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SPECIFIC ABSORPTION RATE IN THE HUMAN BODY DUE TO EM WAVES EMITTED FROM A DIPOLE ANTENNA

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ABSTRACT

This paper deals with the computation of electromagnetic (EM) energy absorption by biological tissues. It is one of the important challenges for the computational EM community to estimate rate of EM energy absorption to asses the potential heath hazard quantitatively. The key issue in bio electromagnetics is how much EM energy is absorbed by a biological body. This is usually quantified in terms of SAR, which is the normalized rate of energy absorbed by the body exposed to EM radiation. The localized SAR indirectly related to the internal electric field and the major effort involves the determination of the electric field distribution within the biological tissues. In this work, evaluation of induced SAR in the human body due to EM waves emitted from a dipole antenna is made by using high frequency structure simulator (HFSS) software. Electromagnetic properties of human body parts such as; brain, blood, muscle and fat are used in the simulation. After performing simulation normalized value of electric field, magnetic field, local and average SAR are presented.

INTRODUCTION

The daily exposure to an electromagnetic (EM) environment raises the question of the effects of EM fields on human health. The accurate assessment of the currents induced in the human body by an EM field is a major issue. The rapid deployment of wireless communication systems such as cellular phones has caused an increased concern for the potential dangers to public health as a result of exposure to EM waves. Signals are transmitted in the form of EM waves in all directions. The EM waves of different power levels and different frequencies penetrate into the human body causing health risks; this is of great public concern. The rate at which EM energy is absorbed by the tissues of the human body is usually quantified by the specific absorption rate or the SAR value. It is a quantity that depends on the tissue mass and the strength of the EM waves inside the body.

To avoid adverse health effects, several reputed organizations such as the Institute of Electrical and Electronic Engineers (IEEE, 1999), Federal Communications Commission (Health Physics, 1998) (FCC), the National Council on Radiation Protection and Measurements (NCRP) and the International Committee on Non-Ionizing Radiation Protection (ICNIRP, 1998) (ICNIRP) and the National Radiation Protection Board (NRPB) have adopted exposure guidelines for the general public as well as for RF workers in the course of their regular duties. According to FCC standards, the safe level of SAR for the general public is 1.6 W/Kg in 1 g of tissue. Standards also specify the exposure level in terms of the incident electric field strength, E (V/m), and the power density, S (W/m^2).

EM energy absorption by biological tissue generally phantoms that contain the biological properties of a human body are generally used to measure specific absorption rate. Unfortunately no such sophisticated arrangements are available in our country. However in the simulation, EM properties of human tissues are used. HFSS is a professional high frequency structure simulator which can used to evaluate the induced SAR in the human body due to EM waves emitted from a dipole antenna. Several methods have been used for numerical calculations of rates of EM energy absorption,

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Finite Element Methods (FEM) used in HFSS numerically. It is high performance full wave EM (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to 3D EM problems are quickly and accurately obtained.

THE HUMAN TISSUES PROPERTIES

Compared to the material usually used in classical EM systems, the human body is made of a variety of organic materials, each of them having specific EM properties. Table 1 depicts the EM properties of human tissues (Stuchly *et al.*, 1980).

Table 1**.** Electromagnetic properties of human tissues.

Human Tissue	Relative Permittivity (ε_r)	Conductivity (σ) in S
Brain	42.9	0.90
Muscle	40.0	0.75
Blood	35.0	1.20
Liver	36.3	0.80
Fat	40.0	0.15

Since biological tissues are mainly consisting of water, they behave neither as a conductor nor a dielectric. Both dielectric and conductive losses are there in biological tissues when they are subjected to EM radiation. The absorption of EM energy by the biological tissue produces heating effect and that might cause detrimental heath effects when exceeds certain threshold value. The effects of EM fields on the biological tissue depend on the frequency of the EM wave. In the low frequency regime particularly in the power frequency range (50 /60 Hz); induced body current is the principal factor that measures the potentiality of the hazard.

