasted with stable pre- and postexposure data. (funding period n/a)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0527 NAVY ENVIRONMENT: EFFECTS OF PULSED MICROWAVE RADIATION FROM NAVY RADAR ON MAMMALIAN BLOOD CELLS. Cleary, S. F. (Virginia Commonwealth Univ., Medical Coll. Virginia, Dept. Biophysics, 1200 E. Broad St., Richmond, VA 23298).

Much recent research has shown that pulse-modulated microwave fields can produce alterations in biologic systems. The mechanisms of the interactions that cause these alterations are not generally understood. As a major producer of such fields from radar and other equipment, the Navy is conducting a program to determine the extent of hazard to its personnel and the public. This study is aimed at elucidating the mechanisms at the membrane level. Pulsed x-band microwave fields will be used to expose cell model systems consisting of human, dog, and rabbit blood cells. Studies will be made of effects on membrane permeability and cellular metabolism. The effects of the fields on membrane ion (Na^+ and K^+) fluxes will be studied to distinguish between active and passive transport alterations. In vitro studies will be carried out on the following mammalian cell lines: lymphocytes, thymocytes, polymorphonuclear leukocytes, and thrombocytes. In addition, osmotic fragility, intracellular proteins, oxygen consumption rates, and cell viability will be studied. Other studies will be carried out with the microwave field parameters as independent variables. (funding period 3/78-cont.)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

0528 ELECTROMAGNETIC RADIATION AND BIOLOGICAL SYSTEMS. Adey, W. R.; Bawin, S. M.; Sheppard, A.; Sagan, P. M. (U.S. Veterans Admin., Dept. Medicine & Surgery, Medical Center, 11201 Benton St., Loma Linda, CA 92357).

The interactions between weak ultra-high-frequency (450 MHz) electromagnetic fields and the central nervous system will be studied. The investigation will continue research that has disclosed power windows and modulation frequency windows for these interactions. Studies of interactions between weak electromagnetic fields and calcium ion binding in the central nervous system will be continued and will serve as reference for experiments involving amino acids and other putative neurotransmitters. Chick and cat cerebral tissues will be compared in their response to field stimulation. Performances of neonate chicks and ducklings exposed to 450 MHz fields will be compared in a series of behavioral measurements ranging from free behavior to sophisticated behavioral tasks, including variation of an interresponse time schedule. Schedule-controlled behavior in monkeys will be tested under similar field conditions. There will be continued collaboration with the Bureau of Radiological Health in measurements of field gradients in tissue as correlates of neurochemical responses. Recent developments in theoretic physics will be applied in modeling non-linear responses of the central nervous system to weak perturbations of the extracellular environment. (funding period 10/78-n/a)

Supporting Agency:U.S. Veterans Admin., Dept. Medicine & Surgery

0529 ELECTROMAGNETIC RADIATION AND BIOLOGICAL SYSTEMS. Adey, W. R.; Bawin, S. M.; Sheppard, A. R.; Sagan, P. M.; LinLiu, S. (U.S. VA, Dept. Medicine & Surgery, Medical Center, 11201 Benton St., Loma Linda, CA 92357).

See Current Research 0528 for description of this research. (funding period 3/78-2/80)

Supporting Agency:HEW, PHS, FDA, BRH

0530 BIOLOGIC CONSEQUENCES OF PULSED VERSUS CONTINUOUS WAVE RADIOFREQUENCY RADIATION (RFR). Caln, F. (Georgia Tech Res. Inst., Atlanta GA 30332).

There is some uncertainty regarding the relative abilities of continuous wave (CW) and pulsed (P) radio frequency radiation (RFR) to produce biologic effects. There is some controversy as to whether the rapid rise and fall of electric and magnetic fields of P RFR are more stressful than CW RFR. This project will attempt to answer some of the questions involved in this controversy. Test animals will be exposed in both P and CW RFR fields to establish relative biologic effects. Effects will be characterized as to frequency, incident power, absorbed power, pulse and modulation characteristics, tissue temperature, and duration of exposure. This is a multi-source contract. (funding period 7/77-6/79).

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0531 BIOLOGIC CONSEQUENCES OF PULSED VERSUS CONTINUOUS WAVE RADIOFREQUENCY RADIATION (RFR). Guy, A. W. (Rehabilitation Medicine, Sch. Medicine, Univ. Washington, 500 17th Ave., Seattle, WA 98122).

See Current Research 0530 for description of this research. (funding period n/a)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

6155 MEASUREMENTS OF THE DENSITY OF THE MICROWAVE POWER FLUX. *(Pol.)* Bogucki, J. (No affiliation given). *Ochr Pracy* 32(12): 12-13; 1978. (0 refs)

Problems associated with the examination of the amount of microwave energy emitted accidentally from high-power generators are discussed. So-called secondary sources of microwave energy can cause uncontrollable emission of microwave energy in the vicinity of a generator and therefore frequent examination of the density of the microwave power flux is needed to safeguard employee health. The measurements should be performed using an apparatus consisting of an antenna, a waveguide, and a meter. The device should be able to measure the density of the microwave power flux in the range of 5×10^{-2}-100 W/m^2. The functioning of an American-made device for such measurements is discussed.

6156 MICROWAVE HAZARDS. *(Eng.)* Goldwag, H. (No affiliation given); Justesen, D. R. *IEEE Spectrum* 16(5): 66-68; 1979. (3 refs)

The adequacy of United States standards for safe exposure levels of microwave and radio frequency radiation is discussed. The American limit of 10 mW/cm^2 is based on the concept of a no-damage threshold and on data from controlled laboratory studies. In contrast, the Soviet standard of 10 μW/cm^2 is based on a no-effects philosophy and on data largely from epidemiologic studies. Although Eastern European data appear to refute the simplistic thesis of gross thermal damage that underlies the American standard, a consensus on the validity of the data has not been reached in the United States. Biologic effects that have been reported in certain frequency windows include insect teratogenesis, efflux of calcium ions from cortical neurons, altered heart rates, transformation of mammalian cells in vivo, break down of the blood-brain barrier, and disruption of innate and learned behavior. Enhanced cell transformation and calcium ion efflux from isolated chick brains are confirmed effects, while others such as insect teratogenesis are believed to be due, at least in large part, to other factors. Measurement artifacts are believed to be responsible for reports of altered blood-brain barrier permeability. Reported alterations of learned behavior in experimental animals involve exposures to field strengths much higher than the current American standard of 10 mW/cm^2. The effects of continuous ultralong-term exposure to weak microwave fields are uncertain at present.

6157 INTERACTION OF RADIOFREQUENCY AND MICROWAVE RADIATION WITH LIVING SYSTEMS: A REVIEW OF MECHANISMS. *(Eng.)* Stuchly, M. A. (Nonionizing Radiation Section, Radiation Protection Bureau, Environmental Health Centre, Health and Welfare, Ottawa, Ontario, K1A 0L2, Canada). *Radiat Environ Biophys* 16(1): 1-14; 1979. (69 refs)

The interaction of radio frequency (RF) and microwave radiation (10 MHz to 300 GHz) with living systems on the molecular, cellular, and macroscopic level is reviewed. There appears to be no adequate basis for establishing frequency specific molecular interactions at electromagnetic field intensities that do not result in an increase of tissue temperature. Data on changes in calcium ion efflux in isolated cerebral tissue of neonatal chicks due to exposure to low frequency fields (5-25 Hz) or RF fields modulated at frequencies of 5-25 Hz suggest a possible interaction on the cellular level. Further progress in understanding the basic mechanisms of neural processes might lead to an explanation of some effects (e.g., calcium ion efflux) that cannot directly be explained by a thermal interaction mechanism. On the macroscopic level involving phenomena that can be described in terms of classical electrodynamics (i.e., Maxwell's equations), the interaction between RF and microwave radiation and living organisms can be defined in terms of absorbed power, which in turn is determined by electric permittivity, magnetic permeability, and internal field intensity. An analysis of human phantoms indicates that an adult man absorbs 50-200% of the power that is calculated as the incident power density times surface area (one side) of a man. The average specific absorption rate can be substantially higher at resonant frequencies, however. The total power absorbed and its spatial distribution within a human body are functions of electromagnetic field frequency, field polarization, body-to-radiation source configuration, exposure environment, and tissue dielectric constant and conductivity. Nonuniform heating resulting from exposure to RF or microwave radiation may cause a variety of secondary interactions. For example, preferential heating of the hypothalamus may affect thermoregulation and elicit aberrant neurophysiologic responses even at relatively low power density levels, which are not accompanied by increase in whole body temperature. One of the most prominent thermally induced effects where temperature increases are very small is the microwave hearing effect. The proposed mechanism for this effect is as follows: electromagnetic radiation causes a rapid temperature increase that generates thermal expansion pressure in the brain matter which then launches the acoustic wave of pressure that is detected by the cochlea. The cochlear microphonic frequency is independent from the microwave frequency and the absorption pattern.

