Effects of Mobile Phone Radiation onto Human Head with Variation of Holding Cheek and Tilt Positions

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ABSTRACT
This paper analyzed the effects of electromagnetic (EM) radiation mobile phone on human head with different holding positions. The EM radiation is measured in terms of specific absorption rate (SAR). The human head exposed to global system for mobile communication (GSM) frequency bands. The radiation absorption analyzed through simulations by applying finite-difference time domain (FDTD) method using computer simulation technology (CST) microwave studio. The specific absorption rate (SAR) was measured for two common holding positions of mobile phone: Cheek and Tilt. In this tilt position, the mobile phone tilted for 15° and 30° from a person's head. SARs exhibited in much lower values as the mobile phone held in cheek position than that of tilt position. Helical antenna with substrate of Rogers RO3006 (loss free) found to be best tested substrate by resulted in lower SAR due to its lower conductivity properties than that of RO4003.

Keywords: different substrates, finite-difference time domain (FDTD) method, head model, mobile phone, specific absorption rate (SAR).

1. Introduction

The application of mobile phone had extended to the worldwide community. This technology had been introduced as early as in the twenty first century and has been evolving since. Worldwide mobile subscribers increased significantly as the awareness of radiation effects of mobile phone towards human health widely spread across the globe [1]. Continuous researches had done to investigate the effect of electromagnetic (EM) radiation from mobile phone on human health [2-4].

This EM absorption by human is measured in terms of specific absorption rate, SAR [5-9]. SAR values show the radiated power from mobile phone absorbed by the human over a particular volume of body tissue corresponding to 1g or 10 g of body tissues [10], and it is measured in watt per kilogram (W/kg) [8].

A particular safe limit of SAR is chosen so that the maximum EM radiation exposure could be sustained without introducing biological changes onto the human health. These standards regulated by world authoritative bodies include International Commission on Non-Ionizing Radiation Protection, ICNIRP and Federal Communications Commission, FCC. According to the ICNIRP standard, the safe SAR limit is 2 W/kg for 10 g of body tissue [11, 12]. Several countries abide by this regulation are Australia, Japan, New Zealand and Brazil. Other countries such as Canada, South Korea, Bolivia and Taiwan followed the standard regulated by FCC. According to this standard, the limit of SAR is 1.6 W/kg over 1 g of body tissue [13].

SAR of mobile phone absorbed by humans is very dependent on the mobile network carrier, characteristics of mobile phone and antenna, antenna positioning, and the radiated power from the mobile phone [14-16]. Other factor which influenced the EM absorption is the positioning of the mobile phone or the phantom itself [17-19]. The dielectric properties of human also effect SAR values [20]. Increase in conductivity and the decrease in permittivity of the human head cause increment of SAR [21]. Particular body tissue with higher water content contributes to higher SAR. Higher water content of body tissue implies that the body tissue has greater conductivity and is more susceptible to absorb EM waves. The magnitude of body tissue's conductivity and permittivity are dependent on the exposure frequency [11, 22]. The permittivity and conductivity of the tissues remain constant as long as the tissues exposed to a constant frequency exposure. Different exposure of operational frequency eventually altered the tissue's conductivity and permittivity accordingly.

The effect of SAR majority depends on the antenna position on the mobile phone. A mobile phone with mounted antenna on top and hold in tilt position results in more absorption of EM radiation by the head [13]. This happens as the antenna is closer proximity to the head. Moreover, SAR values change with variation of holding position of mobile phone. Cheek and tilt are two prevalent ways of holding a mobile phone. Cheek position of mobile phone is parallel to the head of the user and closely located to the user's pinna. This position is the most frequently applied by the users [12]. In this paper, an investigation on SAR is presented with variation of holding cheek and tilt positions at 900 MHz and 1800 MHz. The aim of this investigation is to find out the better mobile phone holding position, which will lead reduced EM absorption in the human head. The mobile phone is then tilted to 15° and 30° from the head in this investigation to take tilt position effects on SAR.

