Design of Material Attachment for SAR Reduction in Human Head

MOHAMMAD RASHED IQBAL FARUQUE[1], MOHAMMAD TARIQUL ISLAM[2], NORBAHIAH MISRAN[1, 2]

[1]Dept. of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600, UKM, Bangi, Selangor, Malaysia

Email: rashedgen@yahoo.com, bahiah@vlsi.eng.ukm.my

[2]Institute of Space Science (ANGKASA),
Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia
Email: titareq@yahoo.com

ABSTRACT:-In this paper, reducing specific absorption rate (SAR) with materials attachment is investigated. The finite-difference time-domain method with lossy-Drude model is adopted in this study. The methodology of SAR reduction is addressed and the effects of attaching location, distance, and size of ferrite sheet material on the SAR reduction are investigated. Materials have achieved a 47.68% reduction of the initial SAR value for the case of 1 gm SAR. These results suggest a guideline to choose various types of materials with the maximum SAR reducing effect for a phone model.

Index Terms — antenna, human head model, lossy-Drude model, materials, specific absorption rate (SAR).

1 Introduction

Sources of radiofrequency/microwave (RF/MW) radiation, particularly cellular phones, are ever present. RF/MW sources are part of daily life, but they also reason for concern regarding the possible biological special effects of microwaves. It is important that the biological effects of RF/MW fields are minimal, at least at the level of their clinical significance, so that health risk can be assessed. Because the potential shock of RF/MW fields on human health has not yet been well characterized, the basic knowledge from laboratory studies based on cellular and animal test systems are invaluable. The interaction of handset antennas with human body is a great consideration in cellular communications. The user's body, especially head and hand, influence the antenna voltage standing wave ratio (VSWR), gain and radiation patterns. Furthermore, thermal effects, when tissues are exposed to unlimited electromagnetic energy, can be a serious health hazard. Therefore standards organizations have set exposure limits in terms of SAR [1, 2].

The exposure limits are defined commonly in terms of the spatial peak SAR averaged either over any one gram or ten grams of tissue. Since 1997, the U.S. Federal Communication Commission (FCC) requires the routine SAR evaluation of phone model prior to device authorization or use. So there is a need to reduce the spatial peak SAR in the design stage of a phone model because the possibility of a spatial peak SAR exceeding the recommended exposure limit cannot be completely ruled out [2-3]. The interaction of the cellular handset with the human head has been investigated by many published papers considering; first, the effect of the human head on the handset antenna performance including the feed-point impedance, gain, and efficiency [4-7], and second, the impact of the antenna EM radiation on the user's head due to the absorbed power, which is measured by predicting the induced SAR in the head tissue [7-9].

The most used method to solve the electromagnetic problem in this area is the finite-difference time-domain (FDTD) technique [6-8]. Although, in principle, the solution for general geometries does not require any additional effort with respect to the standard method, the technique requires the definition of a discretized space by assigning to each cell its own electromagnetic properties, which is not an easy process [8-10]. Specifically, the problems to be solved in SAR reduction need a correct representation of the cellular phone; anatomical representation of the head; alignment of the phone and the head, and suitable design of materials.

Human exposure to electromagnetic (EM) radiation, as well as the pertinent health effects, constitutes a matter of raised public concern, and this issue has undergoing continuous scientific investigation. Various studies on this subject exist [9–11], most of which mainly investigate into the consequences of mobile-phone usage. Yet, devices and communication terminals operating in other frequency bands have also gained substantial interest in the last 15 years. In [5], a ferrite sheet was adopted as protection between the antenna and the human head. A reduction of over 13% for the spatial peak SAR over 1 gm averaging was achieved. A study on the effects of attaching a ferrite sheet for SAR reduction was presented in [11], and it was concluded that the position of shielding plays an important role in the reduction effectiveness. This paper is structured as follows. Modeling and analyzing technique will be described in Section II. Simulation and comparing results of materials will be summarized in Section III and finally in Section IV concludes the paper.

