terations. These alterations have generally been reported to be reversible, and the effects are in many cases induced at intensities that may be associated with low level thermal stress. In experiments in which the effects of radiation heating and nonradiation heating on specific biologic endpoints have been compared, more pronounced effects are usually induced by exposure to electromagnetic fields, and in some instances, decided qualitative differences have been detected. The extent to which such differences may be attributed to variations in the heating patterns and/or heating rates is not evident at this time due to insufficient data. The rather consistent finding that pulse or amplitude-modulated microwave and radio frequency fields produce more profound alterations in living systems as well as the rather limited data on the frequency dependence of such effects suggests that physical interactions other than those resulting in generalized heating may be involved in low intensity field effects in biologic systems. The most likely interaction mechanism appears to involve macromolecular assemblages stabilized by long-range systems of weak time-varying cooperative interactions. Taken with the experimental data on low intensity field effects, it may be suggested that biomembranes may be the primary site for microwave or radiofrequency alterations.

5999 **MOLECULAR ABSORPTION OF NON-IONIZING RADIATION IN BIOLOGICAL SYSTEMS.** *(Eng.)*
Straub, K. D. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 35-42, 1978. (23 refs)

The absorption of nonionizing electromagnetic radiation in biologic systems is discussed in terms of bulk dielectric properties of living tissues and in terms of the biologic function of the molecular species absorbing energy. The bulk dielectric properties of biologic material have been under investigation for over 50 yr. The dielectric constants of the molecular constituents of living cells and the complicated assembly of cells and organs have been measured at frequencies from below 100 Hz to over 10 GHz. The dispersions of dielectric constant with frequency seen in various tissue and cellular suspensions can be understood in terms of certain specific relaxation mechanisms. While the bulk dielectric constants of living matter can be fairly well understood, other more highly specific absorptions of electromagnetic radiation may be important. Examples of such are the following: the maintenance of adiabatic conditions in small membrane-bound volumes for long periods of time, subsequent temperature elevations and their effects on membrane structures or on complex protein assemblies, the rotation or translation of molecules in mitochondria and ribosomes by electromagnetic radiation, the influence of electromagnetic radiation on proton tunneling with resulting isomerization of deoxyribonucleic acid base pairs, and electromagnetically-induced forced oscillation of the otherwise random motion of gates in excitable channels of nerve membranes with resultant membrane depolarization. Further analysis should include consideration of the behavior of membranes as thin films, the existence of electrically ordered domains within the cell or at the membrane, and the restrictions on relaxation mechanisms due to the finite small size of the molecular structures of the cell.

6000 **MILLIMETER WAVE AND FAR INFRARED ABSORPTION IN BIOLOGICAL SYSTEMS.** *(Eng.)*
Illinger, K. H. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 43-66, 1978. (60 refs)

Interactions of millimeter wave and far infrared radiation with biologic systems are discussed. Recent formal theoretic work, which was tentatively supported by experimental findings, suggested that a crucial aspect of the electromagnetic field interaction of biologic systems in the millimeter wave and far infrared region might lie in the existence of long-range collective molecular interactions within membranes associated with coherent electromagnetic oscillations in this frequency regime and result in coupled biochemical reactions (e.g., enzyme-substrate interactions) with extremely-low-frequency (10-100 Hz) oscillatory kinetics. A direct corollary of the analysis of the coherent regime spectra of biologic systems is the relationship of such spectra with cell type and type of substrate-interactant system. Under favorable conditions, differentiation of cell type and reaction type might be achieved, permitting the use of spectroscopic technique for the diagnosis of cell type and function. Differentiation between normal and tumor cells has been claimed in the literature. It is further possible that intervention in the collective mode chemical reactions involving metastable states (with coherent modes) via millimeter wave electromagnetic radiation may have therapeutic as well as diagnostic implications. Conversely, if such controlled biomedical applications are possible, it is a requisite to inquire into possible bioeffects and health implications of technologic electromagnetic radiation in the coherent regime frequency region. Several technologic applications must be considered in this context: multichannel millimeter wave communications systems, millimeter wave high-resolution radar, and microwave power transmission along terrestrial and proposed satellite-based transmission routes through the earth's atmosphere.