6158 SOME PERSPECTIVES ON RESEARCH INTO THE BIOLOGICAL RESPONSE TO NON-IONIZING ELECTROMAGNETIC RADIATION. *(Eng.)* Sharp, J. C. (NASA, Ames Res. Center, Moffett Field, CA 94035). *Radio Sci* 14(1): 5-10; 1979. (0 refs)

Trends in research on the biologic effects of nonionizing electromagnetic radiation over the last three decades are reviewed, with particular reference to the proposed solar energy space power station (SPS). As a result of the advent of radar in World War II, research on the biologic effects of

radio frequency radiation reached a peak in the late 1950s and early 1960s. This was followed by a nadir in research activity, and in 1965 not a single federal agency was supporting research in this area. A resurgence of research has occurred in the past decade, with 13 federal agencies or departments now annually supporting a multi-million dollar effort. One project associated with research on the biologic effects of nonionizing radiation is the proposed solar energy SPS. When fully implemented, approximately 100 satellites would be placed in orbit with solar collectors. Energy would be relayed to any desired location on earth via a carefully controlled microwave beam. Under optimal conditions, the power density at the center of the collecting antenna array would probably be no greater than 25 mW/cm^2 (continuous wave) at a frequency of 2.45 GHz. The environmental and ecologic impacts of such a system are unknown at present, including the effects from the microwaves beamed to earth. It is suggested that a new pragmatism and conservatism have evolved in the United States with regard to such research and that there would be wide opposition to implementing the SPS system if it were initiated today.

6159 A PHYSIOLOGICALLY COMPATIBLE TISSUE-EQUIVALENT LIQUID BOLUS FOR MICROWAVE HEATING OF TISSUES. *(Eng.)* Hand, J. W. (MRC Cyclotron Unit, Hammersmith Hosp., Ducane Road, London W12 OHS, England); Robinson, J. E.; Szwarnowski, S.; Sheppard, R. J.; Grant, E. H. *Phys Med Biol* 24(2): 426-431; 1979. (12 refs)

A physiologically compatible and microwave tissue-equivalent liquid bolus system consisting of dextran in Krebs-Ringer solution was used to provide efficient microwave coupling to irregularly shaped mouse tissue without adversely affecting this tissue. Complex permittivity was measured at frequencies of 915 MHz and 2,450 MHz for Krebs-Ringer solution and for solutions of dextran in Krebs-Ringer solution at concentrations of 200, 300, and 400 g/l. It was estimated that less than 1% of the incident microwave power should be reflected from tissue immersed in the bolus solutions compared with 10-20% for tissue immersed in Krebs-Ringer solution only and more than 50% for an air-tissue interface. In an experiment without a loop of exteriorized mouse intestine present in the bolus cell, the microwave applicator was tuned such that 2 ± 0.2 mW of reflected power was present at a forward power level of 40 W. When a loop of intestine was introduced into the bolus, the reflected power remained virtually unchanged. Tests with mouse leg and mouse tail in the bolus showed that heating rate exhibited little dependence on orientation or position of the sample with respect to the microwave field. It is concluded that the above approach should be useful in developing uniform heating of small laboratory animals. Furthermore, the liquid bolus could be used in direct contact with the skin in treatments involving microwave heating of superficial lesions in human patients and would allow the transformation of the complex shapes of treated areas into ones of simple plane geometry.

6160 A NON-INVASIVE, PARTIAL-BODY EXPOSURE METHOD FOR MEASURING THE COMPLEX PERMITTIVITY OF BIOLOGICAL SUBSTANCES AT MICROWAVE FREQUENCIES. *(Eng.)* Neelakantaswamy, P. S. (Dept. Electrical Engineering, Indian Inst. Technology, Madras 600036, India); Gupta, K. K.; Basavaraju, K. *Med Biol Eng Comput* 16(4): 419-424; 1978. (10 refs)

A non-invasive, partial-body exposure method for measuring the complex permittivity of slab-like dielectric materials at microwave frequencies is described. A Gaussian beam launcher is used to irradiate selectively the test material at the particular position of interest, and an X-band reflectometric bridge arrangement is used to measure the amplitude and phase of the reflected beam wave. The real and imaginary parts of the permittivity are computed using the measured data and the theoretically formulated expression for the reflection coefficient. Measurements at X-band frequencies were performed for dielectric materials, such as, acrylic plastic, bakelite hylam, human skullbone (in vitro measurements), and the midportion of the palm (in vivo measurement). The real parts of the dielectric constants of the test materials measured by the present method agreed closely with the results using von Hippel's method. However, there were deviations in the results for the loss tangents. For the external surface of the human skull, in particular, the real part of the permittivity agreed closely with the nominal value, but the loss tangent indicated deviations that can be attributed mainly to the surface irregularity of the interior base of the skull. Results obtained for the occipital region of the skull were in close agreement with the nominal value owing to the fact that the occipital region is fairly thick and, for the test skull used in this experiment, the external protuberance and crest at the occipit were not geometrically significant. For in vivo measurements on the midportion of the palm, the values of both the real part of the permittivity and the loss tangent agreed closely with the respective nominal values. It is concluded that this noncontact and nondestructive approach to measuring complex permittivity is suitable for in vivo or in vitro measurements in biologic experiments involving radiation dosimetry.

6161 MAPPING OF THE NEAR-FIELD PATTERN IN SIMULATED BIOLOGICAL TISSUES. *(Eng.)* Gajda, G. (Dept. Electrical Engineering, Univ. Ottawa, Ottawa, Ontario, Canada); Stuchly, M. A.; Stuchly, S. S. *Electronics Lett* 15(4): 120-121; 1979. (9 refs)

A simple system for mapping the electric-field pattern in a simulated tissue is described and its performance evaluated. The basic components include a microwave generator, a test applicator, a container with liquid-tissue phantoms, an electric-field probe, a detector, an amplifier, and an X-Y recorder. The system's short probe is sensitive to the E-field in one direction, which is driven along a selected path by the X-scan of the X-Y recorder, while the intensity of the field measured by the

diode detector is recorded simultaneously along the *Y*-coordinate of the recorder. To evaluate the system's performance the probe was inserted into a section of the waveguide terminated by an absorbing mat. The probe penetrated the mat and was arranged in the center of the waveguide parallel to the direction of propagation. The directional response of the probe was found by monitoring the transmitted signal against the angular position of the probe. The coupling coefficient (S_{21}) was found to be -33 ± 1 dB, and the directivity (the ratio of coupling coefficient in two orthogonal directions) was approximately 20 dB. Near-field patterns in simulated muscle tissue (a mixture of water and glycerol), the squared value of the electric field strength at 2 mm from the aperture of an applicator operating at 2.45 GHz, and the patterns of the electric field across the symmetry line of the applicator at distances ranging from 0 to 25 mm from the aperture of the applicator were obtained. The system provides a viable complementary or alternative technique to the thermographic-camera method in evaluating the performance of microwave applicators for local hyperthermia.

6162 CHARACTERISTICS OF THE BIOLOGIC ACTION OF MILLIMETER-RANGE RADIOWAVES AND THEIR POSSIBLE MEDICAL APPLICATIONS. *(Rus.)* Sevast'ianova, L. A. (Oncology Res. Center, USSR Acad. Medical Sciences, Moscow, USSR). *Vestn Akad Med Nauk SSSR* (2): 65-68; 1979. (21 refs)

Studies on the biologic effects of millimeter-range radiowaves and their possible medical applications are reviewed. Millimeter waves do not have any serious injurious effect on microorganisms. They increase the mitotic activity of yeast cells, the number of colicin-synthesizing *Escherichia coli* cells, have an inhibiting effect on adenovirus, and increase the nucleic acid levels in the cells. Millimeter waves cause no mutagenic changes in bacteria. They enhance the antitumor effect of previous x-ray treatment of chemotherapy, and they protect the erythroid cell line of the bone marrow from the harmful effects of x-rays and cytostatic drugs. Millimeter waves may inhibit tumor growth, and no stimulation of tumor growth has been observed. The biologic effects are strongly frequency-dependent.

6163 ELECTROMAGNETIC FIELDS AND POWER DEPOSITION IN BODY-OF-REVOLUTION MODELS OF MAN. *(Eng.)* Wu, T-K. (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA 94086). *IEEE Trans Microwave Theory Tech* MTT-27(3): 279-283; 1979. (15 refs)

The feasibility of using the surface integral equation (SIE) technique to analyze the electromagnetic fields and power deposition in a homogeneous dielectric body of revolution of biologic tissue is demonstrated. The method also applies to any arbitrarily shaped body-of-revolution models of man and animals. Although the illuminating sources considered here are plane waves for near zone sources such as manpack radio antennas, direct-contact aperture sources, and corner reflectors, the technique still applies. Numeric results for electromagnetic fields and power deposition in a body-of-revolution model of a human torso with a height of 1.78 m were evaluated for frequencies of 30, 80, and 300 MHz. It was found that the strongest power deposition in the torso model occurred for fields polarized along the longest dimension and for frequencies near the first resonance (80 MHz) of the torso body. Hot spots were also observed in the neck region of the torso body. The SIE method may be generalized to analyze inhomogeneous bodies by employing the invariant imbedding technique, and the method applies over a wide range of dielectric parameters, with the dielectric constant ranging from 1.1 to 10^2 and the conductivity ranging from 0-10^3 mhos/m. Because of the versatility of the moment method of solutions to changes in geometry with the present technique, a myriad of body configurations may also become tractable, e.g., a human torso with outstretched arms and legs or even a torso carrying a manpack transceiver.