2. Method and Materials

SAR calculations had applied the FDTD method using electromagnetic solver namely CST Microwave Studio. This FDTD method used for the solver had divided the head cells into smaller cell units. Each of the cells unit had been set to specific meshing properties before it was simulated. The mesh type was set to hexahedral. The mesh density control of line per wavelength of 8, mesh line ratio limit of 200 with total mesh cells of 6,211,119 were used. Homogeneous head dielectric properties were set in accordance the frequency exposure.

SAR was calculated for cheek position and tilt of 15° and 30° of mobile phone from the head. For cheek position, the mobile phone was placed directly on the side of the head without any separation distance. This position was taken from the usual placement applied by most users. The human head model, known as specific anthropomorphic mannequin (SAM) [15], comes together with the helical antenna attached to a mobile phone. The homogeneous head model was comprised of two layers which were the inner and outer layer with specific dielectric properties at a particular frequency exposure. At other frequency exposure the head exhibited different dielectric properties. These properties were constant as long as the head was exposed to the same frequency exposure.

SAR calculated through simulation applied the following equation [5]:

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

Where, σ represents the tissue conductivity, E denotes on root mean square, rms electric field, ρ is tissue density.

The radiated power set for the simulation was 0.25 W. The radiated power of a mobile phone could be as high as 1 or 2 W. This occurs mainly due to the distance between the mobile station and the base station variation. Smaller distance of the mobile station to the base station amounts to lower radiated power of a mobile phone. The averaging method for SAR calculation was used in accordance with the IEEE C95.3 standard [25].

The helical antenna used resonated at 900 and 1800 MHz. The substrates for the antenna were Rogers RO3006 (loss free) and Rogers RO4003 (loss free).

The dielectric properties of the substrates are as in Table 1.

Type of substrate	Permittivity, ε_r	Conductivity, σ [S/m]
Rogers RO3006 (loss free)	6.15	0.61
Rogers RO4003 (loss free)	3.38	0.71

Table 1. Helical antenna dielectric properties.

The dielectric properties of homogeneous human head [26] are shown in Table 2.

Frequency [MHz]	Permittivity, ε_r	Conductivity, σ [S/m]
900	41.5	0.97
1800	40.0	1.40

Table 2. Homogeneous human head dielectric properties.

The mobile phone model used is a simple conducting box made of perfect electric conductor (PEC), with the dimensions of 18 × 40 × 100 mm3 (X × Y × Z). The model of the mobile phone is as shown in Figure 1. The length of the helical antenna is 31 mm and diameter of 5 mm. The helical antenna is shown as in Figure 2.

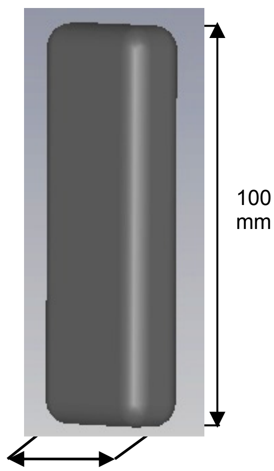

Figure 1. Handset antenna with mobile phone.

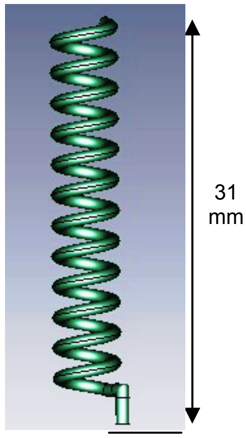

Figure 2. Helical antenna used for SAR calculation.

The holding position of a mobile phone was split into two techniques, which were cheek position and tilt position. A mobile phone held parallel to the user head without separation angle called cheek and the latter position with a user held the mobile phone tilted at an angle of 15° and 30° from a user head. SAR effect onto the user head was observed with these different placements of mobile phone from the head. The holding cheek and tilt positions of mobile phone presented are as shown in Figures 3 (a), (b) & (c).

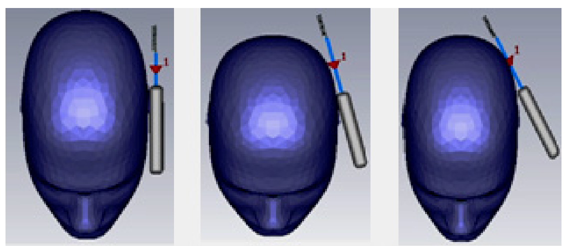

Figure 3. Different position used for SAR measurement: a) Cheek, b) Tilt 150, and c) Tilt 300.

