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Evaluating the Effect of Distance on Specific Absorption Rate Values inside a Human Head Model

Anu Goel and Asst. Prof. Richa

Electronics & Communication Department,
A.K.G.E.C,
Uttar Pradesh, India

ABSTRACT: When using electronic devices such as mobile phone, invisible electromagnetic waves are generated. These waves can be absorbed by lossy material such as human body tissues. The radio frequency field emitted from mobile phones penetrates the exposed tissues and the absorbed energy is converted to thermal energy. This thermal effect can cause harm by increasing the temperature of corresponding tissue, and damaging biological tissue, especially those of head and brain. This paper presents a critical analysis of Specific Absorption rate (SAR) at 900MHz and 1800MHz (2G-GSM) communication frequencies by considering the various gap distances between a numerically simulated human head model and source of radiation (i.e. mobile phone). It is shown here that by increasing the distance between user and mobile phone the effect of absorbed radiations can be minimized. All the numerical results are obtained by making the use of Finite Element Method (FEM).

KEYWORDS: Penetration depth, dielectric properties, finite element method, SAR, radiations.

1 INTRODUCTION

Mobile phones have become an essential part of our daily life. But excess of anything is always harmful. Due to rapid growth in the field of mobile communication technology the effect of electromagnetic radiation on human health is a subject of recent interest and research. Regular and long term uses of mobile phones may lead to detrimental health effects. Generally a mobile phone consists of an omni-directional antenna which ideally radiates in all directions. These radiations are absorbed by nearby biological tissues especially of head. This absorbed energy is then converted into thermal energy and causes the rise in temperature of corresponding tissue. Absorption of radiations beyond a certain limit may also lead to adverse health effects. In [1] authors have reported that a very small temperature rise in hypothalamus of 0.2–0.3°C leads to altered thermoregulatory behavior. However, since the normal active heat transfer is very effective in regulating temperature in the brain, a temperature rise of up to 3.5°C in the brain is harmless and does not cause any physiological damage [2]. A measure of this absorbed radiation is provided by Specific Absorption Rate (SAR) which is defined as the power absorbed per mass of the tissue in watts/kg. When exposed to radiations human head is considered as the most sensitive part of the entire human body. Therefore most of the research has been carried out only on human head. The temperature increase inside the human head, however, cannot be measured directly. In order to overcome this difficulty, a well-known bioheat equation was proposed by Pennes [3] for following the time variation of temperatures in different biological tissues. Pennes suggested that the dissipation of the temperature is due to conduction with other tissue types, convection through blood perfusion rate and radiation to the surroundings.

Different countries follow different standards for specific absorption rate (SAR) analysis. In United State, for exposure to RF energy from wireless devices, the allowable Federal Communications Commission (FCC) SAR limit is 1.6 W/kg, averaged over 1gram of tissue for duration of 30 minutes [4]. While in Europe, according to International Commission of Non-ionizing Radiation Protection (ICNIRP) the allowable SAR limit is 2W/kg, averaged over 10 gram of tissue for duration of 6 minutes [5].

Additionally IEEE C95.1 gives recommendation to prevent harmful effects in human beings exposed to electromagnetic fields in the frequency range from 3 kHz to 300 GHz [6]. The most important aspect for performing the analysis of SAR is the selection of the method to carry out the required measurements. Experimental methods to evaluate SAR are quite costly and also time consuming. It is against the law and moral to expose a human being to electromagnetic radiations for experimental purpose. Moreover, numerical analysis through simulations provides more flexibility to analyze the same. Therefore several different kinds of models can be used to investigate SAR and heating effects. These include Finite Element Method (FEM), Finite Difference Time Domain Technique (FDTD), Finite Difference Method (FDM), Method of Moments (MoM) etc. to make predictions without needing laboratory tests. Among these methods FDTD [7] and FEM [8] are popular choice for performing the numerical analysis of SAR, as these models have shown very accurate results. Also between the two, FEM is found to be a more powerful technique for handling problems involving complex geometries due to its flexible tetrahedral meshing scheme when compared with cubic Yee-type grids of FDTD method.

This paper presents a measure of SAR and corresponding rise in temperature inside a human head model exposed to frequency range used in GSM-900 AND GSM-1800 mobile phones.

2 METHOD AND MATERIALS

In present work a realistic human head model through numerical simulation is developed. Radiation comes from a patch antenna of a mobile phone which is placed on the left side of the head at a distance of 0 cm and 1cm as shown in Fig. 1. SAR is the basic parameter that is taken into consideration for the evaluation of the exposure hazards in the radio frequency and microwave range. “Specific” refers to the normalization to mass, and “absorption rate” refers to the rate of energy absorbed by the object. SAR can be calculated by Equation (1) as follows:

$$\mathrm{SAR} = \frac{\sigma E^2}{\rho} \tag{1}$$

Where, σ is electrical conductivity (S/m), E is electric field intensity (V/m), and ρ is the density of the tissue (Kg/m^3). The first step in the analysis of electromagnetic radiation with human head is the determination of the induced internal electromagnetic field and its distribution. Thereafter, rise in temperature within the human head will be analyzed. The system of governing equations is solved numerically using the finite element method. 900 and 1800MHz spectrum are widely used in the field of GSM mobile communication. The maximum power that GSM phones are permitted to transmit are 2W (900MHz) and 1W (1800MHz). However, the average power transmitted by a phone is never more than one eighth of these maximum values (0.25W and 0.125W respectively).