6001 SOME BASICS OF ELF FIELDS AND THEIR BIOSPHERE EFFECTS. *(Eng.)* Schmitt, O. H. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 71-74, 1978. (0 refs)

The significance of possible biologic effects of extremely low frequency (ELF) electromagnetic fields is discussed, and the results from one particular experiment are reported. It is difficult to design workable, reasonably economical, and ethically acceptable experimental procedures to determine whether some of the suspected subtle ELF effects are real, experimental artifacts, or merely statistical accidents. One experiment was designed to determine whether humans can consciously perceive at a statistically significant level the presence or absence of a moderate strength, low-frequency magnetic field. The ability of these subjects to learn by biofeedback training to perceive such fields was also examined. In general, the subjects did not appear to perceive or to learn to perceive such fields. A few individuals proved to be incredibly skillful in extracting relevant hints from diverse environmental signals such that they put together in a self-taught synthesis subtle subliminal leakages of informational clues. It is concluded that moderate level ELF fields have little direct adverse effect on biologic systems but that they may possibly play a role by intruding competitively into a multivariate filled-channel communication and control system that is more and more frequently found to operate, especially in highly organized biologic organisms and systems.

6002 POSSIBLE MECHANISMS OF WEAK ELECTROMAGNETIC FIELD COUPLING IN BRAIN TISSUE. *(Eng.)* Bawin, S. M.; Sheppard, A.; Adey, W. R. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 75-90, 1978. (22 refs)

The effects of weak electromagnetic fields on calcium efflux from chick and cat cerebral tissue are investigated. The data strongly suggest that the binding and release of calcium occurs cooperatively as a result of long-range interactions between anionic charge sites on the binding substrate. Extremely low frequency fields at frequencies of 6 and 12 Hz and gradients in air of 0.1-0.5 V/cm decreased calcium efflux by 12-15%. Higher and lower frequencies were without significant effect. For chick tissue, the field threshold in air was 0.1 V/cm and for cat tissue, around 0.6 V/m. At intensities above and below these levels, the effects became statistically insignificant. With 147-MHz amplitude-modulated fields, calcium efflux from chick cerebral tissue increased for modulation frequencies from 6-20 Hz, with the maximum efflux increase being more than 15%. No significant changes occurred at higher or lower modulation frequencies or with an unmodulated carrier wave. With 450-MHz fields, amplitude modulated at 16 Hz, increased calcium efflux from chick cerebral tissue occurred at field intensities between 0.1 and 1.0 mW/cm^2. No increase was noted above or below these levels. It is hypothesized that membrane surface charge sites behave coherently over a considerable area and that a coherent patch may be triggered to change state by a very weak trigger at one point. This triggering event may involve proton tunneling at the boundary of such a patch.

6003 CLASSICAL THEORY OF MICROWAVE INTERACTIONS WITH BIOLOGICAL SYSTEMS. *(Eng.)* Schwan, H. P. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 91-112, 1978. (54 refs)

Mechanisms responsible for the interaction of microwaves and other electrical fields with biologic systems are reviewed. Heat development, which is caused by the absorption of microwave energy, is mathematically related to the electrical field strength and the electrical conductivity of the absorber. Various contributions to the total conductivity are analyzed for ions, water, biopolymers, bound water, and lipids. The ionic contribution is frequency independent and has a value of approximately 10 mmho/cm for abundant tissues with high water content and frequencies above about 0.1 GHz. All other contributions are frequency dependent and can be represented by either a single or a sum of Debye expressions. The volume specific absorption rate, as expressed by electrical conductivity, is shown to be greatest for electrolytes up to a frequency of about 0.5 MHz. Water dominates above 4 or 5 MHz. Bound water may be the major absorber between 0.4 and 4 GHz. Ionic contributions and water clearly dominate over the total frequency range, and biopolymer and protein-bound water contribute only insignificantly to the total absorption of energy. Direct field interactions with various biocomponents are also considered. These include membrane interactions, biopolymer interactions, interactions with biologic fluids, and field-generated forces manifested by orientation, pearl chain formation, deformation, movement, and destruction.