2 SAR reduction with lossy- Drude model

2.1 Lossy-Drude Model

The SAR reduction effectiveness and antenna performance with different positions, sizes and materials properties of materials will be analyzed. The head models used in this study were obtained from a MRI-based head model through the whole brain Atlas website. Six types of tissues, i.e., bone, brain, muscle, eye ball, fat, and skin were involved in this model [8-9]. Fig. 1 shows a horizontal cross-section through the eyes of this head model. The electrical properties of tissues were taken from [10]. Numerical simulation of SAR value was performed by the FDTD method. The parameters for FDTD computation were as follows. In our lossy-Drude simulation model, the domain was 128 × 128 × 128 cells in the FDTD method. The cell sizes were set as $\Delta x = \Delta y = \Delta z$ = 1.0 mm. The computational domain was terminated with 8 cells perfect matched layer (PML). A PIFA antenna was modeled for this paper by the thin-wire approximation. Simulations of materials are performed by the FDTD method with the lossy-Drude Model [7-9]. The method is utilized to understand the wave propagation characteristics of materials.

2.2 Analysis Method

Fig. 2 shows a portable telephone model at 900 MHz for the present study. It was considered to be a quarter wavelength PIFA antenna mounted on a rectangular conducting box. The conducting box was 10 cm tall, 4 cm wide and 3 cm thick. The PIFA antenna was located at the top surface of the conducting box. A ferrite sheet with a height of 90 mm, a width of 40 mm and a thickness of 3.5 mm was attached to the conducting box as shown in Fig 2**.** The SAM head model was considered for this research where it consists about 2,097,152 cubical cells with a resolution of 1 mm.

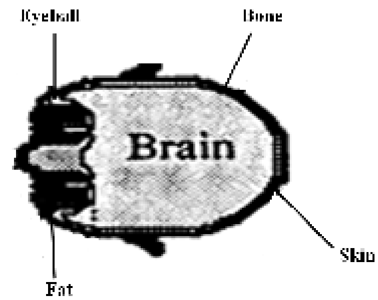

Fig. 1 Human head model for FDTD computation

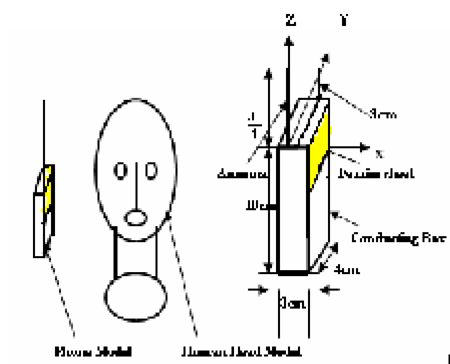

Fig. 2 Models of head and portable telephone with attached ferrite sheet.

3 Impact on SAR of ferrite sheet attachment

In this section, a ferrite sheet is placed between the antenna and a human head thus reducing the SAR value. In order to study SAR reduction of an antenna operated at the GSM 900 band, different positions, sizes, and ferrite sheet materials for SAR reduction effectiveness are also analyzed by using the FDTD method in conjunction with a detailed human head model.

Fig. 3 shows the simulation model which includes the handset with monopole type PIFA antenna and the SAM phantom head provided by CST MWS. The dispersive models for all the dielectrics were adopted during the simulation in order to accurately characterize the ferrite sheet. The antenna was arranged in parallel to the head axis; the distance is varied from 5 mm to 20 mm; and finally 20 mm was chosen for comparison with the ferrite sheet. Besides that, the output power of the mobile phone model need to be set before SAR is simulated. In this paper, the output power of the cellular phone is 500 mW at the operating frequency of 0.9 GHz. In the real case, the output power of the mobile phone will not exceed 250 mW for normal use, while the maximum output power can reach till 1 W or 2 W when the base station is far away from the mobile station (cellular phone). The SAR simulation is compared with the results in [3, 11] for validation, as shown in Table I. The calculated peak SAR 1 gm value is 2.002 W/Kg, and SAR 10 gm value is 1.293 W/Kg when the phone model is placed 20 mm away from the human head model without a ferrite sheet. This SAR value is better compared with the result reported in [8], which is 2.43 W/Kg for SAR 1gm. The ferrite sheet material is utilized in between the phone and head models, and it is found that the simulated value of SAR 1 gm and SAR 10 gm are 1.043 W/Kg and 0.676 W/Kg respectively. The reduction about of 47.68% was observed in this study when a ferrite sheet is attached between the phone and human head models for SAR 1 gm. This SAR reduction is better than the result reported in [5], which is 13% for SAR 1 gm. This is achieved using different radiating powers and impedance factors. Figs. 4-7 show the SAR value compared with the distance between phone and head models, width of ferrite sheet between 20-40 mm, thickness of ferrite sheet between 2-3.5 mm and height between 40-90 mm respectively.