6164 INTERDISCIPLINARY AND INTERNATIONAL CONTRIBUTIONS TO RESEARCH ON BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES: PAST PERFORMANCES AND FUTURE CHALLENGES. *(Eng.)* Johnson, C. C. (Dept. Bioengineering, Univ. Utah, Salt Lake City, UT 84112). *Radio Sci* 14(1): 1-4; 1979. (0 refs)

Progress in research on the biologic effects of electromagnetic radiation is reviewed. The Eastern European countries have made significant attempts to understand the nervous and behavioral response to electromagnetic waves, to gauge the response of the blood-forming and immune systems, and to establish standards that protect the health of occupationally exposed personnel. The Western countries have achieved significant progress in perfecting instrumentation and measurements, in developing dosimetry, and in investigating the potential of electromagnetic radiation in medical applications, especially in the treatment of cancer. Significant accomplishments have also been made in the development of improved equipment for irradiation of biologic specimens and in the development of instrumentation for making nonperturbing measurements of temperature in electromagnetic fields. However, despite these accomplishments, there is no consensus as to the hazards of electromagnetic radiation or to the mechanisms of its effects.

6165 THE ELECTRIC-FIELD PROBE NEAR A MATERIAL INTERFACE WITH APPLICATION TO THE PROBING OF FIELDS IN BIOLOGICAL BODIES. *(Eng.)* Smith, G. S. (Sch. Electrical Engineering, Georgia Inst. Technology, Atlanta, GA 30332). *IEEE Trans Microwave Theory Tech* MTT-27(3): 270-278; 1979. (10 refs)

A worst case analysis was formulated to determine the effect of a nearby interface on the response of an electric field probe. The results of the analysis showed that the interaction between the

electrically short probe and the interface had the following properties. The interaction (error in response) is decreased if the radius or the length of the probe is reduced. A low value for the load admittance at the terminals of the probe will produce less interaction than a high value of the load admittance. An increase in the dissipation in the medium surrounding the probe will decrease the interaction at a distance from the interface but can increase the interaction when the probe is very close to the interface. The use of a probe with a concentric cylindrical insulation of a permittivity ratio much greater than 1 can reduce the interaction to the level that is obtained with an open-circuited bare probe with the same dimensions; the interaction for the insulated probe, unlike that for the bare probe, will be independent of the value of the load admittance used. For electrically short bare probes that are thin, the error in the response for either low or high values of load admittance is found to be less than 5% when the distance from the interface is greater than the half-length of the probe. The addition of an insulating sheath with a permittivity ratio much greater than 1 reduces the error to less than 5% for spacings where the distance from the interface is greater than one-third the half-length of the probe. A simple approximate analysis indicates that the response of all electrically short insulated dipole probes will exhibit a behavior similar to that for the probe with a concentric cylindrical insulation when the insulation is not very thin and the permittivity ratio is much greater than 1. An analysis of data measured for the electric field near an interface using an electric field probe developed by the BRH indicates that the measured results are in general agreement with the theory.

6166 ELECTROMAGNETIC RADIATION EMITTED FROM VIDEO COMPUTER TERMINALS. *(Eng.)* Weiss, M. M. (Bell Telephone Lab., Inc., Murray Hill, NJ 07974); Petersen, R. C. *Am Ind Hyg Assoc J* 40(4): 300-309; 1979. (6 refs)

Electromagnetic radiation (EMR) emissions from typical video terminals (CRT) used by the Bell System were measured. Electric field strength and/or power density measurements were made over the frequency range of 10 kHz to 18 GHz. With the exception of a digital graphics terminal and a Tektronix display unit, measurable levels occurred at frequencies extending only up to a maximum of about 150 MHz. For the above exceptions, a number of small signals in the hundreds of MHz region were detectable; however, these signals were due to computers and other peripheral equipment. In all cases the values of the total root mean square (RMS) electric field strength were well below the most stringent exposure standard used anywhere in the world. The maximum total RMS electric field strength of all measured frequency components for each CRT was about 0.01 V/m and resulted primarily from emissions associated with the sweep circuitry (below 1 MHz including all measurable harmonics). Irradiance measurements indicated that UV exposure levels were well below the recommended levels in the NIOSH criteria document. There is no experimental or epidemiologic evidence presently available to indicate that the above levels of EMR could have any detrimental effects on the health of personnel using CRT devices like the ones examined in this study.

6167 INDUSTRIAL, SCIENTIFIC, AND MEDICAL MICROWAVES: SOME FACTS, SOME FINANCES, SOME FEARS, AND THE FUTURE. *(Eng.)* Herbaugh, R. E. (No affiliation given). *Microwaves* 18(3): 43-45, 48, 49, 52; 1979. (6 refs)

Industrial, medical, and scientific applications of microwave radiation are discussed. Industrial heating systems are available that operate at frequencies of 915 and 2,450 MHz. Output powers vary from about 500 W for some domestic microwave ovens into the 90-kW region for some industrial heaters. In a recent report to Congress (December, 1978), NIOSH noted that 75% of the workers using radio frequency sealing and heating equipment were exposed to radiation levels in excess of the present occupational exposure guidelines. In addition to the assessment of the potential hazards of microwaves, this technology is currently being investigated for the detection and treatment of cancer. One of the standard industrial, scientific, and medical frequencies, 2,450 MHz, is being used at the University of Miami School of Medicine to treat malignant brain tumors that have been implanted in mice. At the University of Utah, researchers are studying the millimeter-wave properties of tissues to try to determine whether some European and Soviet theories are valid. Some U.S. scientists feel there are specific frequency effects on tissues in the millimeter ranges. Also, Utah scientists are studying the water content of the lungs via microwaves. Microwaves have also been used to thaw frozen blood. Georgia Institute of Technology researchers are using microwaves for the uniform heating of frozen animal kidneys. Once perfected, the technique may be used to thaw human organs that are stored in tissue banks.

6168 RADIO AND TELEVISION TRANSMITTERS AND THE LIVING ENVIRONMENT. *(Cze.)* Musil, J. (Institut hygieny a epidemiologie, Srobarova 48, 100 42 Prague 10, Czechoslovakia). *Cesk Hyg* 23(10): 504-508; 1978. (10 refs)

Studies on the possible health hazards of the electromagnetic radiation emitted by radio and television transmitters are reviewed, and typical radiation levels measured in different countries are presented. Hygienic standards are recommended for the general population exposed to electromagnetic radiation generated by radio and television transmitters; the exposure should be limited to 5 V/m in the frequency range of 0.03-30 MHz, 1 V/m in the range of 30-300 MHz, and 2.5 μ/cm^2 above 300 MHz.

6169 A STUDY OF THE HEALTH STATUS OF RADAR WORKERS. *(Eng.)* Djordjevic, Z. (Inst. Aviation Medicine, Zemun, Yugoslavia); Kolak, A.; Stojkovic, M.; Rankovic, N.; Ristic, P. *Aviat Space Environ Med* 50(4): 396-398; 1979.

The health status of 322 radar workers (ages, 25-40 yr) occupationally exposed to pulsed microwaves of various frequencies for 5-10 yr was compared with that of 220 nonexposed controls matched with respect to age, work regimen, and social and living conditions. The intensity of microwave exposure was generally less than 5 mW/cm^2. Clinical examinations of the workers included detailed internal, neurologic, ophthalmologic, otologic, hematologic, and biochemical investigations. There were no statistically significant differences in clinical or laboratory findings between exposed and control workers. However, general subjective complaints such as headache, fatigue, and irritability were observed more frequently in the exposed workers than in controls. These subjective complaints can not be ascribed only to microwave exposure because the workers were also exposed to uncomfortable occupational conditions such as inadequate air temperature, poor lighting, high noise level, and the necessity of paying attention to radar screens. Harmful effects from microwave exposure are concluded to be unlikely in radar workers working under normal conditions.

6170 ELECTROMAGNETIC POWER ABSORPTION IN CYLINDRICAL TISSUE MODELS EXCITED BY A LOOP ANTENNA. *(Eng.)* Yoneyama, T. (Res. Inst. Electrical Communication, Tohoku Univ., Sendai 980, Japan); Suzuki, T.; Nishida, S. *Electron Lett* 15(4): 125-127; 1979. (6 refs)

A cylindrical homogeneous tissue model in the field of a loop antenna located coaxially is proposed to measure electromagnetic power absorption in biologic tissues. Simple computations are derived for the electromagnetic power absorption based on the assumption that the wavelength is large compared to the radius of the cylindrical tissues. The power absorption coefficient for cylindrical tissues (the ratio of the absorbed power in the tissue to the total radiated power in the loop) increases as the radii of the loop and cylindrical tissue approach each other. Although the coaxial arrangement of the loop antenna and the cylindrical tissue is a rather idealized model of the real physical structure, the results may be useful for determining total absorbed power estimates in real tissues. The derived equations are simple and may be computed with a pocket calculator if a table of Bessel functions for complex arguments is available.