ESTIMATION OF INDUCED BODY CURRENT

The voltages and currents induced directly into human body subjected to low frequency EM fields are of great concern if they are high enough to cause health effects. If the conductive object is grounded, the induced current that travels through the object to the ground is called the short-circuit or body current I_{sc} that can be fairly approximated using the following formula when measured in micro-Amperes (mA)(Gabriel *et al*, 1996).

$$I_{SC} = 5.4h^2E\text{..........................}(1)$$

Where h is the height in meter and E is in kV/m.

The physiological effect of electricity depends on the amount of body current. Table 2 shows the possible physiological effects and the magnitude of the corresponding body current (Karunarathna *et al.*, 2005).

SAR DISTRIBUTION IN HUMAN BODY TISSUES

The rate at which EM energy is absorbed by the tissues of the human body is usually quantified by the specific absorption rate or the SAR value. It is a quantity that depends

Table 2. physiological effects and the magnitude of the corresponding body current

Current in mA	Physiological Effects.
0.1 mA	Microshock Fibrillation
0.5mA	Threshold of sensation through skin
1 mA	Painful Sensation
10-20 mA	Muscle Spasm
>100 mA	Ventricular Fibrillation
>1000 mA	Muscle Burns

on the tissue mass and the strength of the EM waves inside the body. At a specific location, SAR may be defined by (Chen *et al.*, 1994)

$$SAR = \frac{\sigma}{\rho} |E|^2 \text{ ....(2)}$$

Where, σ= tissue conductivity, ρ= tissue mass density. E= RMS value of internal field strength. The localized SAR indirectly related to the internal electric field and the major effort involves the determination of the electric field distribution within the biological tissue.

SIMULATION OF BIOLOGICAL TISSUES BY USING HFSS

HFSS is a professional high frequency structure simulator, where FEM method used numerically. It is high performance full wave EM field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to 3D EM problems are quickly and accurately obtained.

Specific setup is necessary to prepare the simulation, and the results are post proceeding for visualization. Simulation setup is shown in Fig. (1).

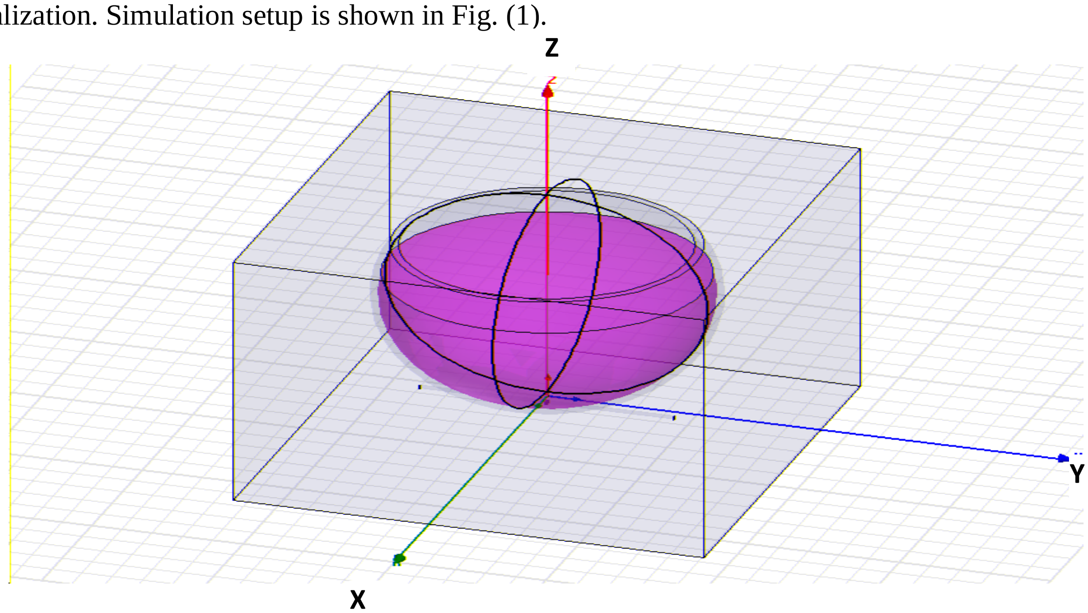

Figure 1. Simulation setup for HFSS.

