Transmission of Time Varying Magnetic Field Through Body Tissue

P. K. Sharma and S. K. Guha

Biomedical Engineering Division
Indian Institute of Technology and
All India Institute of Medical Sciences
New Delhi, India

ABSTRACT. Based on the principles of interaction of electromagnetic waves with semi-infinite media, a simplified model is developed for the study of biological tissue — EM wave interaction problems. The four common types of biological tissues viz, bone, blood, alveolar and muscle tissue, each in turn has been considered. Expression for the transmission loss of the incident EM waves have been derived and numerically evaluated. The results indicate that there is a frequency dependence of the transmission loss and variations with tissue type exist and that losses become significant above 30 MHz. Attenuation for muscular tissue is maximum at frequencies of about 200 MHz whereas the corresponding frequency for lung tissue is nearly the double. Suitable experiments have been designed and performed to verify the salient results of the model and a fair degree of agreement has been found between the experimental results and theoretical predictions. Possibilities for the improvement of the model and future applications of the model have been outlined.

Introduction

Interaction of the electromagnetic fields with biological systems is a subject of continuing interest. The earlier emphasis was on the effects of ionizing radiation on biological tissues and the transmission characteristics of X-rays as associated with imaging of internal body structures. In therapeutics the heating property of radio frequency conduction fields has been utilized. More recently microwaves have come into use in Biomedicine and human beings are inadvertently being subjected to microwave fields. Therefore studies of the interaction of these different types of fields with body tissues have been carried out. In all these investigations the primary parameters were either the photon energy or the electrical component of the field. The magnetic component although always associated with the electric field has a comparatively insignificant role in interactions and therefore has not been adequately examined from the physical viewpoint.
especially for stationary fields. A newer class of application of electromagnetic fields in biomedicine has emerged in which the magnetic component of the electromagnetic field is the dominant factor. The range of problems include electrodeless plethysmography, magneto inductive sleep and anesthesia, neuromagnetics and new methods of imaging internal body structures. Furthermore, there is a strong interest growing in the effects of low frequency fields of radio power stations and even lower frequency fields from commercial electrical power generation systems. As these are current research trends, quite often the effects observed are interpreted in terms of magnetic field interactions without a quantitative understanding of the physics of the magnetic field interaction. As a result conclusions have been drawn which are highly questionable. Therefore, it is appropriate to quantitatively study the physical aspect of the problem, so that a firm foundation for future experimental as well as theoretical research in this area is available.

By and large the current problems dealing with electromagnetic fields where the magnetic field component is important are associated with time varying fields. In such situations the external field induces, by Faraday's principle, currents within the body tissue. As a result, weak magnetic fields are produced by the induced currents. The biological effects of the external electromagnetic field for such cases is primarily mediated through the induced fields. The magnetic field due to induced current opposes the main field and therefore modifies the transmission of the main field through the biological tissue. In other words, there is a transmission loss. The strength of the loss shall depend upon the characteristics of the electromagnetic field as well as of the tissue material. Information regarding the transmission loss consequently leads to information pertaining to the characteristics of the biological tissue. In the following study the transmission is studied theoretically as well as experimentally.

Theoretical Method

Around a coil excited with electromagnetic signal source, there is a characteristic electromagnetic field pattern with each point in space having a definite field intensity. If a biological tissue is placed near a coil as shown in Fig. (1a), the field intensities at various points as for example point 'A,' will be altered. Part of the change is because the presence of the object alters the field produced by the coil and the other part of the change is because of induction effects in the object. For radio frequencies, the first factor will be much smaller in comparison with the second factor and therefore can be neglected.