2. Results and Discussions

Results are discussed for effects of SAR on a human head in cheek and tilt position for frequency exposures of 900 and 1800 MHz. For tilt position, the SAR effect is observed in two conditions. The conditions are with tilt of 15° and 30°. There are significant differences in SAR of both tilted positions. Variation of substrates of helical antenna also influences SAR of human head.

Figure 4 shows the SAR results of cheek position at 900 MHz. Helical antenna with substrate of Rogers RO4003 (loss free) exhibited the highest SAR in both volume of body tissue measured of 1 g and 10 g. This happened as the substrate of Rogers RO4003 (loss free) was higher in conductivity compared with the other substrate used. Substrate with higher conductivity leads higher surface current and hence higher EM absorption in the head. The variation of SARs was from 1.088% to 1.564 % at its minimum and maximum values. These differences were still small and did not alter much the SAR distribution of the human head.

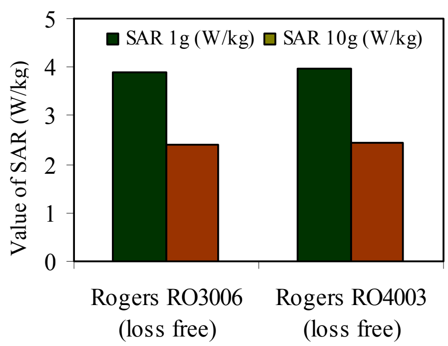

Figure 4. SAR of cheek position with two different substrates at 900 MHz.

The SAR effect of cheek position at 1800 MHz is as in Figure 5.

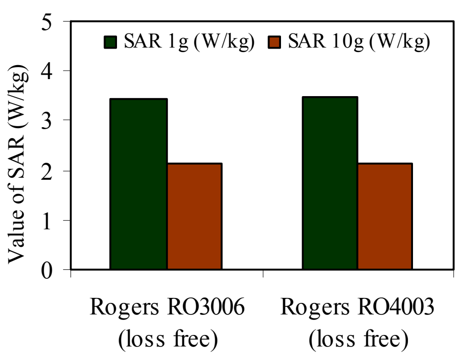

Figure 5. SAR of cheek position with two different substrates at 1800 MHz.

SAR effect onto human head with mobile phone in cheek position which exposed to 1800 MHz showed in Figure 5. The highest SAR was 3.46186 W/kg for SAR of 1 g of body tissue with helical antenna with substrate of Rogers RO4003 (loss free). The helical antenna with substrate of Rogers RO3006 (loss free) resulted in the lowest SAR of 2.12071 W/kg at SAR of 10 g of body tissue. The SARs resulted from helical antenna with substrate of Rogers RO4003 (loss free) were always higher than that the other substrate due to its conductivity property. The conductivity of its substrate was higher and thus influenced to increase the EM absorption towards human head and caused higher SARs.

SARs of human head with mobile phone placed in different tilted positions and exposed to 900 MHz as showed in Figure 6.

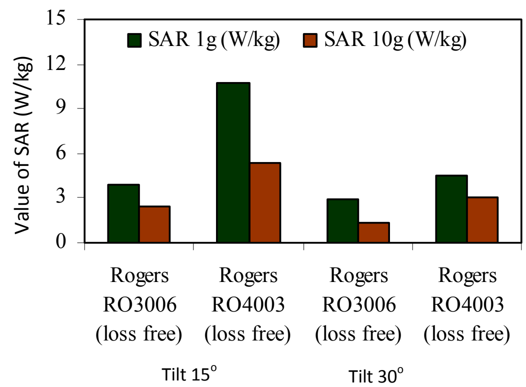

Figure 6. Compared values of different tilt position of SAR at 900 MHz.

