A Study Effect of Specific Absorption Rate in Human Head Model due to Electromagnetic Exposure

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***Abstract*— This study presents a numerical analysis of the specific absorption rate in the human head model due to electromagnetic exposure. A set of dipole antennas operating at 1800MHz and 2600MHz were located at the ear of human head model to investigate the effect of frequency on human head model. The maximum average of 1gram and 10gram of tissue have been presented to show the effect of the electromagnetic field in the human head model. A comparison of the mass averaged SAR in the head shows the 1g of SAR is quintuple at both 1800MHz and 2600MHz respectively.**

***Index Terms*— Electromagnetic Field Effects; Electromagnetic Wave; SAR; Specific Absorption Rate.**

I. Introduction

Nowadays, the conceivable impact of cell phones on human health has been topical a hefty portion of the most recent decades. Since the mobile phone showcase has expanded quickly finished late years, an assessed that market entrance would keep developing. There has been both public and scientific remark that the radiation from mobile phones may unfavorably influence human health [1-9]. A first stage to contemplating and conceivable issues is to build up the possible levels of radio frequency radiation in the head. There are many recent papers have discussed that the coupling of electromagnetic (EM) field emitted by mobile phones with passive implant in the human body might cause notable enhancement in radio frequency absorption under exposure [10-12]. It has been known that the mobile phones can produce a proportion of the radio frequency energy that can absorb in the head [10-12]. In Cooper's initial research [7] concludes that the value of radio frequency absorption within a homogeneous head was significantly increased with the presence of metallic implants. In Whittow's study [10-11], the jewelry and the metallic rings may alter the specific absorption rate (SAR) level distributions within the head.

Specific absorption is defined as the quotient of the incremental energy (*dE)* absorbed by an incremental mass (*dm*) contained in a volume (*dV*) of a given density (ρ). However, specific absorption rate (SAR) is defined as the rate of energy (*dE*) absorbed or dissipated in an incremental mass (*dm*) contained in an incremental volume (*dV*) of a given density (ρ)[1-9, 13-29]. Mathematically, SAR can be expressed in watt per kilogram (W/kg) as

$$SAR = \frac{d}{dt}\left(\frac{dE}{dm}\right) = \frac{d}{dt}\left(\frac{dE}{\rho dV}\right) \quad (1)$$

However, the specific absorption rate for specifying RF absorption by the tissues can be calculated at any location in the tissue from the electric field (E):

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

where: σ = Conductivity (S/m)
ρ = Mass density (kg/m^3)
E = root mean square (rms) (V/m)

The spatially- averaged SAR limits have been enforced worldwide for communication devices that recommended from International Commission on Non-Ionizing Radiation Protection (ICNIRP) that the SAR should be averaged 10gram mass of tissue (SAR_{10g}) is less than 2 W/kg[30]–[35]. However, the Institute of Electrical and Electronics Engineers (IEEE) has set a slightly stricter limit value which is 1.6 W/kg for 1gram of tissue (SAR_{1g}) for the general public[36].

This paper, investigates the effect of specific absorption rate (SAR) in the human ear. For example, the mobile phones communication enabled devices to produce radio frequency energy that can affect human ear. The possible use of mobile phones near to ear effect on human health has been topical over the last several years.

II. Material And Method

A. Simulation and Radiofrequency exposure

The modeling and calculation of EM fields were carried out by using Computer Simulation Technology Microwave Studio (CST MWS). The simulation has been made by using Time Domain Solver (TDM) before the Specific Absorption Rate (SAR) been calculated. The reference power for this paper is defined as output power at 1W (rms) by using the IEEE/IEC 62704-1 averaging method. The head tissue density has been defined as 1030kg/m^3 (bio-tissue).

This paper aims to isolate the relative effect of the RF exposure to a human head. The are many different RF sources, in order to standardize the antenna sources the dipole antennas were used in this paper with single polarisation. Therefore, the simulation can be clearly analyzed. Two types of antennas were used by considered each antenna with 1800MHz and 2600MHz frequencies, respectively. The antenna feed point located in a 1mm air gap between the dipole halves constructed using copper. By using the formulae, Table 1 shows the dipole antennas parameter for both 1800MHz and 2600MHz frequency respectively. Figure 1 shows the diagram of a dipole antenna with the calculated parameter.