6004 DETERMINATION OF BOUND WATER IN BIOLOGICAL MATERIALS FROM DIELECTRIC MEASUREMENTS. *(Eng.)* Grant, E. H. *In: The Physical Basis of Electromagnetic Interactions with*

Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977. Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 113-120, 1978. (5 refs)

Using a spherical shell model for the macromolecule and experimentally determined permittivities and conductivities, variation in specific energy absorption was calculated as a function of the frequency of electromagnetic energy. The calculation indicated that a frequency region exists where the absorption of energy per unit volume of bound water is considerably greater than that of free water; this frequency region occurs around 1.0 GHz. For biologic materials that have a large bound water content (such as lens tissue) this finding could be of consequence in evaluating microwave radiation hazards, particularly if an attempt is made to build a frequency factor into the maximum recommended power levels for personnel exposed to microwaves. The importance of the finding is further enhanced when it is considered that bound water is immediately adjacent to the vital biologic macromolecules.

6005 INTERFACIAL AND INTRACELLULAR WATER: EXPECTED ANOMALIES IN DIELECTRIC PROPERTIES. *(Eng.)* Clegg, J. S.; Drost-Hansen, W. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 121-131, 1978. (31 refs)

The anomalous structure of intracellular water is discussed in relation to the nature of interactions of microwaves with biologic systems. Such water appears to be structurally different from bulk water and, as a consequence, is expected to possess dielectric properties distinctly different from bulk water. Unusual properties of vicinal water, which may be of interest in connection with microwaves, include the enhanced thermal conductivity and the unusual heat capacity of vicinal water. It is suggested that it is reasonable to expect that such water, compared with bulk water, may exhibit decidedly different properties in high frequency electromagnetic fields. Calculations of the amount of intracellular surface area of rat liver cells that perturb water suggest that at least 50% of the total water in these cells must be sufficiently perturbed, due to direct solvation or proximity to a surface, and that its properties should differ significantly from neat water. Inasmuch as the status and disposition of intracellular water are important to the interpretation and understanding of the interactions of electromagnetic radiation with biological systems, it may be useful to consider the vast internal surface areas of cells and their ability to perturb water that is proximal to them.

6006 MICROWAVE FREQUENCIES AND THE STRUCTURE OF THE DOUBLE HELIX. *(Eng.)* Prohofsky, E. W. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 133-144, 1978. (8 refs)

Calculations of vibrational modes of homopolymer deoxyribonucleic acid (DNA) double helices are discussed in relation to the microwave frequency spectrum. Using force constants refined by comparison with infrared and Raman lines, calculations were made of the vibrational modes of the double helices. The results indicated a number of bands within the microwave region of the spectrum. In the case of the B to A conformation change of double helical DNA, the mode of interest, which drove the conformation, was calculated to be at 0.3 cm^{-1}; this is roughly 10^{10} Hz. It is suggested that the frequency of modes of structural importance are low enough to be affected by electromagnetic radiation and that several modes, which exist at higher frequencies, may be involved in similar dynamic roles. Pumping on these modes can cause instabilities that can affect function. Microwave absorption, which is a transfer of energy from a microwave field to the vibrational modes of these macromolecules, may also alter the interaction of modes that modify instabilities driven by other phenomena.

6007 TECHNIQUES OF RAMAN SPECTROSCOPY APPLIED TO STUDY THE EFFECTS OF MICROWAVES UPON SYNTHETIC AND NATURALLY OCCURRING PHOSPHOLIPID MEMBRANES (MEETING ABSTRACT). *(Eng.)* Sheridan, J. P.; Priest, R.; Schoen, P.; Schnur, J. M. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 145-148, 1978. (0 refs)

The effects of continuous wave and pulsed microwave radiation on synthetic and naturally occurring phospholipid membranes were studied using Raman spectroscopy. Single component, binary mixtures, and naturally occurring bovine material were systematically characterized as a function of temperature using Raman scattering to provide information about the phase diagram and the order of lipids within the membrane. These characterized materials were then studied under microwave irradiation. Preliminary results show lipid chain disorder induced by 2-GHz microwave radiation at a power density of approximately 10 mW/cm^2. These

effects were observed in naturally occurring bovine sphingomyelen materials and were most pronounced in the biologically interesting temperature region of 32-37 C.

