Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

Analysis of SAR induced in Human Head due to the exposure of Non-ionizing Radiation

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***Abstract*—Now a days human beings live completely surrounded by many wireless devices. Modern society lives and works with wireless applications such as mobile phones, GPS devices or other wireless devices that make our life easier. It means that humankind are constantly interacting with electromagnetic fields and non-ionizing radiation. The study of electromagnetic fields and non-ionizing effects on human body is a very important subject, due to the possible health effects that these many electromagnetic fields can cause in humans. When Electromagnetic energy is absorbed by human body more than limit than human is unsafe. The study of non-ionizing radiation effects on human head tissue according to Specific absorption rate (SAR) with some interesting results, related with SAR and temperature rise has been found. To obtain trustable results, the use of higher frequency source antenna for the human head tissue with the help of HFSS (High Frequency Structural Simulator) software. This paper examines how the SAR in the human head is analyzing when non-ionized higher frequency wave exposed to the human head from communication Antenna.**

Keywords*— Modeling Human Head, HFSS, SAR, FDTD, Communication Antenna

I. INTRODUCTION

In last few years, the use of electromagnetic devices in our society is increased. The use of these devices for a various purposes has caused growing concern about possible health hazards. The personal communication devices that are usually used in the vicinity of the human body have become popular. It is known that exposure of the human body to high levels of Electromagnetic Radiation (EMR) leads to adverse health effects. Hence, the need for evaluating the interaction between the human body and the electromagnetic (EM) field is increasing. In the microwave region, the EM waves mainly contribute to a heat effect generated by absorption of the energy. In practice, characteristics of the heat effect are evaluated by the absorbed electric power per unit mass in the tissue, i.e., the specific absorption rate (SAR) (in watts per kilogram) [1]. As per the international safety guidelines [4, 5, 9, 11] the SAR must be below the limits. Some results have implied that the peak 1g averaged SAR value may exceed the safety limits. Some results have implied that the peak 1g averaged SAR value may exceed the safety limits when a mobile telephone is placed extremely close to the head. As it can be seen, the studies on electromagnetic radiation of cellular phones on the human head were performed either by using the FDTD, FD, Moment Method or phantoms. In our study, the FDTD was used and compared with the literature.

II. HUMAN HEAD MODELING

An anatomical head model consisting of six tissue types was selected for the simulation study for realistic human head modeling (Brain, CSF, Dura, Bone, Fat, and dry skin).The Dimension of each tissue is described in Figure 1. Each human tissue have a Dielectric Property like relative permittivity, conductivity, penetration depth, loss tangent, and wavelength that we should define and here we calculate Dielectric property at 2.25 GHz that we shown on Table 1 [13].

III. SAR CACULATION

The matrices of specific absorption rate (SAR) in biological system or tissue models have been accepted as the most appropriate quantities, especially at RF frequencies [3]. Regarding the works in RF, SAR is a basic tool or rate for determining EM effect exposure in the very near field of a RF source. The SAR (W/kg) at any point in the human head model is a measure of the rate at which energy is absorbed by the human head tissue when exposed to a radio frequency (RF) electromagnetic field.

TABLE 1. DIELECTRIC PROPERTIES OF DIFFERENT HUMAN HEAD TISSUES AT 2.25 GHZ

Tissue name	Conductivity [S/m]	Relative permittivity	Loss tangent	Wave length [m]	Penetration Death [m]
Brain	1.6714	49.247	0.27114	0.018818	0.02249
CSF	3.2798	66.543	0.39377	0.016037	0.013448
Dura	1.554	42.293	0.29355	0.020276	0.02245
Bone	0.35595	11.5	0.24728	0.038998	0.050956
Fat	0.095981	5.301	0.14465	0.057721	0.12768
Skin	1.3727	38.24	0.2868	0.021333	0.024154

Thus, it measures exposure to fields between 100 kHz to 10 GHz. To calculate SAR, it is necessary to know the electric field (V/m) at that point which affects the tissue. It is calculated as:

International Journal of Engineering Research & Technology (IJERT)
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$$SAR = \frac{\sigma.|E|^2}{\rho} \quad (1)$$

E = RMS value of the internal electric field (V/m)

ρ = Mass Density of the Tissue (Kg/m^3)

σ = Tissue Conductivity (S/m) in which the calculation is done

The absorb energy by the biological tissue is converted to thermal energy and causes a temperature increase. For the purpose of heat transfer analysis the temperature of biological tissue is modeled using the following Penne's bio heat equation as follows [7, 8]:

$$\rho c \frac{\partial T}{\partial t} = \nabla(k\nabla T) + Q_{met} + Q_{ext} - \rho_b c_b \omega (T - T_b) \quad (2)$$

