A New Design of Cell Phone Body for the SAR Reduction in the Human Head

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Abstract ─ In this paper, a new design of cell phone body is presented to reduce the specific absorption rate (SAR) in the human head. The SAR in the human head and total absorbed power by the cell phone user are calculated along with antenna performances in terms of radiation efficiency and directivity to validate the effects of cell phone body. It is found that the SAR in the head is reduced significantly for both the lower and upper global systems for mobile (GSM) frequency band. The new mobile body provides 63.8% reduction in the SAR at 900 MHz and 69.2% reduction at 1800 MHz in comparison of without mobile cover configuration. Moreover, the mobile casing improves the radiation efficiency 6% and 7% in the lower and the upper GSM frequency band respectively.

Index Terms ─ Antenna, FDTD method, human hand model, human head model, mobile body, SAR.

I. INTRODUCTION

The health hazard of emitted electromagnetic (EM) radiation from the cellular phone has become a point of open deliberation as the use of mobile handset is increasing exponentially. For the protection of the human body from EM exposure, international authoritative bodies have defined exposure guidelines [1, 2]. The EM energy absorbed by human body tissues can be evaluated by the specific absorption rate (SAR) [3]. The safety limit of SAR averaging 1 g of tissues (SAR1g) is set to 1.6 W/Kg by Federal Communication Commission (FCC) [4] and 2 W/Kg for 10 g of tissues by IEEE [5]. Therefore, the reduction of the SAR is an essential issue for the cell phones and many researchers are working on this aspect. The simplest and easiest method for SAR reduction is to increase the spacing between human head and cell phone antenna because the SAR values are inversely proportional to this distance [6]. In addition, conducting material closed to the human body processes significant effects on the SAR values, which highly depends on the position and size of conducting material [7,8]. In [9], a conducting material was used as a protection attachment between the handset antenna and the human head. Moreover, radio frequency (RF) shielding using ferrite sheet has proved to be an attractive way of reducing the SAR in the human head [10]. In [11], a ferrite loaded short mono-pole antenna was proposed to reduce the SAR. Numerical results showed that the proposed arrangement can enhance antenna performance and reduce the SAR in the head for the frequency 1800 MHz and higher. On the other hand, a ferrite sheet with PIFA antenna was investigated in [12]. The considerable amount of SAR reduction was observed at 900 MHz.

The SAR values can also be reduced by using artificial magnetic conductor (AMC), electromagnetic band gap (EBG) and photonic band gap (PBG) surfaces. In [13], two patch EBG structure was used in the ground plane of the antenna. The results revealed the reduction in total dispersed power and SAR toward the head. In [14], a study on the effects of EBG structure on the SAR and the radiation characteristics of dipole antenna has been presented. The outcomes indicated that EBG structure can improve the radiation efficiency and reduce the SAR at 3.5 GHz. Recently, metamaterials have been proposed for the SAR reduction of cell phone as they process extraordinary physical properties. The metamaterials are artificially constructed structure having negative permittivity, negative permeability or both simultaneously [15]. In [16], the designed square split ring resonator (SSRR) using metamaterial was used to degrade the SAR values. This investigation has achieved the SAR reduction at 900 MHz. In [17], the proposed metamaterial provided the moderate amount of reduction in SAR values for dual GSM frequency bands.

However, the cell phone casing processes significant effects on the SAR values. In [8], a study of materials to reduce the SAR values has been presented. The numerical results showed that the cell phone case box made of materials with higher conductivity produces higher pick SAR in the human head. In this paper, a new design of mobile casing for PIFA antenna is used for the reduction of EM absorption for both GSM lower and upper frequency bands at 900 MHz and at 1800 MHz respectively. The antenna performances are also

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evaluated to clarify the effectiveness of the new cell phone body.