6008 EVANESCENT WAVES AND WAVES IN ABSORBING MEDIA. *(Eng.)* Felsen, L. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 149-163, 1978. (1 ref)

The application of high frequency evanescent waves to problems involving the diagnostics of dielectric materials is discussed, with emphasis being primarily on new techniques that have been developed for the propagation of fields in lossless materials. Conventional types of evanescent fields arise, for example, when radiation is guided inside a dielectric layer. The fields are trapped by total reflections and are therefore evanescent wiggly arrows on the outside of the layer. The tracking of evanescent waves is done along the phase paths. From the geometry (spreading or contracting) of phase paths, the complete characteristics of the local field can be constructed by subsequent integration. Conversely, by monitoring the phase and amplitude of a field as it traverses a material medium, whether it be a beam field or an ordinary plane wave field, an inverse process can be used to reconstruct the characteristics of the medium through which the field has passed. Although the methods of evanescent fields are applied primarily to lossless media, the basic attributes of complex phase make these techniques relevant also to fields in lossy media.

6009 MICROWAVE AND RF DOSIMETRY. *(Eng.)* Chou, C.-K.; Guy, A. W. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 165-216, 1978. (43 refs)

Factors that determine microwave or radio frequency (RF) power absorption are discussed along with techniques for measuring incident power density and specific absorption rates. Factors that determine microwave and RF power absorption in tissue at the same incident power density include tissue dielectric properties, tissue geometry, tissue size, the frequency of the electromagnetic field, polarization of electromagnetic fields, source geometry and size, the surroundings of the exposed object, and artifacts produced by metal implants. Instruments used for incident power density measurements include the Narda 8100 Series survey meter, the Narda 8300 Series broad band survey meter, the NBS meter, the Golay cell probe, the BRH electric field probe, pyroelectric probes, and magnetic field probes. Techniques for specific absorption rate measurements include a glass probe and thermocouple combination, a fiber-optic liquid crystal probe, a thermistor with high resistance leads, other temperature probes using such devices as birefringent crystals and optical etalons, microwave diodes, thermography, twin-well calorimetry, and waveguide systems. The application of dosimetric techniques is illustrated for a rabbit head exposed to a 2,450-MHz diathermy C director, a rabbit exposed to an approximate plane wave field, a cat exposed to a 918-MHz aperture source, a rat exposed to a 918-MHz aperture source, and a phantom man exposed to simulated 31-MHz RF fields in a cavity. Studies of the coupling of 918-MHz microwave oven door leakage to human subjects, of animals exposed to 500-MHz electromagnetic energy in cavities, and of specific absorption rates in a waveguide chronic exposure system are also reviewed.

6010 ELECTRIC FIELD MEASUREMENTS WITHIN BIOLOGICAL MEDIA. *(Eng.)* Cheung, A. Y. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 217-242, 1978. (9 refs)

A miniature isotropic electric field probe developed by the BRH for implantation type electric field measurements in biologic tissues is described. The probe consists of an array of three orthogonal, electrically short dipoles (2.5 mm in length), each coated with a thin layer of epoxy. Each dipole contains a microminiature beam lead diode detector chip placed directly across the center gap of the antenna. High resistance, thin film leads allow the detected voltage to be monitored by a high impedance direct current amplifier without perturbation of the field under study due to microwave current flow in these leads. The experimental and theoretical response of the probe in muscle tissue agreed within ± 10% when the free space probe sensitivity coefficient was directly used. It is concluded that once calibrated in free space, this probe can be used for accurate measurements of electric fields within infinite slabs of muscular tissues. The response of the probe can be equated with the actual electric field strength existing in muscular tissue at frequencies ranging from 0.915-2.45 GHz by simply using the free space calibration factor for the probe. Problems associated with measurements performed in biologic systems near the boundary layers between various biologic materials were also considered. Worst case (muscle-air) boundary conditions were experimentally measured with continuous scans along an

axis normal to the boundary plane. The experimental findings demonstrated that no detectable probe-boundary interaction occurred during increasing proximity to the boundary. This is unique to the specific probe design utilized in which the diode detector impedance is much higher than the antenna impedance, thus eliminating dipole-boundary interactions. The lack of significant electric field perturbation by the probe itself was also demonstrated in a muscle-equivalent slab.