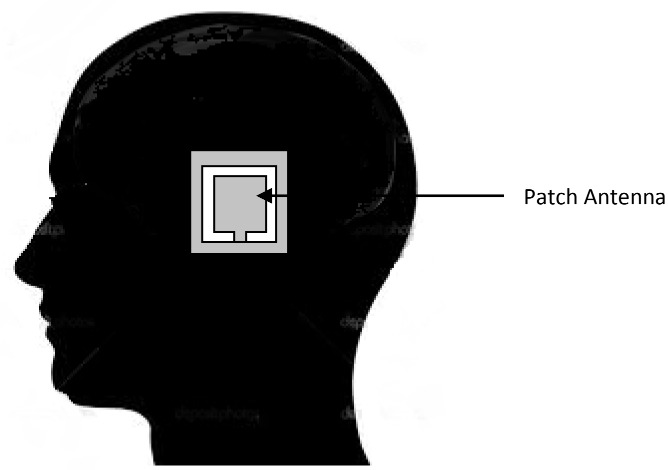

Fig. 1. Human Head Model with Source of Radiation

In this study, a square patch antenna is considered as a source of electromagnetic radiations and is placed at the left side of the head model at a distance of 0cm and 1cm. Fig. 1 is illustrating the human head model exposed to radiations from a mobile phone which consists of square patch antenna. A finite element model of a problem gives piecewise approximation to the governing equations. The basic premise of this method is that a solution region can be analytically modeled or approximated by replacing it with an assemblage of discrete elements. Since, these elements can be put together in a variety of ways; they can be used to represent exceedingly complex shapes. The method is very flexible since the elements can be chosen to closely conform the original geometry of material boundaries. Dielectric properties of brain tissue are tabulated in Table 1. These dielectric parameters are taken from [9].

Table 1. Dielectric Properties of Brain Tissue

Frequency	**Type of tissue (Brain)**	
	ε_r	**σ (S/m)**
900 MHz	45.805	0.765
1800 MHz	43.545	1.153

3 ANTENNA AND HEAD MODEL DISTANCE VARIATION

A very important parameter that affects the energy absorbed in the biological tissues when exposed to radiation from mobile phone is the distance between the antenna and tissue. The rate at which radiations emitted from a source of electromagnetic radiation passes through a surface at a distance d from the source is proportional to 1/d^2. This is known as the Inverse Square Law. According to this law the radiation flow falls off rapidly as the distance between the radiating source and receiving tissue increases. According to [10] if the distance between the antenna and human head increases then the value of SAR decreases. Not only the distance but also the size, type of antenna and its efficiency affect the SAR values [11]. In [12] a comparative study has been performed among patch, monopole and dipole antenna and patch showed the least radiations effect. Therefore a patch antenna is selected here as a source of electromagnetic radiations.

Radio waves become less penetrating into the body tissues as the frequency increases. It is observed that due to short wavelength at higher frequencies radio power penetrates to small distances. Higher the frequency lesser will be the depth of penetration. When tissues are exposed to radiation depth of penetration depends on frequency and electrical properties of tissue and is given by following Equation (2):

$$\delta = \sqrt{\frac{1}{\pi \mu \sigma f}} \tag{2}$$

Where, δ is the penetration depth (m), μ is the tissue magnetic permeability (H/m), σ is the tissue electric conductivity (S/m), and f is the RF source frequency (Hz). Depth of penetration is inversely proportional to the frequency and conductivity of the material. Thus at higher frequency absorptions of radiations become superficial and remain confined to head surface only. Table 2 shows the results obtained for SAR and corresponding rise in temperature at a distance of 0 cm and 1cm between antenna and head model.

Table 2. Peak SAR and Rise in Temperature at Different Distances Between Head model and Mobile Phone

Frequency (MHz)	**Distance 0 cm**		**Distance 1 cm**	
	Peak SAR (W/kg)	**Rise in Temp (^{o}C)**	**Peak SAR (W/kg)**	**Rise in Temp (^{o}C)**
900	0.405	0.028	0.192	0.007
1800	0.625	0.017	0.276	0.004

From these results it is clear that mobile phone operating at 1800 MHz frequency is safer to use than mobile phone operating at 900MHz.

4 CONCLUSION

This paper presents the evaluation of effect of distance between head model and mobile phone on SAR values and corresponding rise in temperature in a human head model at 900MHz and 1800MHz frequencies. This paper has shown that even a small variation of 1cm in the distance between user and mobile phone can have a great impact on SAR values and corresponding rise in temperature. Also at higher frequency the strength of radio wave to penetrate inside the tissues reduces. And finite element method is found to be an effective technique to perform the numerical analysis of complex geometries.

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