6171 MECHANISM OF LETHAL ACTION OF 2,450-MHz RADIATION ON MICROORGANISMS. *(Eng.)* Vela, G. R. (Dept. Biological Sciences, North Texas State Univ., Denton, TX 76203); Wu, J. F. *Appl Environ Microbiol* 37(3): 550-553; 1979. (18 refs)

The mechanism of lethal action of microwave radiation on microorganisms was investigated using various bacteria, actinomycetes, fungi, and bacteriophages exposed in the presence and absence of water. All irradiations were performed in a specially constructed stainless steel cavity coupled to a magnetron tube capable of emitting 1.5 kW of forward power at 2,450 ± 20 MHz. Energy output was a flux of 1 kW (1,000 J/sec) at the sample locations. To examine the thermal component of the bactericidal properties of microwaves, a series of experiments was performed in which the rate of inactivation of viable microorganisms was compared with the temperature of the suspending medium. The system of choice was considered one in which microorganisms could exist in either the presence or absence of water. It was found that inactivation of soil *Azotobacter* depended on the presence or absence of water. It was found that inactivation of soil *Azotobacter* depended on the presence or absence of water and/or on the temperature of the specimen after irradiation. The experiments were repeated eight times with different soil samples, and the results were essentially identical. In 14 other experiments in which the total soil population (heterotrophic, aerobic, mesophilic) was counted, the results were essentially the same as those for *Azotobacter*. The results were interpreted as showing that, in the presence of water, the temperature of the suspending medium and bacterial inactivation are dependent functions of the total amount of radiation delivered into the cavity by the magnetron tube and, also, that temperature increase in the sample depends on the presence of water. Since the loss factor (dielectric constant x loss tangent) of water at 2,450 MHz is much greater than that of soil or that of the glass beakers, it was assumed that the major part (<98%) of microwave energy was absorbed in the soil. Results of experiments in which diverse microbial populations were monitored showed that bacteria, actinomycetes, and fungi were inactivated as a function of the moisture content of the soil. These results proved that the bactericidal effect of microwaves was due to the total amount of water in the soil sample. In more than 70 repetitions of this experiment, the results showed that there was a distinct loss of microbicidal activity as the moisture content of the sample approached zero. To circumvent the problem of energy absorption by water and soil, lyophilized organisms were irradiated in the dry condition and, for comparison, after moistening. The results also showed that cell killing is a function of moisture content; lyophilized yeast cells were inactivated in the presence of water but survived large doses of radiation in the dry state. It is concluded that microbial cells are not inactivated by large amounts of microwave radiation. Furthermore, it is clear that microwaves kill microorganisms only by thermal effect and that, if there is a nonthermal effect, it is not a bactericidal one, although the possibility exists that water may be necessary to potentiate the nonthermal effect.

6172 SEARCH FOR MILLIMETER MICROWAVE EFFECTS ON ENZYME OR PROTEIN FUNCTIONS. *(Eng.)*

Tuengler, P. (Seaver Chemistry Lab., Pomona Coll., Claremont, CA 91711); Keilmann, F.; Genzel, L. *Z Naturforsch [C]* 34c(1/2): 60-63; 1979. (12 refs)

The effects of millimeter microwaves (MMW) on in vitro enzyme and protein functions was investigated. The effect of MMW on an enzyme system was studied in the reduction of ethanol by alcohol dehydrogenase (molecular wt 144,000) in a constant-flow technique. Fresh samples, each with a 1 x 1 cm^2 surface area, were irradiated with MMW of 10 mW/cm^2 intensity; the frequency was varied from 40 to 115 GHz with a resolution of a few MHz. Microwaves had no significant influence, having less than a 1.0% effect on alcohol dehydrogenase turnover rate. The effect of MMW on protein functions was analyzed in the cooperative binding of oxygen and hemoglobin (molecular wt 67,000). Fresh samples, each with a 2 x 2 cm^2 cross section (4 times the sample area of the alcohol dehydrogenase system), were irradiated with MMW of 10 mW/cm^2 intensity in the same manner as the alcohol dehydrogenase system. The irradiation had less than 0.4% effect on the equilibrium oxygen constant of half-oxygenated hemoglobin. Since the amount of possible nonlinear amplification necessary to observe changes in protein and hemoglobin function in vivo is unknown, it cannot be concluded that MMW has no effect on the function of the alcohol dehydrogenase system and on the function of hemoglobin in oxygen transport.

6173 PATHOGENESIS OF INSULIN DEFICIENCY INDUCED BY ALTERNATING MAGNETIC FIELD OF INDUSTRIAL FREQUENCY. *(Rus.)* Kolesova, N. I. (Dept. Biochemistry, Medical Inst., Tomsk, USSR); Voloshina, E. I.; Udintsev, N. A. *Patol Fiziol Eksp Ter* (6): 71-73; 1978. (6 refs)

The effect of exposure to alternating magnetic field (200 Oe, 50 Hz, 1 x 24 hr or 6.5 hr/day for 5 consecutive days) on the overall serum insulin activity, free insulin level, hepatic glycogen, and blood glucose levels was studied in 200 male rats. Single-time exposure caused a significant increase in the overall serum insulin activity (4.1 mg/g/3 hr 1 hr after exposure and 5.1 mg/g/3 hr 48 hr after exposure, compared with 2.5 mg/g/3 hr in the controls); the normalization of this parameter on day 7 after exposure was followed by another increase. The free insulin level was decreased significantly 24-48 hr after exposure, and increased significantly 7-14 days after exposure. The hepatic glycogen level was decreased significantly during the first 24 hr after exposure, and was normal thereafter. The blood glucose level showed no significant change. These findings indicate the development of relative insulin deficiency after single-time exposure. Following repeated exposure, both the overall serum insulin activity and the free insulin level and the liver glycogen level were decreased significantly, and the blood glucose level was increased significantly; these findings are indicative of absolute insulin deficiency. The considerable increase in the insulin activity following single-time exposure was interpreted as an important component of the adaptive reaction of the body to compensate for the neuroendocrine and metabolic shifts observed. The more deep-going changes seen following repeated exposure were closely linked to the derangement of carbohydrate and energy metabolism.

6174 COMPARATIVE ASSESSMENT OF THE EFFICACY OF SEDUXEN AND CYCLODOL, AND THEIR COMBINATION WITH ELECTROPULSE TREATMENT FOR INCREASING THE RESISTANCE TO EXPERIMENTALLY INDUCED MOTION SICKNESS. *(Rus.)* Matsnev, E. I. (Inst. Medical Biologic Problems, USSR Ministry of Public Health, USSR); Zakharova, L. N.; Polevoi, L. G. *Vestn Otorinolaringol* (2): 27-32; 1979. (29 refs)

The effects of sexuden (0.01 and 0.005 mg), cyclodol (0.004 mg), combined seduxen (0.01 mg) and cyclodol (0.004 mg), and of 1-hr electropulse treatment (500-750 Hz, current intensity 0.3-2.5 mA, galvanic component 25-30%) or its combination with seduxen (0.005 mg) or cyclodol (0.004 mg) on resistance to motion sickness induced experimentally by Coriolis acceleration were studied in 30 normal men aged 24-36 yr. Preliminary experiments had demonstrated that electropulse treatment inhibited caloric nystagmus. Only when the two drugs were administered in combination was there a significant increase in the resistance to motion sickness. The effect of the drugs was enhanced by electropulse treatment. The effect of the electropulse treatment can be explained by the stimulation of the hypothalamus and limbic structures.

6175 IMMUNOLOGIC EFFECT OF MICROWAVES. *(Rus.)* Shandala, M. G. (A. N. Marzeev Kiev Scientific Res. Inst. General and Communal Hygiene, Kiev, USSR); Vinogradov, G. I. *Gig Sanit* (10): 34-38; 1978. (5 refs)

Recent studies performed in the USSR on the immunologic effects of super high frequency (SHF) radiation in experimental animals are reviewed. The effect of 30-day exposure to SHF fields (1-50 $\mu W/cm^2$) on the phagocytic reaction of the neutrophils and on the serum complement titer was studied in guinea pigs. The microwaves were found to stimulate phagocytosis, especially in animals exposed to low doses. The serum complement titer was increased significantly even 4 wk after the end of the treatment, especially in the groups treated with low doses. The exposure of albino rats and guinea pigs to a 50 $\mu W/cm^2$ SHF field caused significant increases in the number of plaque-forming cells, basophil degranulation, and in the percentage of damaged neutrophils. Studies on the joint effects of microwaves and environmental pollutants (formaldehyde, carbon monoxide) showed that in the presence of a non-allergenic chemical substance, the end effect is determined by the intensity of the microwave exposure (no autoallergenic effect is seen at low intensity), while the irradiation of animals pretreated with chemical allergens leads to a suppression of the immune

reactivity and of allergic reactions. Low-intensity irradiation does not eliminate the effect of chemical allergens.

6176 MICROWAVE RADIATION AND CHLORDIAZEPOXIDE: SYNERGISTIC EFFECTS ON FIXED-INTERVAL BEHAVIOR. *(Eng.)* Thomas, J. R. (Behavioral Sciences Dept., Naval Medical Res. Inst., Bethesda, MD 20014); Burch, L. S.; Yeandle, S. S. *Science* 203 (4387): 1357-1358; 1979. (7 refs)

The effect of low intensity (1 mW/cm^2) pulsed microwave radiation (2.45 GHz, 2-μsec pulse width, 500-Hz pulse repetition frequency) on chlordiazepoxide-modified fixed-interval behavior was studied in four male Long-Evans hooded rats. The animals were exposed to microwave radiation immediately after drug administration for a 30-min period. Behavioral effects were measured during the 1st hr after termination of the 30-min radiation exposure. All exposures were conducted under near-field conditions with the subjects located 3.75 wavelengths from the antenna. Microwave irradiation potentiated the response-rate increasing effects of chlordiazepoxide, while the general shape of the drug dose-effect functions remained relatively constant under microwave irradiation. These results indicate that brief exposure to low-intensity pulsed microwave radiation can act synergistically with another agent in affecting the behavior of an organism, although the mechanism of interaction is not clear.