6011 SOME RECENT RESULTS ON THE DEPOSITION OF ELECTROMAGNETIC ENERGY IN ANIMALS AND MODELS OF MAN. *(Eng.)* Gandhi, O. P.; Hagmann, M. J. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 243-259, 1978. (15 refs)

The results of studies on electromagnetic deposition in realistic human models and in animals are reported. A total of 180 cubical cells of various sizes were used to obtain a best fit of the contour on diagram of the 50th percentile standard man. Use was made of the moment method solution of the electric field integral equation with a pulse function basis and delta functions for testing. Unlike earlier numeric models, both the average absorption and the distribution of absorbed energy within the model were in good agreement with experimental measurements made using phantom models. The distribution of absorbed energy was found to be frequency dependent and was explained in terms of resonant frequencies for various parts of the body. Numeric solutions for man near a ground plane and near reflectors were also obtained. At a frequency of 10 MHz, the specific absorption rate of a man standing on a ground plane was calculated as 0.0163 W/kg per mW/cm^2, which is about seven times that found for the same model in free space. At 65 MHz, the computed specific absorption rate was 4.87 times the free space value when a man is 0.1875 wavelengths in front of a flat reflector and 16.6 times the free space value when a man is 1.5 wavelengths in front of the axis of a 90-degree corner reflector. Preliminary experiments with adult rats have confirmed the existence of multibody effects. For two animals placed 0.65 wavelengths apart, the average temperature increase in the monitored animals was 1.14 C/min compared with 0.675 C/min for isolated animals exposed to 600 MHz at an incident intensity of 100 mW/cm^2. Therefore, a 70% increase in the specific absorption rate was caused by the presence of the second animal.

6012 THERMOMETRY IN STRONG ELECTROMAGNETIC FIELDS. *(Eng.)* Cetas, T. C. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 261-281, 1978. (39 refs)

New developments in thermometry designed to meet the need for measurements in the presence of strong electromagnetic fields are reviewed. Thermometer probes designed for use in electromagnetic fields include those employing liquid crystals, a liquid menicus, an optically birefringent crystal, an optical etalon, semiconductor optical absorption, thermistors, and the property of fluid viscosity. Five of these designs avoid electromagnetic absorption and reflection effects by using optical fibers rather than electrical conductors. Two others use thermistors as sensors and reduce the electromagnetic interactions through very high lead resistivities to minimize dipole currents and small enclosed loop areas to reduce magnetically induced currents. Another uses the viscosity of a fluid as the sensitive parameter and bypasses electromagnetic interactions. Only one of these minimally perturbing probe thermometers is presently commercially available. It is a liquid crystal-optical fiber type probe. Two optical fiber bundles carry light from the source (a red light-emitting diode) to the sensor and from the sensor to a photodetector (a photodiode). The sensor tip is composed of a liquid crystal mixture, which exhibits strong temperature dependence in its reflectance of red light. Various temperature ranges of about 14 C can be selected by varying the liquid crystal mixture. A precision of 0.1 C is quoted. Also discussed are requirements for calibration facilities, probe thermometers, and thermographic systems. It is suggested that if a thermographic camera is calibrated and if proper account is taken of the radiometric properties of the source, then reliable temperature measurements can be made within the noise specifications of the instrument.

6013 NON-PERTURBING MICROPROBES FOR MEASUREMENTS IN ELECTROMAGNETIC FIELDS. *(Eng.)* Deficis, A.; Priou, A. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 283-293, 1978. (7 refs)

A non-interfering dielectric microthermometer probe for making temperature measurements in electromagnetic fields is described. The microthermometer operates over a temperature range of -40 to +150 C, has a sensitivity of about 0.5 C, and has a response time of less than 15 sec. The principle of probe operation is based on the reflection of a light beam by a thermodilatable liquid contained in a capillary glass pipe of small

dimensions. In the glass pipe, the liquid forms a concave reflector meniscus. The quantity of liquid is very small; therefore, the probe thermal inertia is low, and the temperature readout is rapidly accomplished without any disturbance of the medium. Measurements with such a probe in electromagnetic fields ranging from 900-915 MHz, 2,400-2,500 MHz, and 8.2-12.4 GHz indicate that the perturbation caused by the thermometer is very low (less than or equal to 0.1 dB) whatever the orientation of the probe in terms of the electric field. Further, the voltage standing wave ratio due to the probe is less than 1.1:1.

