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# A study of specific absorption rate in human head due to electromagnetic exposure to 4G signals

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**ABSTRACT**

This paper presents a numerical analysis of the specific absorption rate in SAM phantom exposed to electromagnetic field. A two set dipole antenna operating with 1800MHz and 2600MHz were placed parallel to the z-axis and rotated in clockwise from 0° (vertical) to 180° in steps of 30° to investigate the effect of frequency and polarization. The maximum average of 1gram and 10gram of tissue have been presented to show the effect of SAR in SAM phantom model. A comparison of the mass average SAR in head shows the 1g of SAR at 2600MHz is double to 1800MHz frequency. While for 10g of SAR, slightly different for both 1800MHz and 2600MHz.



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## 1. INTRODUCTION

Nowadays, human health has been topically a hefty portion due to cell phones impacts. Since cell phone are increasingly sophisticated, there has been both scientific and public remark that the human health can be unfavorably influence by radiation from cell phones [1]-[11]. Some researcher has discussed that the coupling of electromagnetic field emitted by cell phones might cause impact to human head because as known, cell phones can produced a proportion of radio frequency energy that can be absorbed in human head [4], [11], [12]. In Cooper's research [7] concludes that metallic implant in head can increased the SAR value. While Whittow's [11], [12], the specific absorption rate (SAR) level can be affected by the jewellery and metallic ring in human head [13], [14].

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]-[3], [5]-[10], [15]-[31]. Mathematically, SAR can be expressed in watt per kilogram (W/kg) as

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

However, the SAR for specifying the radiofrequency absorption by tissue can be calculated at any location in the tissue from the electric field (E) as shown below:

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

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

Averaged SAR limits has been recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP) for communication devices that the SAR should be less than 2W/kg for averaged 10g mass of tissue ($SAR_{10g}$) [32]-[39]. However, for 1g of tissue ($SAR_{1g}$), the Institute of Electrical and Electronics Engineers (IEEE) has sets a slightly stricter limit value which is 1.6 W/kg [40].

In this paper, investigation on the effect of SAR in human head at ear model with different frequency and polarization. Since the possible uses of cell phones near to ear can be effect on human health has been topical over the last several years because communication devices which is cell phones produces radiofrequency energy that can be effect to human.

## 2. RESEARCH METHOD

### 2.1. Simulation and Radiofrequency Exposure

The modelling and calculations of EM fields were carried out by using Computer Simulation Technology Microwave Studio (CST MWS). Time domain Solver (TDM) has been used to simulate the design before the Specific Absorption Rate (SAR) been calculated. By using IEEE/IEC 62704-1 averaging method, the reference power for this experiment are defined as output power at 1W (rms). The head tissue density has been defined as 1000kg/m$^3$.

These research were carried out to isolate the relative effect of the RF exposure to human head with different frequencies and polarizations. In this project, dipole antennas been chosen as a standardized source with a single polarization since the are many different RF sources. Therefore, the simulation can be clearly being analyze. Two antennas were used by considered each antenna with 1800MHz and 2600MHz frequency, respectively. The feed point of antennas was located in a 2mm air gap between the dipole halves constructed by using perfect electric conductors (PEC). The diameter for both antenna has fixed to 1.8mm. Figure 1 show the diagram of dipole antenna.

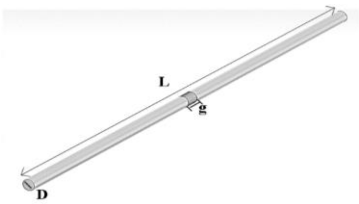


Figure 1. Diagram of dipole antenna design

where :
D = diameter of wire (mm)
g = air gap (mm)
L = length of half wave dipole (mm)
a = Acceleration of the object

A half wave dipole antenna with 1800MHz and 2600MHz was designed with length of half wave dipole, L 74.78mm and 51.5mm, respectively.

### 2.2. Head Phantom

Specific Anthropomorphic Mannequin (SAM) phantom head has been used as the head model in this paper because it is the standard head for SAR investigation. In human head shaped phantom, has a shell filled with a tissue simulating liquid (TSL). The TSL are represent the average dielectric properties of the human head. The outer shell of the SAM phantom head has been fixed relative permittivity with 3.7 and 0.00016S/m for electrical conductivity. The dielectric properties of the TSL for both 1800MHz and 2600MHz are shown in Table 1.