The reduction efficiency of the SAR depends on its width and height. In order to definitely confirm this, 1 gm and 10 gm average SAR versus distance, width, thickness and height are plotted in the Figs. 4-7. In Fig. 4, it is shown that if the distance between phone and human head models is varied then the SAR value decreases. This is because the dielectric constant, conductivity, density and magnetic tangent losses are also varied. In Fig. 5, it can be observed that the SAR value reduces with the increase of the width of the ferrite sheet. As shown in Fig. 6, the SAR value decreases until a thickness of 3 mm, and then a different tendency i.e., it started to increase after 3 mm. The height is varied up to 90 mm in Fig. 7. From this figure it can be shown that if the height of the ferrite sheet increases then the SAR value also decreases up to a height of 80 mm, and it started to increase after 80 mm. The results implies that only suppressing the maximum current on the front side of the conducting box contributes significantly to the reduction of spatial peak SAR. This is because the decreased quantity of the power absorbed in the head is considerably larger than that dissipated in the ferrite sheet.

Table 1 Comparisons of peak SAR with ferrite sheet

Tissue	SAR value (W/kg)
SAR value for [3]	2.17
SAR value for [11]	2.28
SAR value with ferrite sheet for 1gm	1.043

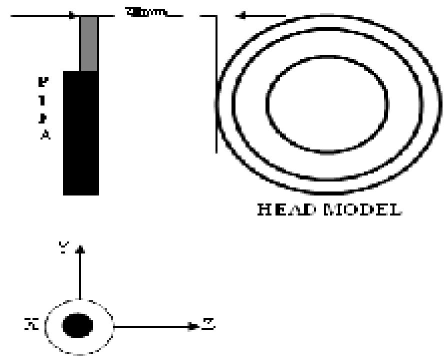

Fig. 3 The head and antenna model for SAR calculation**.**

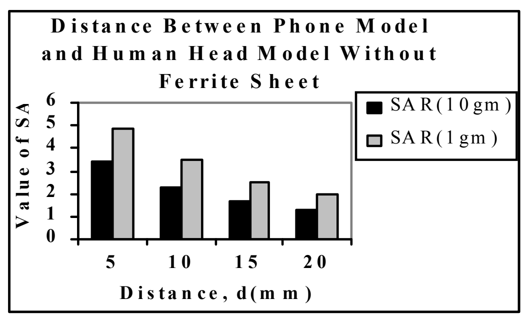

Fig. 4 SAR value versus the distance between phone model and human head model without ferrite sheet

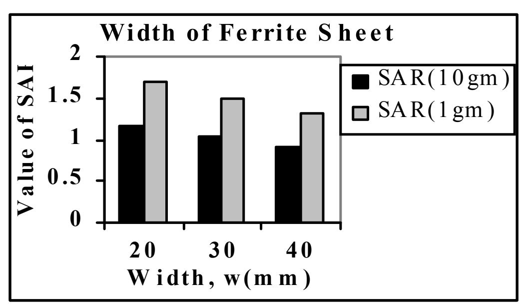

Fig. 5 SAR value versus the width of the ferrite sheet.

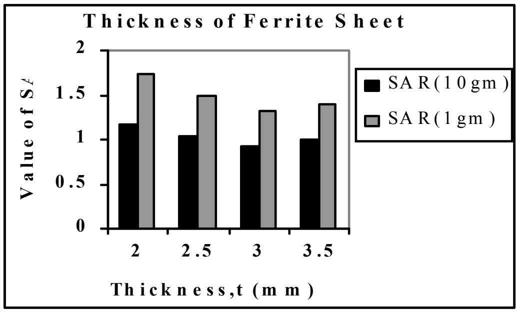

Fig. 6 SAR value versus the thickness of the ferrite sheet.