6177 RADIOFREQUENCY RADIATION ALTERS THE IMMUNE SYSTEM: MODULATION OF T- AND B-LYMPHOCYTE LEVELS AND CELL-MEDIATED IMMUNOCOMPETENCE BY HYPERTHERMIC RADIATION. *(Eng.)* Liburdy, R. P. (Radiation Sciences Div., U.S. Air Force Sch. Aerospace Medicine, Brooks Air Force Base, TX 78235). *Radiat Res* 77(1): 34-46; 1979. (25 refs)

The time course of radio frequency radiation (RFR, 26 MHz)-induced lymphopenia in C57BL/6 ($H\text{-}2^b$) and Balb/c ($H\text{-}2^d$) mice was characterized for single and multiple RFR exposures. In addition, the effects of RFR on thymus-dependent and -independent lymphocyte frequency in the spleen and on cell-mediated immunity were investigated. Whole-body exposure of RFR (26 MHz, 800 MW/cm^2, 5.6 W/kg, raising core temperature by 2 C) induced lymphopenia and neutrophilia that persisted for 12 hr. Maximal lymphopenia, obtained in mice given three hyperthermic RFR exposures, persisted for >15 hr after treatment. Mice exposed to a single RFR dose recovered in 6 hr as compared to 12 hr for mice receiving multiple doses. RFR-induced lymphopenia was accompanied by an increase in splenic T- and B-lymphocytes that was more pronounced after three RFR exposures given at 3-hr intervals. Multiple RFR exposures also led to a significant decrease in thymic weight and thymic and splenic cell density and to suppressed cell-mediated immunity (measured by in vivo local delayed-type hypersensitivity). Warm air exposure (41 C to produce a 2 C core temperature rise in 15 min) increased B-lymphocyte levels, but produced no change in local delayed-type hypersensitivity. To quantitate the degree of stress associated with RFR treatments, plasma corticoid levels and thymus and spleen weight and cell density were measured immediately following thermogenic RFR. Plasma corticoid levels in animals given single or chronic (20 times) RFR exposure were increased by threefold and thymic weight and splenic and thymic cell density in chronically exposed mice were markedly reduced compared to warm air or sham controls. To determine if the steroid-induced effect was qualitatively similar to that observed with RFR, 4 mg/kg methyl prednisolone sodium succinate was injected intraperitoneally. Lymphopenia, increased splenic B- and T-lymphocyte frequency, and thymic involution were observed along with reductions in thymic weight and splenic and thymic cell density after 2 days. The results demonstrate that hyperthermic RFR produces significant alterations in lymphocyte distribution and function. The RFR effect on cell-mediated immunity may be mediated indirectly through steroid-associated actions.

6178 ELECTRICAL WIRING CONFIGURATIONS AND CHILDHOOD CANCER. *(Eng.)* Wertheimer, N. (Dept. Preventive Medicine and Community Health, Box C-245, Univ. Colorado Medical Center, 4200 E. Ninth Ave., Denver, CO 80262); Leeper, E. *Am J Epidemiol* 109(3): 273-284; 1979. (19 refs)

The relationship of excess wiring configurations suggestive of high-current flow to the childhood cancer mortality rate of the greater Denver, Colorado area was analyzed. Cancer data were collected for 344 children who died before 19 yr of age between 1946-1973 and who either remained at the same address for life (109 children) or moved, but whose birth and death addresses were known (147), and for those with only birth (16) or death (72) addresses available. Maps of the addresses denoting the electrical wires and transformers in the vicinity were drawn. The most striking difference between the cases and controls (children from homes not near high-current flow) occurred for children spending their entire life at one address; the effect appeared to be dose-related. The greater the exposure to the current, the greater the excess of cancer in comparison to controls that was observed: substations with very high expected current showed 100% with cancer; other high current configurations (HCC) with high expected current, 63.1%; low current configurations (LCC) with low expected current, 47.1%; and end poles with very low expected current, 30.8%. An excess of cancer cases compared to controls with respect to HCC was noted for several types of cancer (e.g., leukemia, lymphoma, and nervous system tumors), suggesting that HCC may hinder the body's general ability to resist cancer. There was a significant excess of cancer among men with a lower current configuration for the birth than the death address and among men from stable (i.e., lifetime) addresses who developed cancer after at least 1 yr of postnatal life at a residence near primary wires. The HCC-cancer relationship was demonstrated in both younger and older subjects and was largely attributed to the HCC residence near

the time of cancer onset. Neighborhood, street congestion, social class, or family structure had no significant effect on the HCC-cancer mortality rates. Although the reason for the correlation between HCC and childhood cancer is unknown, it is suggested that the current in water pipes or the alternating current of magnetic fields may have hazardous physiologic effects.

6179 MICROWAVE DIATHERMY: THE INVISIBLE HEALER. *(Eng.)* Greene, J. (Food and Drug Admin., Office Public Affairs, Rockville, MD 20857). *FDA Consumer* 13(1): 7-11; 1979. (0 refs)

The medical use of heat produced by microwave radiation (microwave diathermy) is reviewed. Microwave diathermy can induce a deep-heating effect in muscles as much as 2 inches below the skin and can raise the temperature of the area treated to as much as 42 C. Microwave diathermy is used in the treatment of muscle pulls and strains, bursitis, tendonitis, and arthritis. The FDA estimates that about 10,000 such units are being used in the United States by chiropractors, physical therapists, family physicians, and various medical technicians. However, the FDA cautions consumers to check with qualified medical experts before undergoing any microwave diathermy treatment. Radiation from these applicators has been known to cause cataracts in patients being treated for sinus conditions. The possibility also exists that a patient being treated for a neck or shoulder injury could be subjected inadvertently to stray radiation in the eyes. In addition, painful and even severe burns of the skin and underlying tissue can occur if too much radiation is delivered to the area being treated or if the exposure duration is too long. The FDA plans in 1979 to publish a proposed regulation establishing a performance standard for microwave diathermy units that is based on the Agency's overall investigation of these medical devices. The standard will cover four important use areas that the FDA thinks will improve their safety and effectiveness. The areas are minimum therapeutic heating, maximum microwave radiation leakage, product interlocks and controls, and user information. The maximum microwave radiation leakage provision would ban applicators that generate large amounts of stray radiation outside the intended treatment area but would permit a nominal amount of leakage about 2 inches from the outer edge of the various applicators when used on phantoms. Once the standard is published, manufacturers will have 1 yr to comply with its technical specifications and labeling requirements. The FDA can take legal action to remove from the market microwave diathermy units currently in use or manufactured before the standard if they are found to pose a significant health hazard under the Agency's Medical Device Amendments of 1976.

6180 CURRENT STATUS OF MICROWAVE THERMOGRAPHY FOR MEDICAL APPLICATIONS. *(Eng.)* Schultz, S. (Dept. Physics, Univ. California, San Diego, La Jolla, CA 92093). *IEEE Trans Nucl Sci* NS-26(2, part 2): 2722-2723; 1979. (4 refs)

The physical processes involved in microwave thermography of the human body are described and the problems associated with the determination of the volume temperature of the body are discussed. In addition, some possible biomedical uses of microwave thermography are presented. Microwave thermography of the human body is based on the measurement of infrared radiation emitted by the human body over a continuous frequency, from which the absolute temperature may be inferred. The electromagnetic absorption properties of water determine the absorption length (or penetration depth) of the body's thermal radiation. Since the penetration depth is less than 1 mm at infrared frequencies, conventional thermography can only determine the surface or skin temperature. A technique that uses much lower frequencies, 1-10 GHz, to determine the body's radiation temperature has recently been implemented. Since penetration depth increases significantly with lower frequencies, temperature "hot spots" or anomalies may be detected in regions several centimeters below the skin. However, technical problems, such as impedance matching and receiver sensitivity, and spatial resolution of temperature mapping must be solved before microwave thermography will be useful for determining the thermal radiation from a specific region of the human body. Microwave thermography has been used under clinical conditions to screen approximately 3,000 women for breast anomalies at 3.3 GHz and 1,000 women at 1.3 GHz. Anomalies were determined by comparing the magnitude of the temperature asymmetry between corresponding locations on the right and left breast. With an asymmetry threshold of 1.3 C at 1.3 GHz, the true positive and the true negative probabilities were 0.76 and 0.63, respectively; these results are comparable to those obtained with infrared thermography. Microwave thermography is a noninvasive technique that does not expose the patient to any radiation or harmful effects. Other medical problems may benefit from the noninvasive determination of volume temperature, such as, vascular congestion, internal infection, hypothermia as applied in cancer treatments, and energy deposition monitoring.