Table 1. The Dielectric Properties of TSL for 1800MHz and 2600MHz Frequency

| Frequency(MHz) | Relative Permittivity | Electrical conductivity (S/m) |
|---|---|---|
| 1800 | 40.0 | 1.4 |
| 2600 | 39.0 | 1.96 |

Hence, the SAM phantom head model were attached with dipole antennas. The antennas were designed for both 1800MHz and 2600MHz with 2mm air gap, g, diameter of wire, D 1.8mm. While for length of half wave dipole, L for 1800MHz and 2600MHz frequency are 74.78mm and 51.5mm, respectively. The dipole antenna located with 0.1mm between dipole antennas and ear of SAM phantom are fixed.

Figure 2 show the SAM phantom head model attached with dipole antenna in $0^o$. The dipole antenna is set in vertically to head and will be rotate until $180^o$ in steps of $30^o$.

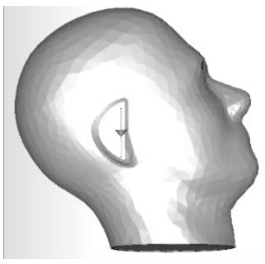

Figure 2. The SAM phantom head model with dipole antenna

## 3. RESULTS AND ANALYSIS

In order to study the effect of 1800MHz and 2600MHz frequency to human head, the maximum mass averaged for 1g and 10g of SAR in head was investigated. The dipole antenna was chosen in this project is 1800MHz and 2600MHz frequency. The frequency was commonly in used in many countries including Malaysia.

Firstly, parallel to z-axis ($0^o$) the dipole antenna will be rotated in clockwise from $0^o$ (vertical) to $180^o$ in steps of $30^o$ (while in $90^o$ is parallel to the y-axis). The variations of dipole antenna angle were to investigate the worst case situation. In this paper, 1W has been fixed as output power.

Figure 3 and 4 shows the result for both 1800MHz and 2600MHz frequency for $SAR_{1g}$ respectively. The peak average $SAR_{1g}$ was at $60^o$ for 1800MHz while for 2600MHz at $120^o$ with 28.364W/kg and 41.9741W/kg respectively. However, at $30^o$ to $120^o$ has little effect on mass averaged SAR for 1800MHz frequency same as at 2600MHz frequency, the effect to average mass SAR has little effect.

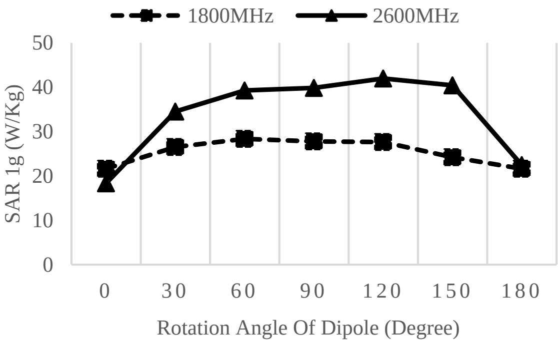


Figure 3. The maximum $SAR_{1g}$ as a function of dipole's antenna's rotation angle

for both 1800MHz and 2600MHz

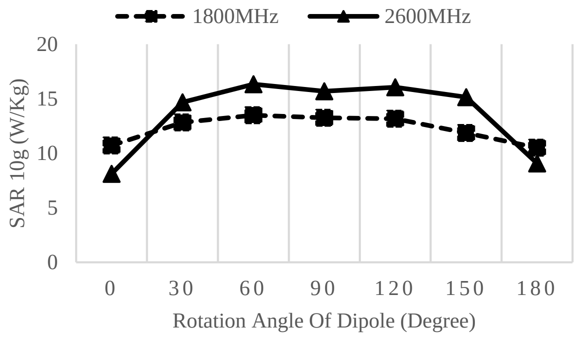


Figure 4. The maximum $SAR_{10g}$ as a function of dipole's antenna's rotation angle for both 1800MHz and 2600MHz

It should be noted that in this paper, the SAR values with the dipole sources are higher than allowed in the standards. This is partly due to all the simulations were normalized to 1 Watt output power with half-wave dipole antennas.

## 4. CONCLUSION

The SAM phantom head has been used in this paper which is the standard head for SAR investigation. The RF sources was 1800MHz and 2600MHz frequency with half-wave dipole antennas. This paper has shown how the SAR in the head can be effected by frequency and polarization. It can be seen that cell phone usage near to human ear, can be lead to risk of human health. The main of this research is to study the effect of cell phones usage near to human ear can be effected by the SAR absorption with different frequency and polarization.

In conclusion, the result shows the maximum SAR that obtain is much higher than standard limit value which is 1.6W/Kg and 2W/Kg over for 1g of tissue and 10g of tissue respectively. The investigation will proceed with metal-embedded in ear prosthesis exposure to 4G signals.

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