Setup Specifications

In the SAR calculation setup, the biological tissue is placed in a dielectric bowl. The bowl is irradiated by EM wave using an omni directional dipole antenna placed underneath the bawl. The dimensions of the bowl and the antenna are given below.

Bowl: Inner radius = 106.5±5 mm, thickness = 5±0.5 mm. opening = d_2 =170 mm, ε_r= 4.6.

Dipole Antenna: Overall length = 168 mm, gap between dipoles = 1 mm and wire diameter = 3.6mm EM properties of human brain, blood, muscle and fat are used in simulation. After performing simulation, normalized values of electric field ,magnetic field ,local SAR and average SAR are taken as output and that are presented in the following section.

RESULTS AND DISCUSSION

When the E-field distribution inside the body is estimated, the SAR distribution can easily be obtained from equation (2). The region with the maximum field corresponds to the region with maximum SAR value. Hence, the maximum SAR and the SAR distribution for different body organs of different shapes and sizes having different electrical properties, μ, ε and σ can be estimated from the E-field distribution. In this simulation, the whole bowl is considered as one unit. The closed vicinity of antenna feeding point mentions local SAR and the SAR in whole bowl are considered as average SAR. Local and average SAR are plotted in Fig. 2 and Fig. 3, respectively for different body tissues. It is shown that the maximum of local SAR is 22 and average SAR is 13. Since blood has much water content compared with that of the other tissue of human body, blood is more conductive than other organs. The SAR is directly proportional to the conductivity. From Fig. 2 and Fig. 3 it can be observed that blood has maximum value of local and average SAR. Since, human fat has low water content, its conductivity is low compared with that of the other organs. Fig. 2 and Fig. 3 also present simulation results where fat has minimum value of local and average SAR. Frequency is a great factor in SAR calculation. In this simulation, we used frequency range (300 MHz-1GHz). For the particular length of antenna, there is a maximum radiation point in a particular frequency.

It has been observed that the maximum value of both local SAR and average SAR occur in the 800-900 MHz frequency range for all types of tissues.