From Figure 6, it can be seen that the SARs of 15° tilts were always higher than the SARs of mobile phone with 30° tilt from the human head. In this tilted position of 15°, the human head more readily absorbed electromagnetic waves emitted from the mobile phone due to the placement of the helical antenna. The electromagnetic radiation was absorbed mostly toward the skin at the closest area of the head from the mobile phone was held to. The highest absorption of radiation is at the head part; mainly over the area of the frontal lobe and side of the brain which is the usual placement of the mobile phone among the users. Since the brain is one of the conductive parts of the body, the radiation was more susceptible to be absorbed in this region.

When the human head experienced higher frequency exposure from a mobile phone which tilted exhibited SARs differently. Figure 7 showed the SAR of tilt position at 1800 MHz.

It showed that there was a significant drop as the mobile phone tilted 30° from the human head. This was due to the helical antenna being situated near to the radiation absorption susceptible area of the brain. This is showed in Figures 3 (b) and 3 (c), as the mobile tilted 15°, the helical antenna is nearer to the side of the human head compared to the mobile phone tilted at 30°. SARs of 1 g were all higher than the SARs of 10 g. For smaller volumes of body tissue, the resolutions of calculating SAR values are much better. The higher volume of body tissue as 10 g tend to hinder the whole SAR value of the tissues [23, 24]. At low frequency, the SAR value is high due to penetration of the microwave fields towards a subject at those frequencies.

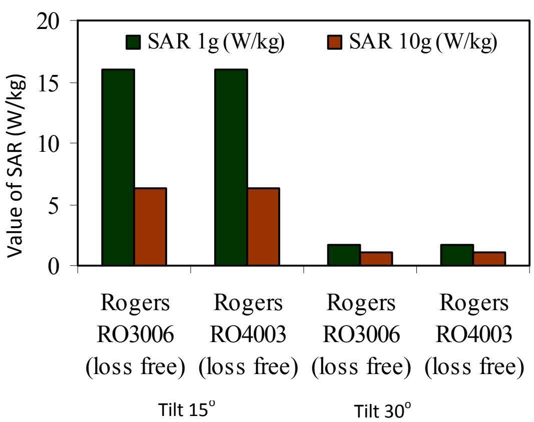

Figure 7. Compared values of different tilt positions of SAR at 1800 MHz.

3. Conclusion

From the work, SARs at the human head were much lower as the mobile phone was held in cheek position. In this position, the helical antenna mounted onto the mobile phone was situated far from the head. Tilt positions of mobile phone produce higher SAR than that of cheek position due to the reduced distance between helical antenna and human head. Although the body of the mobile phone was directly next to the head, the antenna extrudes far from the head. It is essential to keep human head as distant from the antenna as possible, since it is the source of radiation emission. The antenna substrate material effects SAR significantly. Substrate with lower conductivity leads lower induced surface current and lower radiation towards human head.

References

[1] WHO 2011 Research Agenda for Radio Frequency Fields, World Health Organization. (2011). Available from:http://edition.cnn.com/2011/HEALTH/05/31/who.cel.phones/index.html

[2] M. R. I. Faruque et al., “Design analysis of new metamaterial for EM absorption reduction”, Progress In Electromagnetics Research, PIER. Vol. 124, pp. 119-135, 2012.

[3] M. T. Islam et al., “Design analysis of ferrite sheet attachment for SAR reduction in human head”, Progress In Electromagnetics Research, PIER. Vol. 98, pp. 191-205, 2009.

[4] O. Fujiwara and J. Wang, “Comparison and Evaluation of Electromagnetic Absorption Characteristics in Realistic Children for 900 MHz Mobile Telephones”, IEEE Trans. Microw. Theory Tech., vol. 51, no. 3, pp. 966-971, 2003.

[5] M. R. I. Faruque et al., “Electromagnetic (EM) absorption reduction in a muscle cube with metamaterial attachment”, Medical Engineering & Physics, vol. 33, no. 5, pp. 646-652, 2011.

[6] Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields 3 kHz to 300 GHz, IEEE Standards Coordinating Committee 28.4, 2006.

[7] Human Exposure to Radio Frequency Fields from Hand-held and body-mounted Wireless Communication Devices- Human Models, Instrumentation, and Procedures – Part 1 Procedure to Determine the Specific Absorption Rate (SAR) for Hand-held Devices Used in Close Proximity to the Ear 300 MHz to 3 GHz, IEC 62209-1, 2006.