6014 THE VISCOMETRIC THERMOMETER. *(Engr.)* Cain, C. A.; Chen, M. M.; Lam, K. L.; Mullin, J. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 295-308, 1978. (14 refs)

A viscometric thermometer that can be used for temperature measurement in electromagnetic wave environments, such as those encountered in microwave- or radio frequency-induced hyperthermia, is described. The thermometer is based on the measurement of temperature-dependent viscosity of a fluid flowing through a small sensing capillary in the probe tip. Since the change in viscosity of most liquids is in the range of percents per degree Celsius, very high temperature sensitivities are possible. A large number of pumping and measuring arrangements can be made to measure the flow resistance and, indirectly, the viscosity in the probe tip. These include a constant flow pump with measurements of the pressure difference, a constant pressure rise pump with measurements of flow, and systems representing intermediaries of these two examples. Advantages of the viscometric thermometer over other existing temperature measurement techniques include thermal and mechanical stability, the minimizing of electrical and thermal perturbations, and simplicity of operation.

6015 MICROWAVE THERMOGRAPHY: PHYSICAL PRINCIPLES AND DIAGNOSTIC APPLICATIONS. *(Engr.)* Myers, P. C.; Barrett, A. H. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 309-325, 1978. (19 refs)

The physical principles and diagnostic applications of microwave thermography are discussed. Microwave thermography is possible because human tissue emits thermal radiation whose intensity at microwave frequencies is proportional to tissue temperature. Several medical problems, including cancer, are accompanied by local changes in temperature of the order of 1 C. Present day radiometers can detect intensity changes corresponding to emitter temperature changes of less than 1 C. Specific tissue model studies of microwave penetration depth indicate that at 3 GHz the penetration depth is 5 cm (about 1 tissue wavelength) in fat and 0.8 cm in muscle or skin. The penetration depth decreases with increasing frequency. At frequencies above 10 GHz, escaping thermal emission originates in a skin layer less than 1 mm deep. This suggests that thermography at millimeter wavelengths may be expected to give results very similar to those of infrared thermography. For a rectangular waveguide antenna in direct contact with the skin surface, the thermographic antenna response pattern is a combination of the near- and far-field patterns of each aperture dimension. The response pattern resembles a funnel whose cone opens away from the antenna with a half angle of about 50 degrees. A 3.3-GHz radiometer is described that has a temperature sensitivity of approximately 0.1 C for an integration time of 6 sec. During data taking, the antenna aperture is placed flush against the skin to eliminate reflective loss at the tissue-air interface and to permit minimum spatial resolution for the given antenna size. Potential medical applications of microwave radiometry include the detection of subsurface thermal anomalies, such as, malignant tumors, localized inflammations, and vascular insufficiency in the limbs and in the brain. Studies with the use of 3.3-GHz microwave thermography for detecting breast cancer indicate true positive and true negative rates slightly inferior to those of infrared thermography. In combination with infrared thermography, microwave thermography yields true positive rates in excess of 90%, and there is no radiation exposure risk as with mammography.

6016 DESIGN AND STANDARDIZATION OF EXPOSURE SYSTEMS FOR RF AND MICROWAVE EXPERIMENTATION. *(Engr.)* Swicord, M. L.; Ho, H. S. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 327-358, 1978. (32 refs)

Currently used microwave and radio frequency (RF) animal and cellular exposure systems are described. The better exposure systems presently in use define either external unperturbed fields or absorbed dose and have provided fairly well-defined exposure levels at which biologic effects have been observed. Types of exposure systems discussed include free space whole body exposure systems using anechoic chambers, parallel plate transmission line animal exposure systems, waveguide animal exposure systems, cellular exposure systems, and selective exposure systems using dielectric lens, RF cavity exposure, or microwave waveguide/cavity exposure. It is

suggested that there is a need for the design of exposure systems that will aid in determining biophysical mechanisms rather than demonstrating the existence of biologic effects of microwave radiation. Biologic considerations may dictate either selective or whole body exposure. In either case, the standard universal exposure system does not exist. There are, however, standard procedures and measurements that should be incorporated. First, temperature and humidity should be controlled and held at a fixed agreed-upon value unless variation is desired or other extenuating circumstances exist. These parameters could be appropriately 28 C and 40% humidity for whole body exposure and 37 C for cell exposure. Secondly, internal fields throughout the exposed animal or cell system should be described through measurement or calculation so that an appropriate comparison of experimental results can be made. Hypotheses concerning mechanisms can only be tested if a detailed knowledge of energy deposition exists. Thirdly, the exposure field characteristics of frequency and modulation must be monitored and controlled.