II. MODELS AND METHODS

In this investigation, the study of SAR reduction using cell phone body was conducted by the finite-difference time-domain (FDTD) method to lossy Drude model [18-19]. The major simulation tool used in this study, was Computer Simulation Technology Microwave Studio (CST MWS) based on the FDTD method [20]. A dual band PIFA was used in experimental set-up. The antenna elements were made of PEC comprising patches, ground plane, feed, and shorting wall. Additionally, FR-4 circuit board and electrical circuits were used along with antenna to take effect on the real cell phone. The dimensions of the circuit board are 80 mm × 40 mm × 1.6 mm. Figure 1 and 2 shows the return loss characteristics and the geometry of the antenna with circuit board respectively. A body of the mobile phone was modeled using two different materials. The body of the mobile phone was modeled using plastic with dimensions 82 mm × 42 mm × 10 mm. The thickness of plastic sheet is 0.5 mm with 2.9 relative permittivity. The LCD, dimensions 60 mm × 38 mm × 2.2 mm, of the cell phone was considered as a part of handset body. An additional double-layer sheet of thickness 2 mm was placed below the LCD monitor which contributed to reduce the SAR values considerably. The additional sheet consists of silicon (1 mm) and PEC (1 mm). The permittivity and tangent loss of silicon sheet are 11.9 and 0.00025 respectively. Figure 3 (a) indicates the cell phone model with proposed body structure. The dimensions and properties of handset components were set to comply with industry standard. The specific anthropomorphic mannequin (SAM) phantom was used as a head model which consists of SAM shell and SAM liquid. A hand model was also utilized in this study. The dielectric properties of head and hand model have been listed in Table 1. Figure 3 (b) represents the simulation setup of handset model with head and hand phantom. In this lossy-Drude simulation model, domain was 128 × 128 × 128 cells with cell sizes $dx = dy = dx = 3$ mm. The evaluation of SAR is defined as SAR = $\sigma E^2/2\rho$, where σ, ρ and E represent the conductivity of the tissue, the density of the tissue and induced electric field strength in the human head respectively. The peak SAR values were averaged over 1 g of tissue.

Table 1: Properties of head and hand models

Materials	Relative Permittivity, ε_r		Conductivity, σ (S/m)	
	900 MHz	1800 MHz	900 MHz	1800 MHz
SAM shell	3.7	3.5	0.0016	0.0016
SAM liquid	40.5	40	0.97	1.42
Hand	36.2	32.6	0.79	1.26

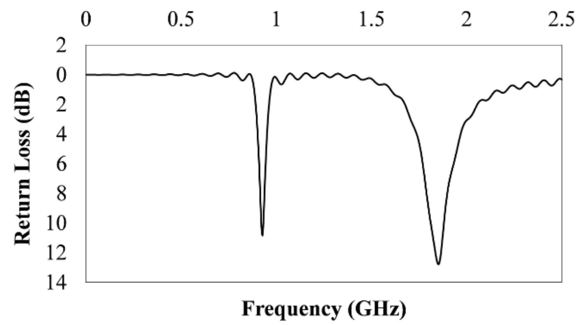
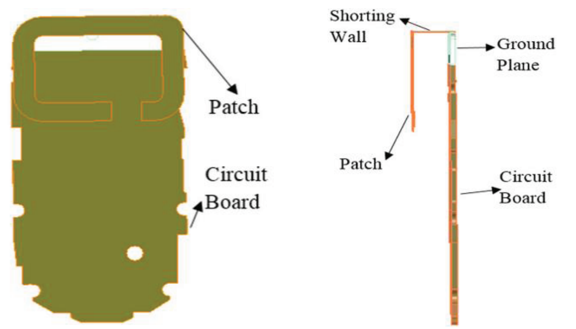
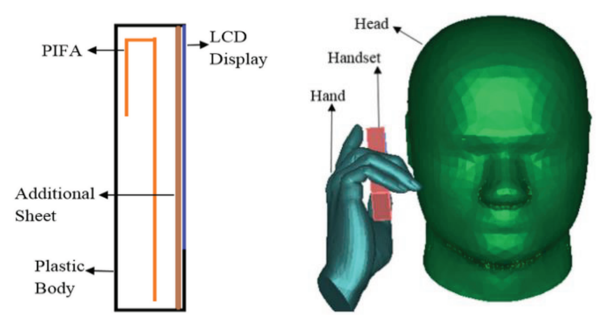


Fig. 1. Return loss characteristics of the PIFA.