6181 THRESHOLDS FOR PHYSIOLOGICAL EFFECTS DUE TO RF AND MAGNETIC FIELDS USED IN NMR IMAGING. *(Eng.)* Budinger, T. F. (Donner Lab., Univ. California, Berkeley, CA 94720). *IEEE Trans Nucl Sci* NS-26(2, part 2): 2821-2825; 1979. (52 refs)

The biologic effects of radio frequency (RF) heating, static magnetic fields, and electric current induction due to rapid changes (dB/dt) induced by nuclear magnetic resonance (NMR) body imaging were investigated. Heating, the major effect of RF fields on the body, is not associated with any serious health hazards provided the average power densities do not exceed 10 mW/cm^2 for 30 min. The safety level established by OSHA of 10 mW/cm^2 for 10 MHz-100 GHz averaged over 6 min is based on the concept that the electro-

magnetic heat load should not exceed man's basal metabolic rate. However, Russia and Eastern European countries have lower limits for safety that are based on central nervous system and behavioral responses. Static fields below 0.5 tesla (T) should be tolerated without ill effects. However, this standard has not been confirmed and no well-defined epidemiologic study with a sufficiently large population of exposed individuals showing the integrated effects of magnetic field exposure of levels >0.5 T has been undertaken. Current densities of 3 $\mu A/cm^2$, produced by rapid changes in magnetic fields of 3 T/sec, should not cause any biologic effects. However, wave form, energy, dose rates, and time intervals must also be considered when assessing the physical stimulation of biologic systems by electric current induction, particularly if a dB/dt of >3 T/sec is applied. Safe NMR imaging is possible if time varying fields such as 1.5 mT (15 G) at 60 Hz are used. In conclusion, NMR imaging should not produce health hazards if RF power densities are less than 10 mW/cm^2, static magnetic fields are less than 0.5 T, and the temporal variation of fields is less than 3 T/sec.

6182 RF USED TO FIGHT CANCER. *(Eng.)* Brinton, J. B. (No affiliation given). *Electronics* 52(9): 88-90; 1979. (0 refs)

The use of radio frequency (RF) hyperthermia in experimental cancer therapy is reported. The technique is based on the fact that normal tissue is capable of dissipating more heat than tumor tissue; the heat generated in cancer cells causes changes in cellular pH and other factors that can kill the cancer cells. In one clinical trial 27.12-MHz RF heating (42.2 C) was used for 30 min just prior to radiation therapy (RT) for the treatment of malignant melanoma, a tumor resistant to ionizing radiation. At 6 mo after this combined therapy, 16 of 18 tumors in 9 patients had completely responded in contrast to only 1 of 8 tumors in patients treated with radiation only. Two factors inhibiting the development of RF hyperthermia in cancer therapy are a lack of firm research results based on well-controlled experiments and a paucity of RF hyperthermic equipment. A system especially developed for RF hyperthermia research has recently been introduced that uses a microprocessor-controlled RF generator that operates over a frequency range from 10-2,500 MHz. Temperature is measured in the tumor with nonmetallic thermistors whose output is fed to a microprocessor that in turn controls RF output. Temperature is controlled to within ±0.1 C.

6183 HYPERTHERMIA - 'HOTTEST NEWS IN CANCER THERAPY.' *(Eng.)* Leff, D. N. (No affiliation given). *Med World News* 20(10): 52-53, 57-58, 60, 65, 69; 1979. (0 refs)

The use of microwave and shortwave radio hyperthermia for cancer therapy is reported. Based on the fact that cancer cells are more sensitive to heat than normal cells, hyperthermia is being used to selectively destroy tumors. In one case, a 54-yr-old woman with three surface nodules that grew at the scar site 6 yr after a radical mastectomy was treated with 10 40-min applications of 2,450-MHz microwave energy. Tumor temperatures reached 43-45 C. At the end of her twice-weekly hyperthermia sessions, the nodules had disappeared; however, 4 wk later all three recurred, though only at the margins. Central areas of necrosis were healed. At least a 90%-plus response to treatment was observed in another patient who was treated with hyperthermia in combination with drugs and ionizing radiation for a bleeding vaginal leiomyosarcoma. In general, microwave hyperthermia is used only for small skin surface or subcutaneous tumors because of the inability of microwaves to penetrate more deeply into the body. However, tests with shortwave radio hyperthermia at a frequency of 13.56 MHz indicate that this modality is capable of elevating the temperature of a tumor of any size and anywhere in the body to 50 C. Radio frequency hyperthermia appears to be theoretically ideal for large sarcomas that keep growing despite surgery, irradiation, and chemotherapy. To date, 75 malignancies in 64 patients with large sarcomas, melanomas, and other diseases that had failed standard therapy have been treated with radio frequency hyperthermia; marked tumor necrosis has been observed in about half of these patients, and there have been a few remarkable remissions.

6184 MICROWAVES HELP DETECT TUMORS. *(Eng.)* Hindin, H. J. (No affiliation given). *Electronics* 52(8): 85-86; 1979. (0 refs)

The use of microwave radiometers for the detection of breast cancer is discussed. Cancerous tissue is usually accompanied by an increase in local temperature of a few degrees. This radiation can travel through human tissue for distances up to several centimeters, and it can also escape from the body if its source is close enough to the surface. Once out, the radiation is readily detected by present-day microwave radiometric receivers. Thus, noninvasive scanning of a patient's natural microwave emissions can be used to locate possible cancerous hot spots. Microwave detection at frequencies of 1.3 and 3.3 GHz has been used in clinical tests, and it has been demonstrated that microwave scanning in combination with infrared thermography can detect as many cancers as X-rays alone and has the same true negative rate. Both the 1.3- and 3.3-GHz radiometers are comparison-type superheterodyne receivers with a 100-MHz intermediate frequency bandwidth centered at 60 MHz. The input to the first-stage tunnel-diode amplifier is switched at an 8-Hz rate between the antenna that picks up the human body radiation and a matched load whose temperature is controlled by a thermoelectric refrigerator. Tests funded by the NIH are being conducted on the properties of millimeter microwave thermography (11 and 30 GHz), and clinical trials of millimeter systems combined with conventional infrared and mammograms are being conducted at Denver's Swedish Hospital. In Europe, a group from Phillips GmbH in Hamburg, West Germany is performing 2-GHz examinations at a breast cancer detection

clinic in Strassburg, France. Their system features real-time compensation for variable antenna-skin interface energy reflections.

6185 A HISTOPATHOLOGIC STUDY ON THE EFFECTS OF RADIOFREQUENCY THERMOTHERAPY ON MALIGNANT TUMORS OF THE LUNG. *(Eng.)* Sugaar, S. (Dept. Surgery, State Univ. New York, Downstate Medical Center, Brooklyn, NY); LeVeen, H. H. *Cancer* 43 (2): 767-783; 1979. (42 refs)

Histologic alterations of malignant lung tumors in three patients treated by repeated local radio frequency (RF) heating are reported. All patients were heated by the dielectric method using 13.56-MHZ RF radiation. Short bursts of power were sequentially switched to different electrode pairs that continuously heated the cancer but avoided overheating the skin. In addition to expected tumor cell degeneration, changes in the tumor's stroma were also observed after RF heating. Stromal blood capillary walls were massively infiltrated with round cells and underwent degenerative changes leading to necrosis and obliteration of the tumor's vascular supply. Extensive infiltration of the stroma with the host's round cells also occurred. Following focal necrosis and rupture of the stroma, pools of lymphocytes established direct contact with heat damaged malignant cells, leading to further destruction of persisting tumor. The histologic evidence of widespread necrotic changes of all histologic elements of the tumor's stroma and a reduction and widespread destruction of still recognizable but obviously nonviable nests of tumor alveoles was best seen in the most central area of the large tumor mass. The histopathologic changes induced in solid tumors by local RF thermotherapy appeared to be similar to histologic changes occurring in acute allograft rejection. This similarity has not been noted following other treatment modalities in cases of spontaneous human or animal malignant tumors.

6186 THE USE OF 2450 MEGAHERTZ OF MICROWAVE IN CANCER THERAPY. *(Eng.)* Luk, K. H. (Dept. Radiation Oncology, Claire Zellerbach Saroni Tumor Inst., Mount Zion Hosp. and Medical Center, P.O. Box 7921, San Francisco, CA 94120); Baker, D. G.; Purser, P.; Castro, J. R.; Manuel, F. *Phys Ther* 59(4): 405-408; 1979. (9 refs)

Preliminary results of a pilot study on microwave-induced hyperthermia (average 42.5 C) for the treatment of 26 patients with superficial tumors are reported. Local tissue hyperthermia was induced using a microwave unit operating at 2,450 MHz with a maximum power of 125 W. From December 1976 to June 1977, 28 courses of hyperthermia were given. Ten of these courses were hyperthermia treatment alone; 18 were combined with radiation therapy. The entire procedure of tissue hyperthermia normally lasted about 90 min. Generally, the induction phase of the heating occurred within 5 min, with the temperature rising from 36.0 C to 41.7 C. The treatment was then given for another 60 min. Minor fluctuations in the recorded temperature ranged from 41.7 C to 43.5 C. At the end of the treatment course, the thermal washout was recorded for 3 min and the temperature dropped from 43.5 C to 38.6 C. Whole body temperature was not significantly elevated (<1 C), as measured by an oral mercury thermometer placed under the tongue for 5 min before and after hyperthermia treatments. When the applicator of the microwave unit was directed over major blood vessels, the potential for the temperature to rise was greater. Twenty-six courses of treatment were evaluated. Local tumors showed an improved response rate to the tissue hyperthermia alone, as well as to tissue hyperthermia combined with radiation therapy. There were 7 complete responses, 11 partial responses, 5 minimal responses, and 3 with no response. In addition to objective evaluation of tumor responses, 70% of the patients reported palliation of pain, decreased or controlled bleeding, reduction of oozing and crust formation, and decreased foul odors concurrent with tumor regression. Blistering occurred in seven patients; two of these patients suffered third-degree burns in the fat layer, which required debridement of eschar and frequent dressing change. These burns resulted from transient rise in temperature to more than 44 C for more than 10 min. One patient developed a cellulitis, which was treated successfully with oral antibiotics. Two patients had massive tumor necrosis, leaving large open ulcers that required a long time to heal. The occurrence of such complications underlines the necessity of medical team care for patients receiving hyperthermia treatment.