6017 CALIBRATION TECHNIQUES FOR MICROWAVE AND RF EXPOSURE MEASUREMENT DEVICES. *(Eng.)* Bassen, H. I. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 359-382, 1978. (11 refs)

Plane wave (far-field) and guided wave calibration techniques for microwave and radio frequency devices are described. One technique, which is most suitable above a frequency of 500 MHz, utilizes an anechoic chamber and waveguide horn antennas. In BRH plane wave calibration systems, extensive use is made of the power equation techniques developed by the NBS, allowing the basic quantities of power and mismatch in a waveguide to be transferred to the calibration of radiated power. Accurate measurement of the path loss between two truncated waveguide horn antennas is performed in an anechoic chamber, facilitating antenna gain determination. A high power directional coupler in series with the transmitting antenna is calibrated to allow absolute transmitted power to be monitored. A small isotropic probe may be placed at a point in the chamber and calibrated using a television camera with a telephoto lens to observe the instrument's indicated power density. The evaluation of multipath reflections and other error sources allows the precise prediction of plane wave power density at this specific point in the chamber. Below a frequency of 500 MHz, serious problems occur when probe calibration is attempted via the free space, power density methods involving horn antennas, and an anechoic chamber. An accurate and convenient guided wave system has been developed by the NBS. This system utilizes a rectangular transverse electromagnetic mode (TEM) transmission line cell. The TEM cell consists of a rectangular metallic outer enclosure, a flat, wide center conducting strip, and tapered input and output feed sections, which maintain a 50-ohm characteristic impedance throughout the transmission line. This rectangular coaxial line has been thoroughly analyzed, both theoretically and experimentally, and has been developed into a commercially available product. Advantages of the TEM cell are that it can be used to generate electric and magnetic fields with an absolute uncertainty of approximately ± 1 dB below 500 MHz and that it does not require either high power generators (greater than 100 W) or a large amount of physical space.

6018 WORKSHOP SUMMARY. *(Eng.)* Cleary, S. F. *In: The Physical Basis of Electromagnetic Interactions with Biological Systems: Proceedings of a Workshop held at Univ. Maryland, College Park, MD, June 15-17, 1977.* Sponsored by Office of Naval Res., Naval Medical Res. & Development Command, BRH, FDA (available through NTIS, Springfield, VA 22161, Document No. AD A051218): pp. 383-395, 1978. (0 refs)

Contributions to a workshop on the physical interaction mechanisms of electromagnetic fields with biologic systems are summarized. The topics discussed at the workshop included the development of dosimetry and calibration methods and techniques for quantitating electromagnetic fields; the necessity for accurately measuring field intensities, electric field strengths, and temperatures in tissues; the design and standardization of exposure systems for radio frequency and microwave experimentation; recent results on the deposition of electromagnetic energy in animals and models of man; the relationship of energy absorption, radiation frequency, and polarization to the geometric characteristics of biologic absorbers; the use of Raman spectroscopy for studying the effects of microwaves on phospholipid membranes; the effects of microwaves on biologic macromolecules; the use of dielectric measurements in studying electromagnetic interactions with biologic systems; possible mechanisms of weak electromagnetic field coupling in brain tissue; millimeter wave and far infrared absorption in biologic systems; and a survey of microwave and radio frequency biologic effects and mechanisms.

6019 RADIATION EMISSIONS FROM NEW MOBILE COMMUNICATION SYSTEMS. *(Eng.)* Lee, A. M.; Baldwin, B.; Frey, J. *In: Communications for a Mobile Society: An Assessment of New Technology.* Bowers, R.; Lee, A. M.; Hershey, C., eds. (Beverly Hills: Sage Publications): pp. 275-292; 1978. (51 refs)