ρ = Mass Density of the Tissue (Kg/m^3)
c = Heat Capacity of Tissue (J/Kg//°C)
k = Thermal Conductivity of the tissue (W/m/°C)
ρ_b= Blood Mass Density (Kg/m^3)
c_b= Blood Heat Capacity (J/Kg//°C)
T_b= Body Core temperature
T = Final temperature considering the EM fields Exposure
Q_{met}= Metabolism Heat Source (W/m^3)
Q_{ext}= External Heat Source (W/m^3) which is equal to the electromagnetic power absorbed
ω = Blood Perfusion Rate (1/s)

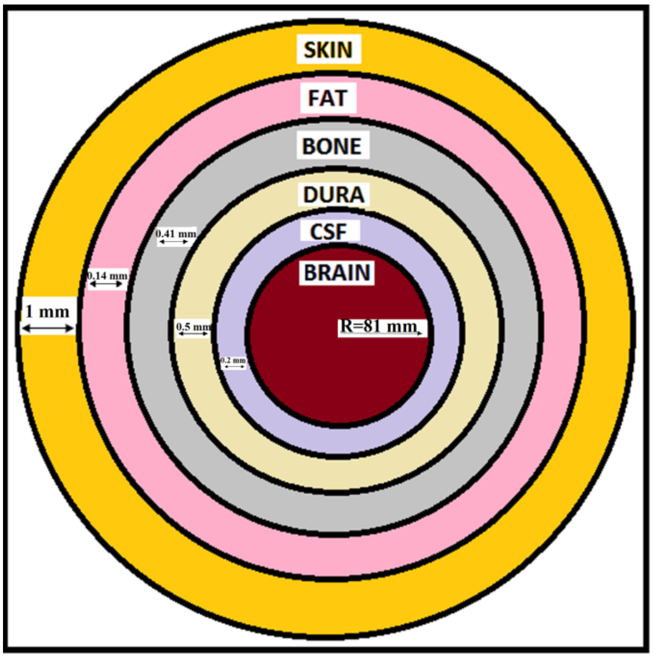

Figure 1 Human Head Model for SAR Calculation

TABLE 2. HUMAN HEAD TISSUES THICKNESS AND OTHER PROPERTIES AT 2.25 GHz

Tissue name	Thickness [mm]	Mass Density [kg/m^3]	Thermal Conductivity [W/m/°C]	Heat Capacity [J/kg/°C]
Brain	81	1045	0.55	3696
CSF	0.2	1007	0.57	4096
Dura	0.5	1174	0.44	3364
Bone	0.41	1908	0.32	1313
Fat	0.14	911	0.21	2348
Skin	1	1109	0.37	3391

The SAR value was calculated for an antenna output power equal to 250mW. To evaluate mobile telecommunication equipment, standard methods for measurement of the SAR are presently under discussion by international standard organizations [15]. In these standards, SAR is determined by measuring the electric field distribution in an artificial head (head phantom) made of a head shaped shell and filled with tissue equivalent dielectric liquid. The proposed human head model for SAR calculation is shown in Figure 1.

It consists of six layers. The outer most layer in the human head is skin and the inner layer is the human brain. In between these layers Fat, Bone, Dura, and Cerebrospinal Fluid (CSF) are present respectively. The electric properties of all tissues are shown in Table 1 [13]. Even the thickness of each human head tissues and other properties are shown in Table 2 [11].White and Gray brain tissue has no any type of distinction even though they have different dielectric properties. It should be noted that the averaged values between white and gray brain tissues were used as the electric properties of brain [14].

IV. SIMULATION SETUP

The simulation was done in the ANSYS HFSS 15 program, an interactive software package for calculating the electromagnetic behavior of a structure. The software includes post-processing commands for analyzing this behavior in detail. Using the HFSS, the basic electromagnetic field quantities and, for open boundary problems, the near and far radiated fields, characteristic port impedances and propagation constants, the Eigen modes or resonances of a structure and many other parameters can be calculated . First, it is necessary to construct a simulation model of a human head, which is presented as a Six-layer structure which consist of Skin, Fat, Bone, Dura, CSF, and Brain. Every layer has its own electric, magnetic, and conductive properties.

International Journal of Engineering Research & Technology (IJERT)
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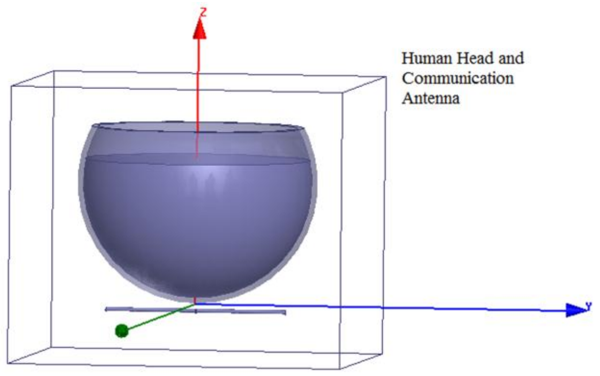

Figure 2 Model of Human Head and antenna for SAR calculation using HFSS 15.

