K1. Biological Effects of Electromagnetic Fields

Non-thermal biological effect of modulated radio frequency electromagnetic fields on vasodilatation of anesthetized Xenopus laevis was demonstrated. Irradiated electromagnetic field was 10 MHz, 7.3 mG, 2.19 V/m, pulsed wave with 10 kHz burst rate. The vasodilatory effect was specific for pulsed waves because magnitude of this effect depended on duty ratio and no effect was observed for continuous wave irradiation [Miura and Okada, 1991]. This phenomenon has been clinically applied in alleviation of muscle stiffness and lumber pain [Ashida, 1992; Hashida, 1992].

Exposure of developing chick embryos to 428 MHz radio frequency radiation at a power density of 5.5 mW/cm² for more than 20 days resulted in embryo lethal and/or teratogenic effects and delayed hatching. These adverse biological effects were not attributed to thermal effect based on the results of SAR estimation [Saito, et al., 1991].

Changes in plasma and pineal melatonin levels in rats due to exposure to circularly polarized 50-Hz magnetic field were observed. Statistically significant decrease of melatonin occurred at a flux density in excess of 1 micro tesla [Kato, et al., 1993]. The exposure system was specially designed one with square coils five in vertical and five in horizontal, respectively [Shigemitsu, et al., 1993].

Biological effects of intense static magnetic field was investigated. Magnetic orientation of fibrin was observed under 6.34 T magnetic field. Ferri-magnetic fine particles were mixed in the fibrinogen, and the gelling process of the mixture was exposed to a 0.5 T magnetic field. Magnetic orientation of fibrin was enhanced [Ueno, et al, 1991]. Intense static magnetic field up to 6.34 T did not affect appreciably the rapid cleavage and the following cell multiplication and differentiation in Xenopus laevis [Ueno, et al., 1990].

Isolated sartorius muscle from bullfrog was exposed to 0.65 T static magnetic field. Responses to electrical stimulation were examined, and the latency and the maximal rate of rise of muscle tension were measured. The results showed that latency was shortened and maximal rate of rise of the tension became faster by exposure to magnetic field within 3-hours [Satou, et al., 1991]. Growth of a primary root of the corn was found to be restrained in alternating field of 10 Hz, 200 gauss [Muraji, et al., 1991].

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K2. Exposure Assessment

A dry phantom material having the same electric properties in the UHF band as biological tissues was developed. The material was composed of ceramic powder, graphite powder, and bonding resin. Problems inherent in conventional jelly phantom were overcome by this material. Experiments were performed to estimate the specific absorption rate (SAR) of human heads exposed to microwaves by using thermography method [Kobayashi, et al., 1993].

Synthetic paste phantom containing a non-ionic surface active agent was developed. Its opacity depended on temperature, which provided means to visualize three dimensional distribution of absorbed power of electromagnetic waves [Miyakawa and Yamaura, 1990].

Specific absorption rate in human head irradiated by UHF plane waves was evaluated using spherical model of human head. Dependence of SAR on tissue electric constants were also discussed [Ilno, et al., 1990]. Calculated SAR distributions in human model exposed to UHF plane-waves obtained by different methods were compared [Fujiwara and Ilno, 1993]. Near-field exposure of human head to electromagnetic fields from portable radio transmitters was investigated based on spherical model of human head. Relationship between output power and spatially peak SAR averaged over any 1 g tissue was examined, and it was suggested that local peak SAR exceeded 8 W/kg unless human head was kept away at least 7 cm from the antenna even for low power device with output power of 7 W.

A three-dimensional method for calculating currents induced in bodies by extremely low-frequency electric fields were presented. A user-friendly, numerical program has been developed to permit the calculation of induced currents in modeled bodies of human and infrahuman subjects. The program was based on a charge-simulation method (CSM), and it takes into account the three-dimensional (3-D) character of the extremely-low-frequency (ELF)
electric field and of the models to be exposed.