Table 1
The parameter of Dipole Antennas for both 1800MHz and 2600MHz Frequency

Parameter	1800MHz	2600MHz
Wavelength, Wv	166.67mm	115.38mm
Length of half wave dipole, L	79.44mm	55mm
Radius of wire, R	0.16657mm	0.1154mm
Feeding gap, g	0.3972mm	0.275mm

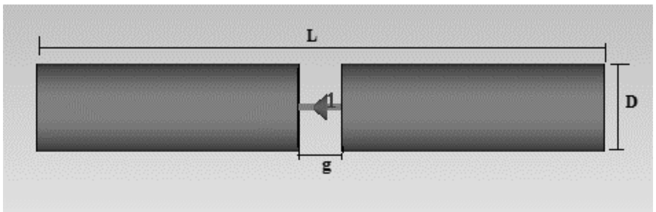


Figure 1: Diagram of dipole antenna design.

A half wave 1800 MHz dipole antenna was designed with a cylinder head model was simulated by using CST MWS. The cylinder head model was designed as the parameter of average head and average human ear. According to Patel et al. [37], 123 volunteers were randomly selected. There are consisted of 34 men with age ranging from 18 until 61years old while 89 remaining were women age range 19 to 65 years old. The average head was 6.5 inches in diameter and 8.5 inches in height. While, the average ear was 2.48 inches in ear height and the thickness of average ear was 3 millimeters (mm).

B. Head Model

The cylinder head model was designed in this paper by using the average diameter of normal human head. By using this cylinder head model, the result will be compared by using Specific Anthropomorphic Mannequin (SAM) phantom head. This cylinder head model was using bio-tissue with the density, ρ 1030kg/m^3, the thermal conductivity, 1.13w/k/m and the permeability, μ 1. Table 2 shows the average human head and average human ear that has been selected in this designed.

Table 2
Average Human Head and Human Ear parameter

Parameter	Head	Ear
Height	8.5inches	2.48inches
Diameter	6.5inches	-
Circumference	3.5inches	-
thickness	-	3milimetre

Hence, the head cylinder human model was designed in CST MWS. Therefore, the antenna for 1800 MHz frequency was attached to head cylinder model. The antenna was designed according to 1800 MHz and 2600 MHz frequencies respectively. Figure 2 show (a) the head cylinder human model and (b) the antenna attached to the head cylinder human model.

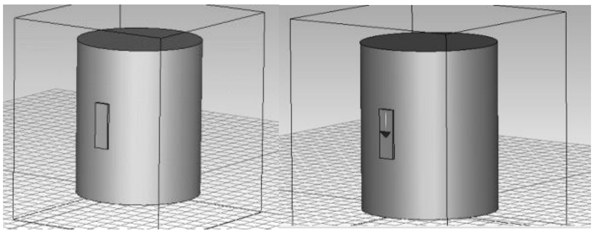


Figure 2: The model of cylinder human head attached to an antenna

III. RESULT AND DISCUSSION

In order to study the effect of 1800MHz and 2600MHz frequencies to a human head. The maximum mass averaged SAR_{1g} and SAR_{10g} in the head was investigated. The dipole antenna was placed parallel to the z-axis. The output power was fixed in this paper which is 1W.

The dipole antenna was chosen in this project because of the most relevant antenna. The frequency that has been chosen which is 1800MHz and 2600MHz, commonly used in many countries, including Malaysia. In Figure 3 (a) shown that at frequency 1800MHz slightly increase at -20.292244dB after drops at frequency 1655MHz while at frequency 2600MHz is drops to -17.8794dB.