6187 THE CAUSE OF CANCER: BIOCHEMICAL DEFECTS IN THE CANCER CELL DEMONSTRATED BY THE EFFECTS OF ELECTROMAGNETIC RADIATION, GLUCOSE AND OXYGEN. *(Eng.)* Holt, J. A. (190 Cambridge St., Wembley, Perth 6014, West Australia, Australia). *Med Hypotheses* 5(1): 109-143; 1979. (17 refs)

Studies of the effects of very-high-frequency (VHF) radiation on cancer patients are discussed in relation to the mechanism of carcinogenesis. High intensity VHF (over 50 mW/cm^2) can cause cancer cells to die from thermal and/or nonthermal effects. Low intensity VHF (below 10 mW/cm^2) can stimulate the rate of growth of many common cancers and alter the microscopic appearances of the cancer. During and shortly after such irradiation, the cancer cells produce progeny that reveal a more primitive, less differentiated form with suppression of whatever sophisticated somatic characteristics their ancestors may have formerly exhibited. Normal adult cells are not macroscopically or microscopically altered by VHF at any intensity up to 150 mW/cm^2, making VHF a unique tool to show the differences between cancer cells and histologically similar normal cells. Studies on the effects of applying 434-MHz VHF radiation to cancers and normal tissues while they were normo- or hypoglycemic and simultaneously oxygenated or anoxic demonstrate that each human cell contains at least two separate respiratory pathways that can convert glucose to

energy. The first pathway produces energy by an anaerobic mechanism and it can be demonstrated that this energy is used for cell replication. The second pathway(s) produces energy from glucose by aerobic oxidative processes that can be shown to energize other cellular functions, including that of controlling cell division. Release of the anaerobic system from supervisory control of the aerobic system permits unlimited cell division, which is characteristic of cancer. Circumstantial evidence suggests that this is not the result of nuclear or chromosomal defects or mutations but is due to direct irreversible sublethal damage to the cellular aerobic glucose metabolic system while the anaerobic system remains intact.

6188 SELECTIVE OCCLUSION OF TUMOR TISSUE CAPILLARIES BY HYPERTHERMIA SHOCK DURING HYPERGLYCEMIA. *(Ger.)* von Ardenne, M. (Forschungsinstitut Manfred von Ardenne, Zeppelinstr. 7, DDR-8051 Dresden, E. Germany). *Dtsch Gesundheitsw* 33(45): 2158-2159; 1978. (14 refs)

The effect of local hyperthermia on erythrocytes was studied in capillaries of DS carcinomas of 20 rats in connection with investigations on the effects of hyperthermia and hyperacidification of tumor tissue by glucose infusion in cancer multistep therapy. The tumor pH was adjusted to 6.1. A 8-kW high-frequency generator with moving applicator (CMT Selectotherm unit) was used to generate hyperthermia (41 C). Due to the highly homogeneous energy supply, it was possible to induce hyperthermia shocks by 2-4 C at a rise time of 3-6 min. The temperature peak was maintained for 5-15 min. Hyperglycemia caused a total loss of flexibility of the erythrocyte membrane, which, combined with the local hyperthermia, led to a total stoppage of microcirculation at the venous capillary end in the carcinosarcoma. The terminal section of the tumor capillaries was found to be more sensitive to hyperthermia and hyperacidification than the tumor cells supplied by the capillary network.

6189 INTRACELLULAR HYPERTHERMIA: A BIOPHYSICAL APPROACH TO CANCER TREATMENT VIA INTRACELLULAR TEMPERATURE AND BIOPHYSICAL ALTERATIONS. *(Eng.)* Gordon, R. T. (4936 W. Estes, Skokie, IL 60077); Hines, J. R.; Gordon, D. *Med Hypotheses* 5(1): 83-102; 1979. (21 refs)

The use of intracellular hyperthermia for the destruction of cancer cells is described. Submicron particles were colloidally suspended, injected intravenously, and were phagocytized by cancer cells. Application of an external high frequency or pulsed electromagnetic field then raised the particles' temperature, thus generating intracellular heat in precise increments and resulting in selective thermal destruction of the cancer cells with little effect on normal cells. Sprague Dawley rats bearing spontaneous mammary tumors were given intravenous injections of iron-containing particles and 48 hr after the last injection were exposed to a 450-kHz electromagnetic field for 12 min. Tumor necrosis was seen in 11 of 12 animals treated in this manner. In the animals where tumor cells were destroyed, normal tissues were histologically unchanged, even when particles were found in these tissues. There was no uptake of particles in the bone marrow, and the treatment had no effect on either bone marrow or on surrounding connective tissue. It is suggested that the sensitivity and affinity of cancer cells for these particles may be increased by the use of specific radioisotopes or tumor specific antibodies bound to such particles or to chemotherapeutic microspheres.

6190 BIOLOGIC EFFECT OF PERMANENT MAGNETIC FIELD ON THE HEMATOPOIETIC SYSTEM OF INTACT AND TUMOR-BEARING ANIMALS. *(Rus.)* Savchik, A. B. (Lvov Inst. Hematology and Blood Transfusion, Lvov, USSR); Savchuk, L. F.; Ivasivka, S. V.; Savchik, B. A. *Probl Gematol Pereliv Krovi* 24(3): 58-60; 1979. (6 refs)

The effect of exposure to a permanent electromagnetic field (16 kA/m, 1 hr/day on 2 consecutive days) on the hematopoietic system was studied in intact male albino mice and mice with transplanted subcutaneous solid Ehrlich's carcinoma and intramuscular lymphoma NK/Ly. A total of 132 animals was used in the experiments. The hematologic changes were studied on the day after the second exposure. In the intact controls, the irradiation caused significant decreases in the Hb level, erythrocyte and thrombocyte counts, and a significant increase in the reticulocyte count. In the animals with NK/Ly, the Hb level decreased from 12.6 g% before exposure to 8.7 g% ($p<0.001$), the erythrocyte count from 9,300,000/µl to 6,800,000/µl ($p<0.01$), the leukocyte count from 27,000 to 13,600/µl ($p<0.05$), and the thrombocyte count from 278,400 to 81,200/µl ($p<0.001$). In the mice with Ehrlich's carcinoma, the Hb level decreased from 13.98 g% to 8.97 g% ($p<0.001$), the erythrocyte count from 9,830,000/µl to 7,710,000/µl ($p<0.05$), and the thrombocyte count from 453,400 to 159,700/µl ($p<0.001$), and the reticulocyte count increased from 4.918% to 11.24% ($p<0.001$). The leukocytes of the controls as well as those of the animals with Ehrlich's carcinoma were not affected by the exposure.

6191 INVESTIGATIONS OF THE SHAPE TRANSITIONS OF HUMAN ERYTHROCYTES IN AN OUTER MAGNETIC FIELD. INFLUENCE OF TEMPERATURE AND ALBUMIN. *(Eng.)* Leitmannova, A. (Sektion Biologie, Bereich Biophysik, Humboldt Universitat, Hessische Str. 3/4, 104 Berlin, E. Germany); Bilke, C.; Lerche, D.; Stoesser, R.; Glaser, R. *Stud Biophys* 72(2): 85-90; 1978. (13 refs)

The influence of temperature, human serum albumin (HSA), and magnetic field on human erythrocyte shape transition was studied. For temperature studies, ACD blood (1- to 2-day old; A, Rh+) was diluted to a 0.1% hematocrit with Krebs Ringer solution and subjected to temperatures from 20 to 48 C for up to

10 min while the magnetic field strength was varied from 1 to 11.0 kOe. For albumin studies, the blood was diluted to a 0.1% hematocrit with phosphate-buffered sodium chloride solution (PBS) and HSA while the temperature and magnetic field strength were maintained at 37 C and 1 kOe, respectively. Only the shape transition of echinocytes adhering to the surface of the glass chamber into discocytes and stomatocytes was observed. Neither discocytes nor stomatocytes underwent any transition under a magnetic field of 1.0-11.1 kOe. No significant dependence of shape transition on magnetic field strength was observed from 20-35 C. Shape transitions occurred above 35 C; however, at temperatures >35 C, thermally-induced shape transition accounted for some of the increased transition. At 37 C, there was no significant difference between Ringer solution and PBS incubations with respect to shape transition. HSA-incubated PBS-diluted cells showed increased shape transitions in comparison with control blood diluted with PBS only. The results demonstrate that both temperature and HSA affect the membrane structure or cell interior, which leads to echinocyte shape transition. Both of these effects are amplified by exposure to an outer magnetic field.