(a) (b)

Fig. 2. PIFA with circuit board: (a) front view, and (b) side view.



(a) (b)

Fig. 3. (a) Handset model, and (b) head and hand model in talk position.

III. RESULTS AND DISCUSSIONS

In this paper, a mobile body with an additional sheet has been proposed to reduce the peak SAR in the human head. The additional sheet was double layer. Additionally, single layer sheets of aluminum, silicon and PEC with mobile casing was also investigated. The investigation results may be classified into three broad categories:

A. Without additional sheet configurations;
B. Single-layer additional sheet configurations;
C. Double-layer additional sheet configuration.

A. Without additional sheet configurations

In this section, plastic mobile casing without additional sheet is used. Figure 4 represents the values of SAR and total absorbed power off with and without cell phone body configurations. The body is made of plastic materials with 1 mm thickness. The plastic cell phone body leads to reduce the SAR 57.9% at the lower frequency band and increase the SAR 3.6% at the upper frequency band as compared to without casing configuration. Moreover, the total absorbed power is reduced 53.7% at 900 MHz and increased 4.6% at 1800 MHz due to the plastic body. It is clear from the obtained results that the plastic body affects the EM absorption greatly at the lower frequency band and slightly at the upper frequency band.

However, this plastic body can reduce the SAR at the lower frequency band considerably, but increases the SAR at the upper frequency band. Moreover, the plastic cell phone body increases radiation efficiency 12% at 900 MHz and decreases 1% at 1800 MHz as indicated in Fig. 5. The directivity of antenna is not affected greatly due to the plastic body for both frequency bands.

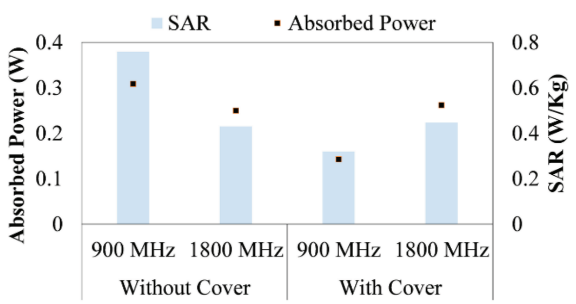


Fig. 4. SAR values and absorbed powers considering with and without phone body.

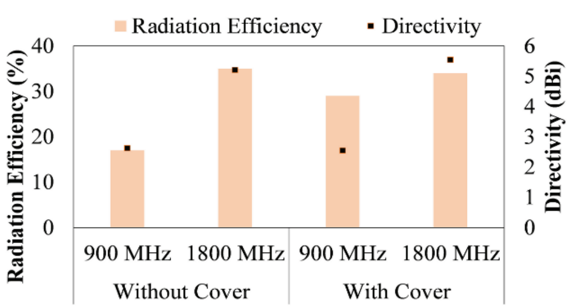


Fig. 5. Radiation efficiency and directivity considering with and without phone body.

B. Single-layer additional sheet configurations

A single layer of silicon sheet was used as an additional sheet with plastic mobile body. The SAR values and absorbed power are plotted in Fig. 6. The results indicate that the mobile body with 1 mm additional silicon sheet provides 68.4% SAR reduction at 900 MHz and 2.4% SAR at 1800 MHz as compared to without casing configuration. Sequentially, 1 mm additional aluminum sheet lead to 68.3% SAR reduction at the lower frequency band and 4.22% increment at the upper frequency band as shown in Fig. 7. The PEC sheet of 1 mm reduces the SAR 59.2% at 900 MHz and 66.1% at 1800 MHz (as indicated in Fig. 8). The reduction in total absorbed power is 68.3%, 67.96% and 58.9% for 1 mm silicon, aluminum and PEC additional sheet respectively in the lower frequency band. At the upper frequency band, 3.85%, 3.85% and 14.4% increment in total power absorption are observed after using additional silicon, aluminum and PEC sheet respectively. The additional sheet (silicon, aluminum and PEC) thickness of 2 mm provides a further little bit lower the SAR values and total adsorbed powers. The PEC sheet can reduce the peak SAR sufficiently rather than total absorbed power.