Then, it is necessary to construct the simulation model of the Antenna. Each model is modeled according to the manual specification [x, y, z], where the antenna is modeled as a Hertz dipole. After that step, it is necessary to set up the solution properties as frequency, boundaries, calculation steps etc. Before the start simulation, it is preferable to validate the simulation, that is, check the parameters and conditions of the simulation. After that step, the simulation can start. Depending on the complexity of a structure and solution conditions, the simulation can last several hours [12].

V. Result

In this section we have the results of six layer human head model and communication antenna which are modeling in ANSYS HFSS-15 Software. Figure 3 shows SAR distribution in six layer Human Head Model expose by 2.25 GHz so here we observed that most affected tissue is the cerebrospinal fluid (CSF) in case of the SAR due to the more energy is absorb and if the source exposure is set more time than more energy absorb and this is the beyond limit define by FCC and ICNIRP standard [5, 11] which effect to our Health.

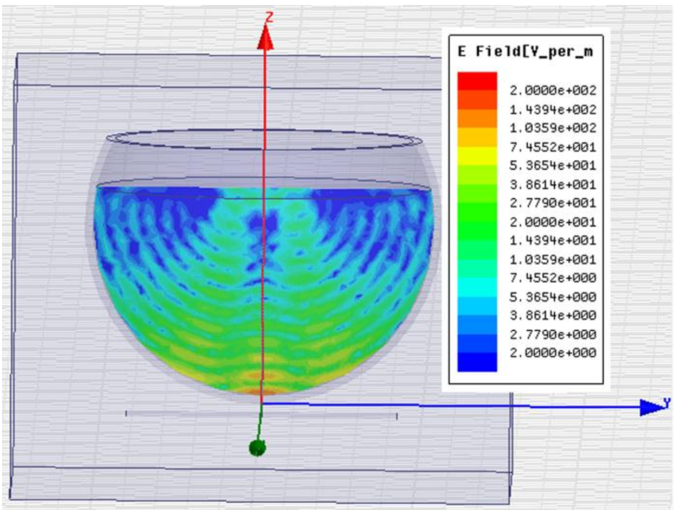

Figure 2 Distribution of SAR in Human Head Model Expose by 2.25 GHz

TABLE 3. SAR VALUE OF HUMAN HEAD CSF TISSUE FOR DIFFERENT DISTANCE (D)

Distance between antenna and Human Head (D)	D = 5mm	D = 10 mm	D = 15 mm	D = 20 mm
SAR value (W/kg)	9.3528	5.5192	3.1622	1.7950

The local SAR and average SAR value of CSF tissue which is most affected in Human Head is shown as a function of the distance between the human head model and dipole in Figure 3. The maximum value of SAR1g in the CSF tissue of head model is at the nearest point to the source exposure which is shown in red color which is 14.5780 W/Kg. When the distance (D) between the antenna and human head is decreased the value of SAR is increased and when the value of D is increased the value of SAR is decreased. For the different values of D the SAR value is shown in Table 3.

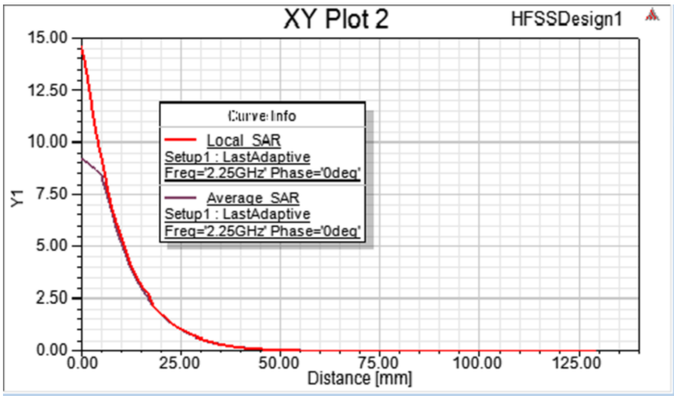

Figure 3 SAR value distributions in CSF as a function of the distance between Human Head model and dipole.

VI. Conclusion

Hear we see that the most effected tissue in human head is Cerebrospinal Fluid and when the distance between human head and antenna is changed the effective change is seen in SAR. We also see that temperature of human head is high when the distance between head model and antenna is less. The temperature rise is caused due to the absorb power in the form of SAR from a cellular antenna and these all effect is done because of electromagnetic energy is depend on SAR. When SAR value is high and it increase beyond limit than it is dangerous to our health. When we talk long time on mobile phone at that time we feel that our ear become so hot this is the experience example of our life. Some International standard prefer that in a day talk less than 6 minute on mobile phone otherwise it is harmful for our health.

Acknowledgment

I would like to thank my dissertation guide Prof. Gaurav R. Joshi who give me a good support and guide me. All friends and staff members of my department who have given direct and indirect support to carry out this work. And also thank full to my college which provide me good resources for that.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

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