[8] M. R. I. Faruque et al., “Effect of human head shapes for mobile phone exposure on electromagnetic absorption”, Informacije MIDEM, vol. 40, no. 3, pp. 232-237, 2010.

[9] M. I. Hossain et al., “Application of Auxiliary Antenna Elements for SAR Reduction in the Human Head,” Advanced Materials Research, vol. 974, pp. 288–292, 2014.

[10] A. H. Kusuma et al., “A new low SAR antenna structure for wireless handset applications”, Progress in Electromagnetics Research, vol. 112, pp. 23-40, 2011.

[11] J. Keshvari et al., “The effect of increase in dielectric values on specific absorption rate (SAR) in eye and head tissues following 900, 1800 and 2450 MHz radio

frequency (RF) exposure", Physics in Medical and Biology, vol. 51, no. 6 pp. 1463-1477, 2006.

[12] T. Takebayashi et al., "Mobile phone use exposure to radio frequency electromagnetic field and brain tumor: A Case-control Study", Brit. J. Cancer, vol. 98, no. 3, pp. 652-659, 2008.

[13] N. Varsier et al., "Categorization of mobile phone for exposure assessment in epidemiological studies on mobile phone use and brain cancer risk", IEEE Trans. Microw. Theory Tech., vol. 56, no. 10, pp. 2377-2384, 2008.

[14] J. Wiart et al., "Analysis of the influence of the power control and discontinuous transmission on RF exposure with GSM mobile phone", IEEE Trans. Electromagn. Compat., vol. 42, no. 4, pp. 376-385, 2000.

[15] M. R. I. Faruque et al., "Design of metamaterial attachment for SAR reduction in human head", Applied Computational Electromagnetic Society Journal, vol. 25, no. 12, pp. 1097-1107, 2010.

[16] M. R. I. Faruque et Al., "Effects of dielectric values & substrate materials on electromagnetic (EM) absorption in human head", Frequenz Journal, vol. 66, no. 3-4, pp. 79-83, 2012.

[17] B. Beard et al., "Comparisons of Computed Mobile Phone Induced SAR in the SAM Phantom to that in Anatomically Correct Models of the Human Head", IEEE Trans. Electromagn. Compat., vol. 48, no. 2, pp. 397-407, 2006.

[18] J. Mar et al., "A three-dimensional position architecture using digital TDE receiver and cylindrical array antenna", Journal of Applied Research and Technology, vol. 11, no. 2, pp. 175-182, 2013.

[19] O. Sharifi-Tehrani, "Design, simulation and implementation of an active sound-noise cancellation system for use in a cockpit intercommunication system", Journal of Applied Research and Technology, vol. 10, no. 5, pp. 731-736, 2012.

[20] J. Z. Bao et al., "Complex dielectric measurements and analysis of brain tissues in the radio and microwave frequencies", IEEE Trans. Microw. Theory Tech., vol. 45, no. 10, pp. 1730-1741, 1997.

[21] P. Gajšek et al., "Parametric dependence of SAR on permittivity values in a man model", IEEE Transactions on Biomedical Engineering, vol. 48, no. 10, pp. 1169-1177, 2001.

[22] Michtchenko, "Numerical and experimental analysis in the manipulation of the mechanical properties for enhancing the mechanical resistance of a material", Journal of Applied Research and Technology, vol. 9, no. 2, pp. 156-172, 2011.

[23] K. J. Rothman et al., "Assessment of Cellular Telephone and Other Radio Frequency Exposure for Epidemiology Research", Epidemiology, vol. 7, pp. 291-298, 1996.

[24] M. R. I. Faruque et al., "Analysis of SAR levels in human head tissues for four types of antennas with portable telephones", Australian Journal of Basic and Applied Sciences, vol. 5, no. 3, pp. 96-107, 2011.

[25] IEEE," C95.3-2002 IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz–300 GHz," IEEE vol. New York, 2002. IEEE, New York, 2002.

[26] Ebrahimi-Ganjeh et al., "Interaction of dual band helical and PIFA handset antennas with human head and hand," Progress In Electromagnetics Research, Vol. 77, 225–242, 2007.