At 900 MHz, mobile cover with silicon and aluminum additional sheet of thickness 1 mm improve the radiation efficiency 11% (as shown in Figs. 9 and 10) and PEC leads to increase 6.5% (as indicated in Fig. 11) compared to without casing configuration. On the other hand, 1 mm silicon and aluminum sheet provide 1% degradation of radiation efficiency and 1 mm PEC leads to degrade 3% at the upper frequency band. The results of antenna directivity do not change considerably after using a mobile body with additional sheet.

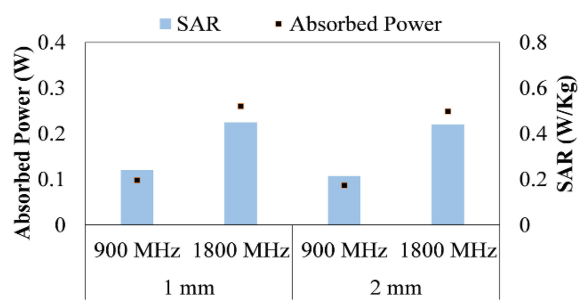


Fig. 6. SAR value and absorbed power for plastic mobile body with additional silicon sheet.

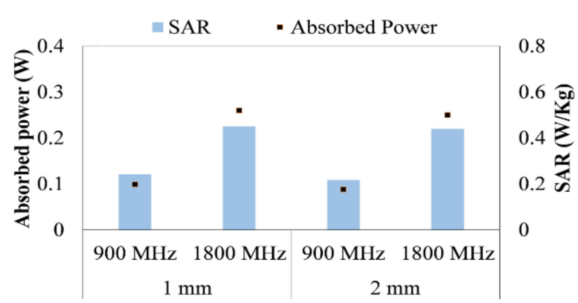


Fig. 7. SAR values and absorbed powers for plastic phone body with additional aluminum sheet.

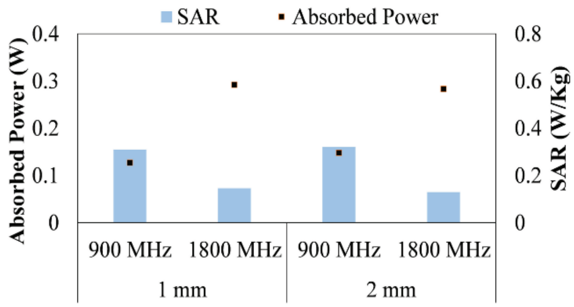


Fig. 8. SAR values and absorbed powers plastic phone body with additional PEC sheet.

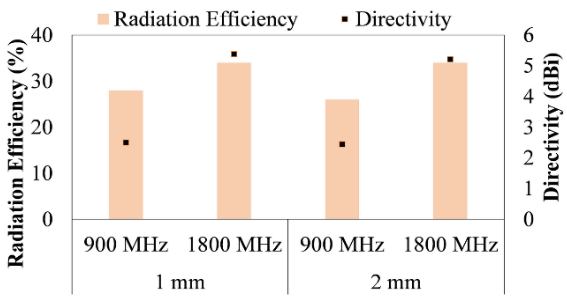


Fig. 9. Radiation efficiency and directivity of plastic cell phone body with additional silicon sheet.

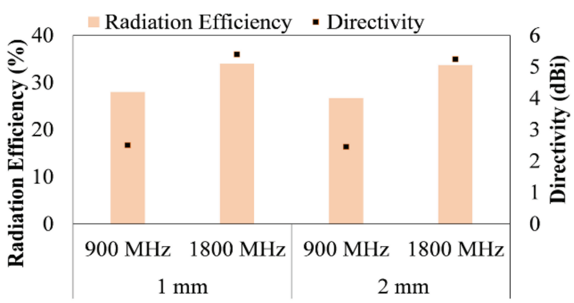


Fig. 10. Radiation efficiency and directivity considering plastic body with additional aluminum sheet.

