

New Horizons in Electromagnetics in Medicine and Biology

The field of electromagnetics in medicine and biology is called “Bioelectromagnetics”.

This interdisciplinary field has been rapidly developing and expanding in these decades. We review briefly recent developments in this field and discuss new horizons in bioelectromagnetics.

We discuss the following 4 categories in bioelectromagnetics.

(1) Magnetic stimulation of the human brain, called TMS (transcranial magnetic stimulation)

Transcranial magnetic stimulation (TMS) is a technique to stimulate the human brain transcranially by a coil positioned on the surface of the head. A localized stimulation with a figure-eight coil developed by Ueno et al. has enabled us to stimulate the human brain within a 5-mm resolution. The TMS with figure-eight coils has been widely used for the studies of brain function and cognitive brain research. New methods for deep brain stimulation are needed for the treatments of mental diseases such as depression. The so-called H-coil, combination of halo coil and round coil, and other coil configurations have been proposed. Better coil systems with better focality are required for the non-invasive treatment of brain diseases.

(2) Magnetic and electromagnetic control of living system and its medical applications

Magnetic orientation of living system is a phenomenon that living cells and tissues are aligned in the direction in parallel or perpendicular to magnetic fields based on the mechanisms of anisotropy of magnetic susceptibility in diamagnetic materials. We introduce new findings related to bone acceleration by magnetic fields, alignment of blood vessel tissues by magnetic fields, and magnetic control of orientation of nerve axons during sprouting processes obtained by *in vitro* and *in vivo* experiments. We also introduce an effect that iron ion release and uptake from and into ferritins, iron cage proteins, are affected by radio-frequency electromagnetic fields. This effect may be used in diagnosis and treatment of brain diseases, for example, for the imaging and dissolution of the β -amyloid aggregates related to Alzheimer's disease.

(3) Bioimaging or imaging by light and electromagnetics in medicine and biology

Imaging and sensing techniques are essential in medicine and biology. We focus on the imaging tools using light and electromagnetics. The techniques in molecular and cellular level include molecular probing and interrogation techniques, optogenetics in which cellular activity is controlled by light, genetically encoded Ca^{2+} indicators, and MR-based molecular imaging such as chemical exchange saturation transfer (CEST) imaging. We also discuss a neuronal imaging by new types of magnetic resonance imaging (MRI), brain imaging with superconducting quantum interference devices (SQUIDs) or ultra-low-field MRI.

(4) Biological and health effects of magnetic and electromagnetic fields

The studies of possible health effects of magnetic and electromagnetic fields are important to assess and to make guidelines not only for medical usage but also for mobile telephony. For example, biological effects of electromagnetic fields related to MRI are discussed with three types of fields; static magnetic fields, time-varying magnetic fields generated by gradient coils, and thermal effects generated by radio frequency electromagnetic fields at the resonant frequency. The guidelines are issued by the international commission on non-ionizing radiation protection (ICNIRP) and other international and national institutions.