Portable ELF magnetic dosimeter with a solid state electrochemical cell was developed [Hayashi, et al., 1991]. Experimental and theoretical analyses of 60 Hz magnetic field at and near ground level in power substations were presented. Analytical method was a simple one based on Biot-Savart law. Comparisons between analytical and experimental results verified that the assumptions employed were applicable except for areas where localized B-field sources such as power transformers and underground power cables existed [Hayashi, et al., 1991].

References


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K3. Magnetic Stimulation

Localized stimulation using a pair of opposing magnetic field was proposed. The opposing magnetic field was generated by figure-eight coil designed based upon computer simulation. Resolution of selective stimulation of the brain was achieved within 5 mm. Functional mapping of human motor cortex related to the hand, arm, and foot area was obtained [Ueno, et al., 1990]. Spinal reflex were also investigated by similar stimulation method [Ueno, et al.,1991].

Induced current densities by magnetic stimulators were evaluated experimentally and theoretically [Yunokuchi, 1991].
K4. Microwave Radiometry

Non-invasive thermometer based on microwave radiometry was developed. The system employed a model fitting technique combined with a Monte Carlo technique to retrieve temperature-depth profiles from multi(4-6)-frequency-band microwave radiometric data [Mizushina, et al., 1992].

A microwave radiometer system consisting of a frequency sweep-type radiometer and an ultra wideband antenna has been developed. It covers the input frequency range from 0.5 GHz to 8 GHz. It can be used not only as a multispectral radiometer system whose frequencies can be chosen freely, but also as a frequency sweep-type radiometer system whose frequency is continuously swept during measurement. When an antenna is attached to a forearm, the sensitivity of the radiometer system exceeds 0.09 degree in Celsius when the integration time is 3 second and IF bandwidth is 500 MHz. The new microwave radiometer system may be utilized for non-invasive thermometry of the human body [Miyakawa, 1991].

Microwave computed tomography using chirp radar-type signal (1 - 2 GHz) has been developed. This system provides not only reconstructed image of distribution of electrical properties of the tissue but also temperature distribution in the section based on the dependence of dielectric constants on temperature. Temperature change by 2 degrees was successfully imaged in spatial resolution of 1 cm [Miyakawa, et al., 1992].

References


K5. Optics in Biomedicine

Near-infrared has been widely used in noninvasive measurement of human body. The oxygenation state of hemoglobin (Hb) in the monkey forebrain was monitored continuously throughout nocturnal sleep using a near-infrared spectrophotometric technique. An increase in oxygenated Hb and decrease in deoxygenated Hb were observed during rapid eye movement (REM) sleep, while no significant changes in Hb oxygenation were observed during slow wave sleep (SWS) [Onoe, et al., 1991].

A portable apparatus for near-infrared (NIR) laser spectrophotometry was developed to monitor the oxygenation state of the human brain. Three different wavelengths of the NIR laser beam were used, 780, 805 and 830 nm, to illuminate the head through a fiber optic bundle. The amount of light reflected by or transmitted from the tissue was detected by a photomultiplier or photodiode. The oxygenated state of Hb content and blood volume changes were calculated from detected signals non-invasively [Tamura, 1991].

Picosecond laser pulse of near-infrared light at 1,064 nm was used to detect the temporal profile of the transmitted light through the anesthetized rat head. The mean concentration of hemoglobin in the brain could be determined quantitatively. The oxygen saturation of venous blood determined by this measurement was very close to that in the internal jugular vein determined directly with a gas analyzer [Nomura and Tamura, 1991].

The infrared absorption spectra ranging from 2.5 to 10 microns in wavelength at various layers of both the human normal abdominal aorta wall and the fibrofatty atheroma were measured by transmission spectrophotometry. Pathological examination was simultaneously performed to identify tissue type of the optical specimen [Arai, et al., 1990].