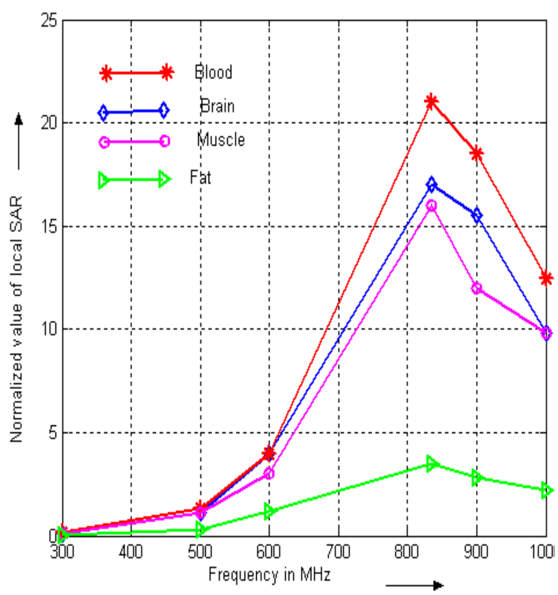

Figure 2. Normalized value of local SAR for different type of human tissues

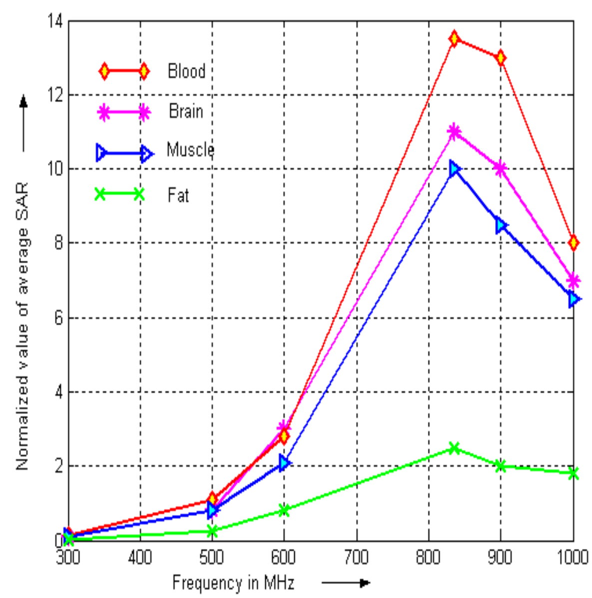

Figure 3. Normalized value of average SAR for different type of human tissues

The electric field distributions are also calculated. The calculated results are presented in Fig. 4, Fig. 5 and Fig. 6, respectively for brain, blood and fat tissues. The calculation is made at 835 MHz. As expected, the strength of the filed is maximum near antenna and some undulations are present in the filed profile with diminishing amplitude.