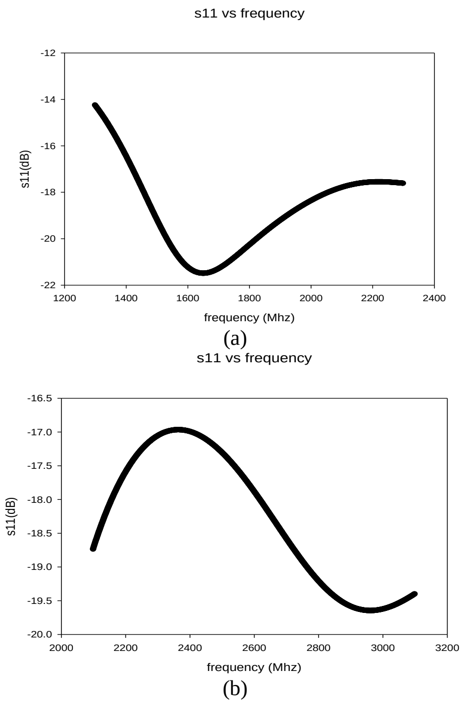
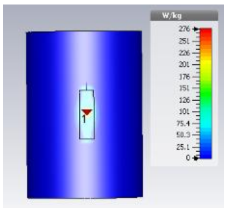
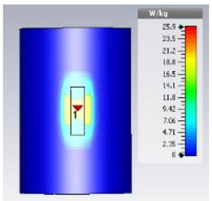
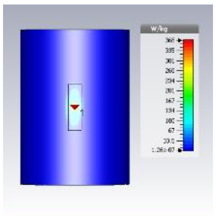
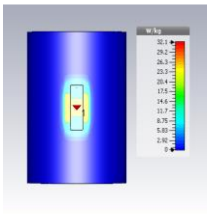


Figure 3: The performance magnitude of dipole antennas s11 value in dB for (a) 1800MHz frequency and (b) for 2600MHz frequency

The result of the frequency 1800MHz and 2600MHz exposure for both maximum SAR_{1g} and $SAR_{10g}$are summarized in Table 3. Table 3 shows the location of maximum absorption in 3D view in CST MWS software.is clear that the SAR is inversely proportional with frequency.

Table 3
The Maximum SAR for 1g of Tissue and 2g of Tissue for 1800MHz and 2600MHz Respectively

Frequency	1g	10g
1800MHz	 Maximum SAR:363.383 W/kg	 Maximum 65.2321 W/kg
2600MHz	 Maximum SAR:273.847 W/kg	 Maximum SAR:52.2853 W/kg

All the simulations were normalized to 1 Watt output power with half-wave dipole antennas, the maximum SAR_{1g} and SAR_{10g} of tissue for 1800MHz frequency is 363.383W/kg and 65.2321W/kg while for 2600MHz, 273.847W/kg and 52.2853W/kg respectively.

It can be seen, the SAR is more for 1g of tissue compared to 10g of tissue while the maximum SAR for both gram of tissue for difference frequency, the higher the frequency, the maximum SAR becomes lower. It is clear that the SAR is inversely proportional with frequency. It can be seen in Table 3 that, the maximum SAR_{1g} for 1800MHz frequency much higher than 2600MHz frequency. Same goes for SAR_{10g} which the maximum SAR for 1800MHz higher than maximum SAR for 2600MHz frequency.

IV. CONCLUSION

The numerical analysis FIT technique using CST MWS was used to examine the most suitable head phantom based on simple geometrical shapes. The RF sources were 1800MHz and 2600MHz frequency with half-wave dipole antennas. The effect of SAR for difference frequency for the human head model can give the approximately the RF sources can affect the SAR values. It can be seen that mobile phone usage near to human ear, can lead to a risk to human health. The main point of this experiment is to study the effect of mobile phone usage near to human ear can be affected by the SAR absorption. Hence, the model of the human head can affect the SAR value.

The result shows, the maximum SAR that obtain is much higher than established maximum value which is in U.S and Europe, the limit are 1.6W/kg over 1g of tissue and 2W/kg over 10g of tissue, respectively. The investigation will proceed with the SAM phantom head model and with difference angle of dipole antenna in the future studies.

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