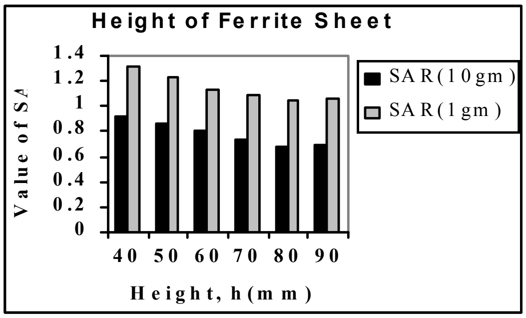

Fig. 7 SAR value versus the height of the ferrite sheet.

4 Conclusions

The EM interaction between an antenna and the human head with materials has been discussed in this paper. Utilizing material in the phone model a SAR value is achieved about 0.676 W/Kg for SAR 10 gm and 1.043 W/Kg for SAR 1 gm. Based on the 3-D FDTD method with lossy-Drude model, it is found that the peak SAR 1 gm and SAR 10 gm of the head can be reduced by placing the materials between the antenna and the human head. Numerical results can provide useful information in designing communication equipment for safety compliance.

References:

[1] IEEE C95.1-2005. “IEEE Standards for safety levels with respect to human exposure to radio frequency electromagnetic fields,3 KHz to 300 GHz,” *Institute of Electrical and Electronics Engineers*, Inc. New *York*, NY 2005.

[2] L.C Fung, S .W. Leung, and K. H. Chan, “An investigation of the SAR reduction methods in mobile phone application,” *IEEE International Symposium on EMC.*, vol.2, pp. 656-660, Aug. 2002.

[3] J. Wang and O. Fujiwara, “FDTD computation of temperature rise in the human head for portable telephones,” *IEEE Trans. Microwave Theory Tech*., vol. 47, no. 8, pp. 1528-1534, Aug.1999.

[4] S. Curto, P. McEvoy, X. L. Bao, and M. J. Ammann, "Compact Patch Antenna for electromagnetic interaction with human tissue at 434 MHz,” *IEEE Trans. on Antennas and Propagation*, vol. 57, no. 9, Sep. 2009.

[5] J. Wang and O. Fujiwara, “Reduction of electromagnetic absorption in the human head for portable telephones by a ferrite sheet attachment,” *IEICE Trans. Commun.*, vol. E80b, no. 12, pp. 1810-1815, Dec. 1997.

[6] R. G. Vaughan, and N. L. Scott, “Evaluation of antenna configurations for reduced power absorption in the head,” *IEEE Trans. On Vehicular Technology,* vol. 48, no. 5, Sep. 1999

[7] C. H. Li, N. Chavannes, and N. Kuster, “Effects of Hand Phantom on Mobile Phone Antenna Performance,” *IEEE Trans. On Antennas and Propagation*, vol. 57, no. 9, Sep. 2009.

[8] J. N. Hawang and Fu-chiarng chen. “Reduction of the peak SAR in the human head with metamaterials,*” IEEE Trans. on antenna and propagation* vol-54(12) 3763-3770, Dec. 2006

[9] J. B. Pendry, A. J. Holen, D. J. Robbins, and W. J. Stewart, “Magnetism from conductors and enhanced nonlinear phenomena,” *IEEE Trans. Microwave Theory Tech.*, vol. 47, no. 11, pp. 2075–2084, Nov. 1999.

[10] G.F. Pedersen and J.B. Andersen, “Integrated antennas for hand-held telephones with low absorption,” *Proc. 44th IEEE Veh. Tech. Conf.,* Stockholm, Sweden, June. 1994, pp. 1537-1541.

[11] C .M .Kuo. and C. W. Kuo, “SAR distribution and temperature increase in the human head for mobile communication,” *in IEEE-APS* Int. Symp. Dig., Columbus, OH, 2003, pp. 1025-1028