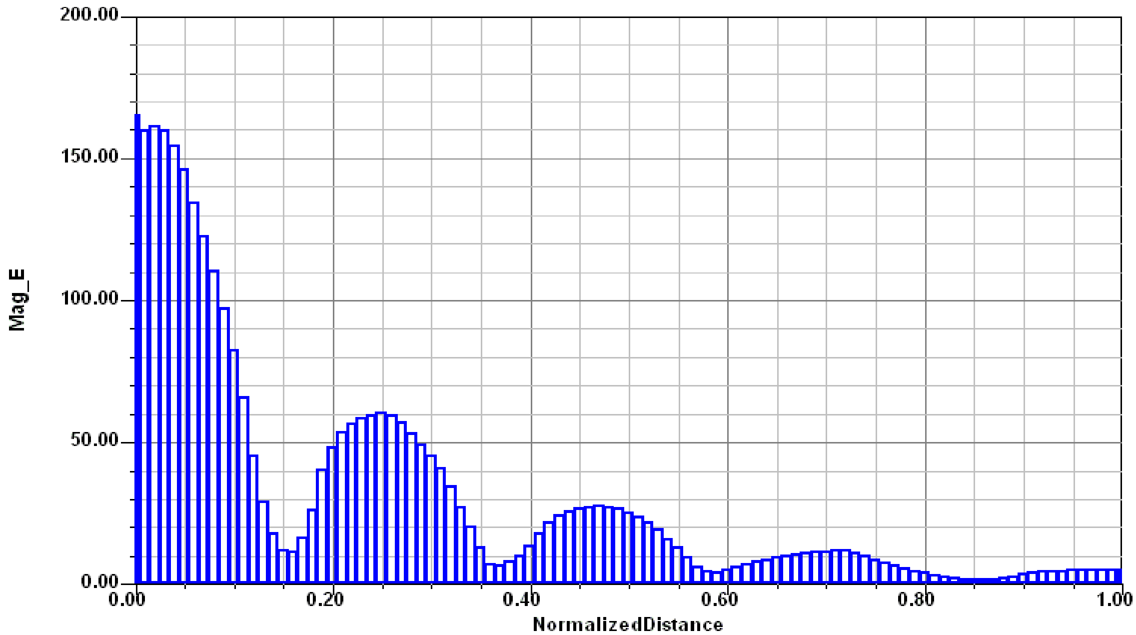

Figure 4. Normalized value of electric field for brain at 835 MHz

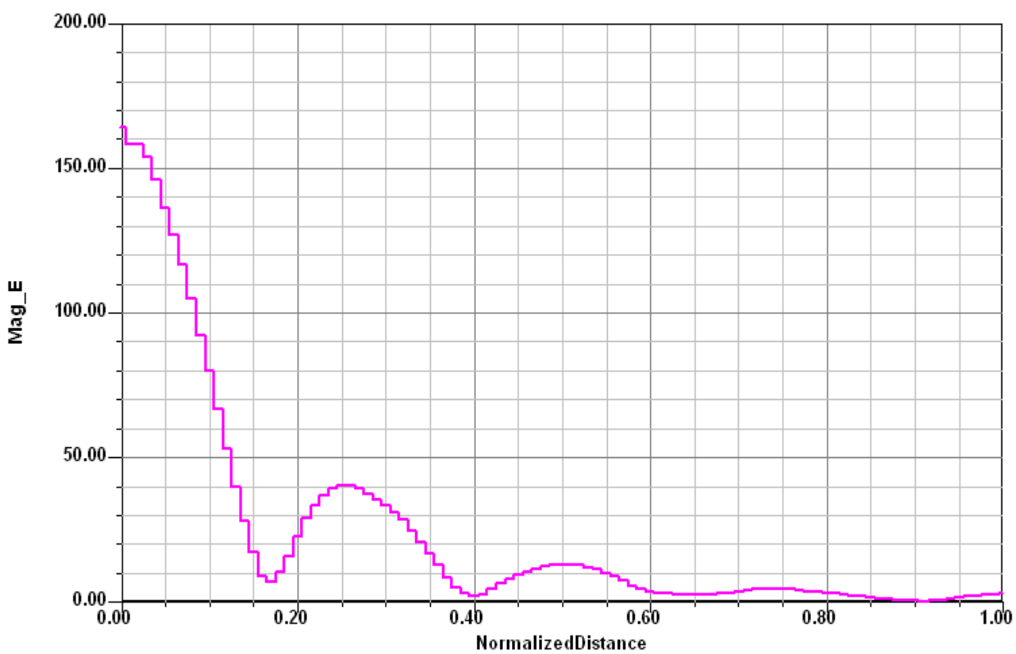

Fig. 5 Normalized value of electric field for blood at 835 MHz

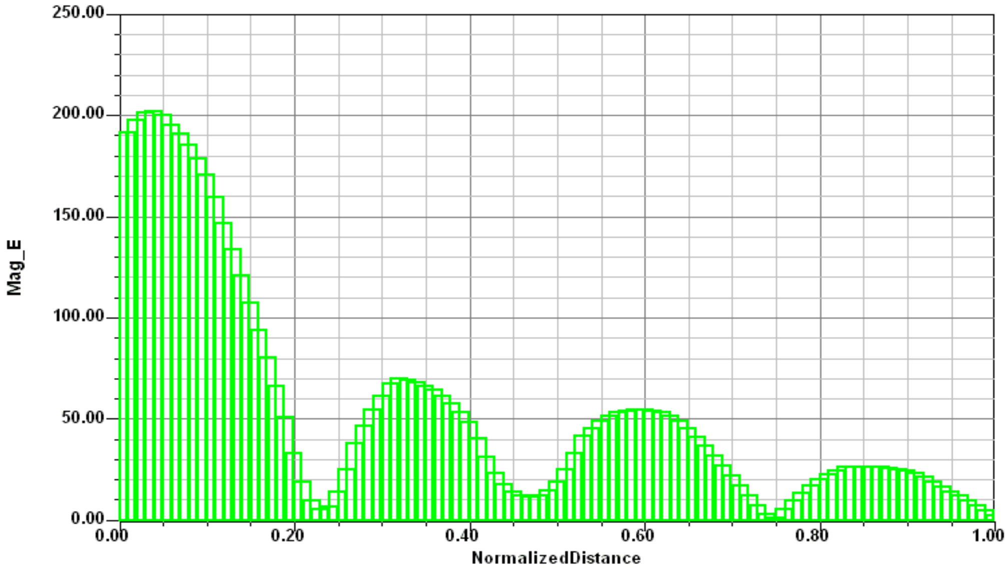

Figure 6. Normalized value of electric field for Fat at 835 MHz.

CONCLUSION

We use a large number of equipment everyday are electric or electronic ones, and thus generate EM fields. People are more and more concerned with the consequences of the exposure to the EM fields. Modeling the EM field distribution in the human body allows providing a good answer to the worried persons. In our modern science and technology we cannot pass a moment without microwave communication such as mobile communication and antenna to antenna communication, etc. In work, lower range of microwave frequencies has been used. As the direct measurement of the EM absorption is not possible, this type of simulation is used worldwide to estimate the amount of EM energy absorption in the human body.

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