A new catheter-type laser Doppler velocimeter has been developed to monitor coronary vein flow. The blood flow velocity in the great cardiac vein was measured by this method in five dogs [Mito, et al., 1990].

References


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K6. Applications in Cellular and Molecular Biology

Magnetic particles such as Ni and gamma-Fe$_2$O$_3$ were used for estimating the phagocytic rate of hamster pulmonary macrophages in vivo and investigating various aspects of intracellular movement of organelles and filamentous structures. This technique, though in its premature stage, implies quite a large area of applications from cellular physiology to environmental sciences.

An extracellular stimulation system with arrayed electrodes was developed. This system can stimulate an isolated cell such as a neuron and measure action potentials instead of intracellular method with micro-pipette. This method is suitable for long term experiments because of the reduced damage to membranes [Shiina, et al., 1992].

A novel device called "Fluid Integrated Circuit (FIC)" has been developed for the electrostatic manipulation of biological objects by high frequency electric fields. The FIC is made with photolithographic micro-machining techniques used for production of IC and LSI [Washizu, 1990]. This technique has been applied to manipulation of DNA to determine molecular size [Washizu, 1990]. Characteristics of bacterial motor was measured using FIC technique. External force -to-velocity characteristics and torque-to-speed characteristics of swimming bacteria were obtained [Washizu, 1991]. Orientation time constant of flagella in electrostatic field produced by microfabricated electrode were investigated. Transformation of flagella was observed by further raising the field intensity [Washizu, 1992]. The FIC technique provided means to create very high intensity high frequency field over 10$^6$ V/m at 1 kHz to 10 MHz using micrometer-sized electrodes. Under this field molecular dielectrophoresis (DEP) of biopolymers was observed. As applications of molecular DEP, a novel molecular patterning method was proposed [Washizu, 1992].

References


K7. Hyperthermia

Metal plate lens applicators which can converge microwave electromagnetic energy of 430 MHz in the lossy medium such as human muscle have been developed to attain deep and localized heating for hyperthermic treatment of cancers [Nikawa, et al., 1990]. Heating depth of 6 cm was obtained using a four-aperture lens applicator in miniature pigs. This almost doubles the depth of conventional waveguide applicator. The heating area was 12 X 6 cm at the depth of 4 cm [Matsuda, et al., 1990]. The lens applicator microwave equipment had been used to treat 90 patients with a total of 96 tumors. The results showed that even tumors larger and deeper than 5 cm could be heated above 42 degrees in Celsius. The heating area is much wider comparing with those of the other 2450, 915, 430 MHz microwave heating equipments.

Induction heating type equipment for hyperthermia was developed based on figure-eight coil technique similar to that applied in field of electromagnetic stimulation [Nishide, 1992]. Induction heating of tissue using temperature-sensitive ferrite rod, which has been called soft heating method, was applied for hyperthermia as a cancer treatment [Matsuki, et al., 1991]. Three dimensional distribution of eddy current and temperature elevation for RF magnetic induction type hyperthermia using troidal-shaped ferrite core were analyzed by finite element method [Yanagida, et al., 1991].

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K8. Bioimpedance

A new tetrapolar circuit method using a magnetic field was proposed to measure the local electric impedance change in living tissue. An apparatus was developed which can detect impedance changes in closely-situated two parts of living tissue, simultaneously and independently.

Transcellular fluid shifts in ischaemic brain oedema was evaluated by applying an impedance method. The admittances of tissues were measured at various frequencies based on a simple electrical equivalent circuit for tissues. Using this impedance technique, fluid accumulation and shift may be examined by changes of parameters in equivalent circuit.

Electrical impedance in the frequencies between 2 and 200 kHz in lower limbs were measured for nine patients with Duchenne muscular dystrophy and 12 normal subjects. The intracellular resistance was higher and the membrane capacitance was lower in patients than in normal subjects [Noshiro, et al., 1993].

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References