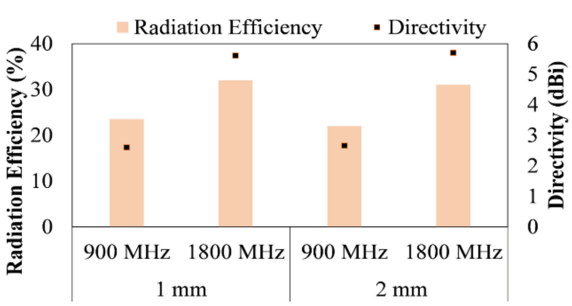


Fig. 11. Radiation efficiency and directivity for plastic phone body with additional PEC sheet.

C. Double-layer additional sheet configuration

From the results of single layer additional sheet, it is clear that the cell phone body with silicon and aluminum additional sheet decreases the SAR at the lower frequency band significantly and PEC sheet degrades the SAR highly at the upper frequency band. The body with silicon-PEC double-layer additional sheet can affect both frequency bands. Figure 12 shows the SAR values and absorbed powers in case of mobile body with double-layer and without casing configuration.

The 3D distribution of the SAR values is shown in Table 2. Comprising with without body configuration, the proposed cell phone casing with double-layer sheet can reduce the SAR 63.8% and 69.2% at 900 MHz and 1800 MHz respectively. Similarly, 45% and 14% reduction in total absorbed power can be achieved at the lower and upper frequency band respectively, due to the cell phone casing with double-layer additional sheet. Moreover, the proposed cell phone body leads to improve radiation efficiency 6% at 900 MHz and 7% at 1800 MHz (as shown in Fig. 13). Figure 14 represents the curves theta versus directivity with constant phi (φ=90). The antenna directivity is not affected significantly for both frequency bands.

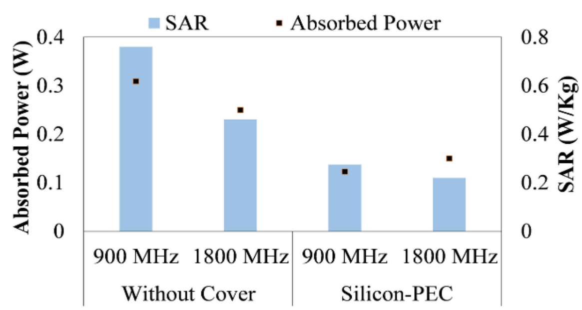


Fig. 12. SAR values and absorbed powers in case of plastic mobile body with additional silicon-PEC double-layer sheet.