6192 EFFECT OF A HOMOGENEOUS MAGNETIC FIELD ON RED BLOOD CELLS: A CELL ELECTROPHORETIC STUDY. *(Fre.)* Bellossi, A. (Service de Physique Medicale, U.E.R. Clinique et Therapeutique Medicales, avenue du Pr L. Bernard, 35043 Rennes, France); de Certaines, J. *Biol Cell* 33(3): 263-264; 1978. (11 refs)

The effect of a 2-hr exposure to a homogeneous magnetic field (5,000 G) generated by an electromagnet on the electrophoretic mobility of erythrocytes was studied in 92 blood samples from 92 healthy blood donors (68 men and 24 women, average age 44 yr). Thirty-five donors were blood group O, 34 blood group A, 5 blood group B, and 5 blood group AB. The blood group was not determined in 13 cases. Fifty-six donors were Rh-positive, 18 Rh-negative; the others were not identified. The exposure increased the electrophoretic mobility of the erythrocytes in 41 cases, and decreased it in 41. An increase in electrophoretic mobility was seen in 24/68 men, 17/24 women, 10/35 donors of blood group O, and in 22/34 donors of blood group A. The electrophoretic mobility was reduced by 65% in the men and increased by 71% in the women, and it was reduced by 71% in the donors of blood group O and increased by 65% in blood group A donors. The differences between men and women and those in blood groups O and A were statistically significant ($p<0.01$) as to the extent of the change, but there were no significant differences in the distribution of increase and decrease as to age, sex, blood group, and Rh factor.

6193 PHENOMENON OF MIGRATION AND SEDIMENTATION OF ERYTHROCYTES INDUCED BY MAGNETIC FIELDS. *(Eng.)* Porath-Furedi, A. (Dept. Biological Chemistry, The Hebrew Univ., Jerusalem, Israel); Yanai, P. *J Histochem Cytochem* 27(1): 371-374; 1979. (2 refs)

Suspended erythrocytes were exposed to static and to moving nonhomogeneous magnetic fields to investigate the effect of such fields on erythrocyte migration and sedimentation. In experiments with static weak magnetic fields, erythrocytes became more concentrated along the edges of the magnetic poles than in the rest of the container. The sedimentation was affected by the chemical state of the hemoglobin and by the geometry of the field. In an experimental system in which the erythrocytes had been previously oxygenated, the cells sedimented on the bottom of the container homogeneously; in a system in which the erythrocytes were deoxygenated, the sediment layer became dense closest to the edges of the magnetic poles beneath. In several different experiments in which the shape of the magnetic poles was different, the applied magnetic field resulted in a sedimentation pattern in which the density of the sedimented cells was highest at the points of greatest magnetic field density. Another series of experiments was carried out in which the induction of electric currents was based, not on the Brownian motion of the erythrocytes in a stationary magnetic field but rather on the effect of a magnetic field rotating rapidly. As this treatment separated the suspended cells while the suspension was moving in the direction of the inducing field, it was concluded that the moving magnetic field is able to cause or to direct motion of the cells in suspension. The disappearance of the phenomenon at a lowered but constant temperature showed that induced temperature rise is a prerequisite of the separation and directive cell motion. Added grains of dye revealed streaming in the system in the direction of the motion of the magnetic field, whereas in a cell-free system no such streaming was detected. In both the stationary magnetic field and in the moving magnetic field systems, the directing factor was the anisotropic Brownian motion caused by induced electric currents. In the stationary system, this restricts the particles to oscillations along the field, aided by the very weak magnetic attraction and by the force of gravity, bringing them to the magnetic poles. In the system with the magnetic field in motion, the cells are repelled from the magnetic poles to the farthest possible point. During this process, cell fractionation occurs, leaving above cells that are smaller than those in the bulk; at the same time, the force of gravity reduces by sedimentation the number of cells still in suspension.

6194 CHANGES IN THE BLOOD COUNT OF GROWING RATS IRRADIATED WITH A MICROWAVE PULSE FIELD. *(Eng.)* Pazderova-Vejlupkova, J. (Klinika nemoci z povolani, Vysehradska 49, 128 21 Praha 2, Czechoslovakia); Josifko, M. *Arch Environ Health* 34(1): 44-50; 1979. (12 refs)

Changes in the blood count of growing rats were investigated in 20 male rats *(Rattus norvegicus*, f. albus, Wistar strain, Konarovice breed) irradiated for 7 wk (5 days/wk, 4 hr/day) with an electromag-

netic pulse field of the following parameters: working frequency 2,736.5 MHz; repeated frequency 395 Hz; pulse width 2.6 μsec; vertical polarization; mean power density 24.4 mW/cm^2; accuracy of measurement ±6%. During irradiation the animals were placed singly in perforated Plexiglas boxes situated above each other according to equal power density planes. A group of 20 control rats was also placed singly in Plexiglas boxes in the irradiation room but outside the electromagnetic field. The rectal temperature was measured in a selected group of rats before exposure and at 1-hr intervals during irradiation. Blood samples were taken before the onset of irradiation, and others were collected at the end of wk 1, 3, 5, and 7 of irradiation and at the end of wk 1, 2, 6, and 10 after termination of the exposure. Rectal temperatures rose during irradiation, with a maximum after 3 hr. The mean temperature rise was 0.3 C, the maximum increase was 0.5 C, as compared with the initial level. Prior to irradiation, experimental animals had a higher mean body weight than did controls. This statistically insignificant difference disappeared in wk 3 of irradiation, and the body weight increase of the controls began to consistently exceed that of the experimental animals. The difference attained a significant level in wk 1 after the termination of exposure. The mean hematocrit value of the experimental animals was somewhat higher before irradiation than that of the controls. Beginning with wk 3 of irradiation, experimental animals exhibited a statistically significant reduction of hematocrit values that persisted even after termination of irradiation and finally disappeared in the last sampling, i.e., 10 wk after irradiation. The mean number of leukocytes was insignificantly lower in experimental rats than in controls. Beginning in wk 3 of irradiation this difference disappeared, but a significant decrease in the leukocyte count of irradiated animals occurred from wk 5 of irradiation on. This significantly lower leukocyte count persisted even after irradiation and disappeared only after 10 wk. The mean value of the absolute count of neutrophil leukocytes in irradiated animals was lowered only in the last week of irradiation. Statistical evaluation revealed no significant differences in the percentage proportion of the individual elements of the white blood count. Alkaline phosphatase activity showed a statistically significant transient increase at the end of wk 1 of irradiation and a transient drop immediately after irradiation. The results indicate that a microwave pulse field of given intensity affects both the white and red blood count in peripheral blood in its volume component. However, it is not clear if the growing organism is more sensitive to microwave radiation than the adult one since no analogous experiment has been done on adult rats under identical conditions. Whether the observed changes in the peripheral blood count were caused by the thermal effect of microwaves or by other effects remains to be determined.

6195 COAGULATION PROPERTIES OF PLATELETS IN CONSTANT MAGNETIC FIELD. *(Rus.)* Rusiaev, V. F. (Dept. Physics, Poltava Inst. Stomatology, Poltava, USSR). *Probl Gematol Pereliv Krovi* 24(2): 19-23; 1979. (21 refs)

The effect of a constant magnetic field (1,200 Oe) on the coagulation characteristics of platelets was studied in blood taken from exposed dogs, and on the bleeding time in 19 human volunteers. Exposure of dogs to a constant magnetic field decreased the recalcification time from 130 sec in the controls to 113 sec ($p<0.01$), the plasma tolerance to heparin from 309 sec to 284 sec ($p<0.01$), the thrombin time from 30 sec to 29 sec ($p<0.01$), the factor XIII activity from 51 sec to 44 sec ($p<0.01$), and increased the fibrinolysis time from 29 min to 35 min ($p<0.01$), and the prothrombin consumption rate from 85 to 92 sec ($p<0.01$). The exposure also reduced the sorption of fluorochrome by the platelets and the accumulation of acridine orange, and stimulated the aggregation in the presence of adenosine diphosphate. The bleeding time of a punctured finger was reduced significantly in the volunteers from 135 sec before exposure to 108 sec. The findings indicate that the constant magnetic field caused a considerable alteration in the morphologic and functional properties of the platelet membranes.

6196 A NEW OPERATIVE PROCEDURE OF HEPATIC SURGERY USING A MICROWAVE TISSUE COAGULATOR. *(Eng.)* Tabuse, K. (Dept. Gastroenterological Surgery, Wakayama Medical Coll., 7 Bancho, Wakayama-shi, Wakayama, Japan). *Arch Jpn Chir* 48(2): 160-172; 1979. (22 refs)

Partial resection (average, 30%) of 52 liver lobes was performed on 26 rabbits with the aid of a microwave tissue coagulator in an attempt to control bleeding and bile leakage. The output power of the 2,450-MHz microwave coagulator varied from 25-65 W for 20 sec; a monopolar antenna was inserted into each parenchyma several times causing a coagulated beltlike area 10 mm in width on the parenchyma surface, with the depth determined by the length of each insertion. Transection of parenchyma was performed with a surgical knife. Complete control of bleeding and bile leakage was achieved. Autopsy performed 1 day to 6 mo postoperatively revealed satisfactory healing without infection in all animals except one. Portoanglography indicated that veins up to 3 mm in diameter could be sealed. Temperature measurements indicated that the extent of thermal damage caused by microwave energy was less than 10 mm wide from the center of the coagulated tissue. Biochemical analysis and histologic studies indicated that liver cell damage was transient and that adverse systemic effects can be avoided by proper coagulation-necrosis of liver tissue by microwave energy.

6197 RESPONSE OF STRESS-SUSCEPTIBLE AND STRESS-RESISTANT HAMPSHIRE PIGS TO ELECTRICAL STRESS. I. PHYSIOLOGICAL AND BIOCHEMICAL EFFECTS. *(Eng.)* Veum, T. L. (Dept. Animal Husbandry, Animal Science Res. Center, Univ. Missouri, Columbia, MO