Potential hazards associated with nonionizing radiation emissions from 900-MHz mobile communication systems are reviewed. It is concluded that the power radiated by 900-MHz mobile communication systems will not create field intensities that are

large enough to be a substantial hazard. It is estimated that in an extremely high use situation with a congested urban market, new 900-MHz mobile communication systems could contribute something less than 1 $\mu W/cm^2$ of radiation in particular parts of cells. This density is roughly equivalent to the emissions from a strong frequency-modulated (FM) radio station at a distance of 2,500 m. While exactly how much the ambient level will rise in response to a high deployment of mobile communication technology cannot be determined exactly, it can be concluded that the new level will be five orders of magnitude less than intensities that cause thermal damage (i.e., 100 mW/cm^2) and well below the safety standard of 10 mW/cm^2. Moreover, this average calculated ambient level is below the much more stringent nonoccupational standard recommended by Soviet authorities. Users of portable, hand-held equipment might be exposed to significant amounts of radiation independent of deployment levels. Though the very localized density may be on the order of a few milliwatts per square centimeter, certain body organs in close proximity to the emitter may nevertheless be affected. The essentially avascular middle ear may be affected by microwave power densities as low as 2 mW/cm^2. Given the uncertainties of the biologic effects of nonionizing radiation and the fact that local radiation levels may depart substantially from average ambient levels, it seems prudent to incorporate some monitoring devices into new systems as they are deployed.

MEETING ABSTRACTS

6020 MIGRATION OF ERYTHROCYTES AND THEIR SEPARATION INTO FRACTIONS INDUCED BY MAGNETIC FIELDS (MEETING ABSTRACT). *(Eng.)* Porath, A. (Dept. Biological Chemistry, The Hebrew Univ., Jerusalem, Israel). *In: Abstracts of the VIth Engineering Foundation Conference on Automated Cytology held in Schloss Elmau, Bavaria, West Germany, April 23-29, 1978.* Plenary Session 7; 1978. (0 refs)

Suspended and chemically reduced erythrocytes in weak magnetic fields flock along the edges of the magnetic poles. This aggregation occurs during the spontaneous sedimentation of the cells by the force of gravity above a magnet, or when the sedimentation was previously completed and the magnetic field was applied later. When erythrocytes in a container were allowed to form a sediment layer on the bottom, and a rotating magnetic field was later maintained in the layer, the formation of cell aggregates was observed. These aggregates tended to stick together to form one single lump that exhibited ferromagnetic behavior. When a rotating magnetic field was applied to an erythrocyte suspension in such a way that an elongated, horizontal container was tangential to the rotating magnet, the cell suspension became separated from the medium with an "S"-shaped boundary between them. The boundary was found to move in the direction of the magnet's rotation. Parallel to the boundary and above it, a separate low-density cell cloud formed and followed the boundary's movement. The cells sedimented slowly during the treatment to the bottom of the container causing the boundary to move. The low density cell cloud moved together with it, and since it was formed of cells with lower specific gravity, it was the last to sediment.

6021 CYTOFLUORIMETRY OF ELECTROMAGNETICALLY CONTROLLED CELL DE-DIFFERENTIATION (MEETING ABSTRACT). *(Eng.)* Chiabrera, A.; Hinsenkamp, M.; Pilla, A. A.; Ryaby, J.; Belmont, A.; Beltrame, F.; *et al.* (Univ. Genoa, Genoa, Italy). *In: Abstracts of the VIth Engineering Foundation Conference on Automated Cytology held in Schloss Elmau, Bavaria, West Germany, April 23-29, 1978.* Poster Session I(15); 1978. (0 refs)

De-differentiation was produced in vitro in nucleated red blood cells of frogs by magnetically inducing an alternating current electric field and by modifying the ionic concentration of the isotonic Ringer medium. The cells were stained by fluorochrome acridine orange (AO), so that the green fluorescence reflected the AO primary binding sites with chromatin-DNA. Laser flow microfluorimetric measurements showed a bimodal distribution. The higher fluorescence peak corresponded to de-differentiated cells, while the lower one to control differentiated cells. The modified Ringer solution partially triggered the de-differentiation process. When the stimulating electric field was switched on, a frequency window could be found such that if the signal frequency was external (internal) to the window, the process was inhibited (enhanced). Preliminary automated image analysis of cell smears suggest that de-differentiated and normal cells have the same integrated optical density but different nuclear areas. The findings suggest that the first stage of the de-differentiation process, when cells move from an inactive state toward an active one, is the unfolding of their chromatin supercoiling, without any DNA synthesis. It is concluded that cytofluorimetry offers reliable means of evaluating the effects of electromagnetic stimulation.

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

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