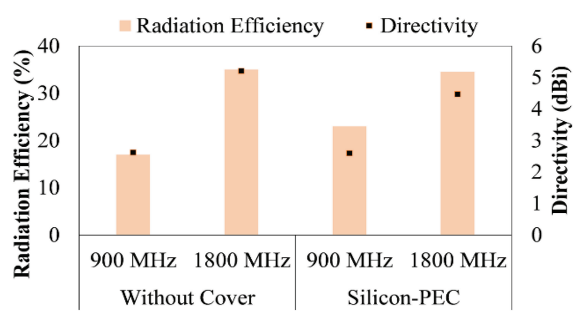
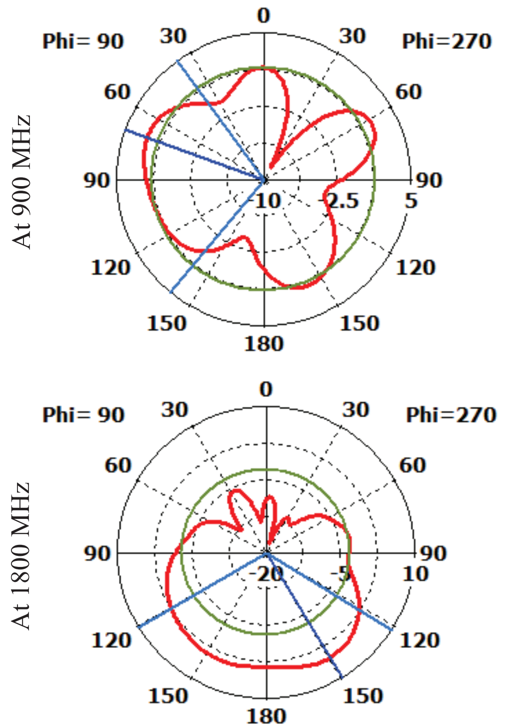
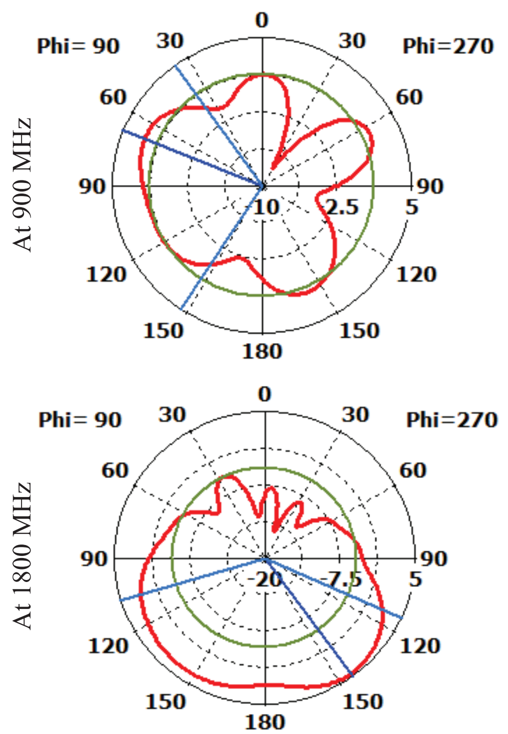


Fig. 13. Radiation efficiency and directivity for plastic phone body with additional silicon-PEC double-layer sheet.



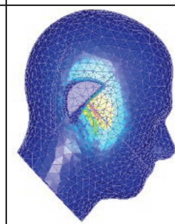
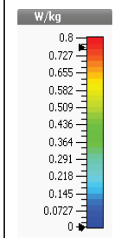
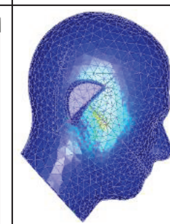
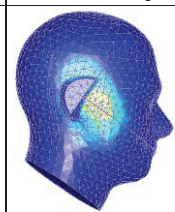
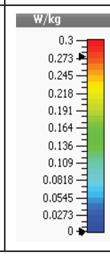
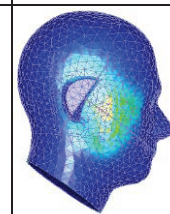
(a)



(b)

Fig. 14. Theta (degree) vs. directivity (dBi) curves xz-plane for: (a) without casing, and (b) new body configurations.

Table 2: 3D distribution of SAR values of without body and body with silicon-PEC double-layer sheet

	At 900 MHz	Scale	At 1800 MHz
Without casing	 0.76 W/Kg		 0.461 W/Kg
Casing with silicon-PEC sheet	 0.275 W/Kg		 0.22 W/Kg

IV. CONCLUSION

In this paper, a new design of cell phone body has been proposed for the reduction of EM absorption in the human head. The mobile body consists of plastic and a double-layer silicon-PEC additional sheet. The numerical results show that the proposed casing provides significant reduction of EM absorption towards the human head as well as improve radiation efficiency for both lower and upper GSM frequency bands. The silicon layer of additional sheet provides SAR reduction, particularly for the lower frequency band and PEC layer for the upper frequency band. Although the proposed design increases the cell phone thickness about 10%, it reduces the SAR 63.8% and 69.2% for the lower and upper frequency band of PIFA respectively. In case of total absorbed power by the user, 45% and 14% reduction are achieved. Moreover, the presented cell phone body improves the radiation efficiency 6% and 7% at 900 MHz and 1800 MHz respectively. It can be concluded that the proposed cell phone casing may process significant role to protect cell phone user from health risk of EM radiation.

REFERENCES

[1] I. Guideline, “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz),” *Health Phys.*, vol. 74, pp. 494-522, 1998.

[2] M. I. Hossain, M. R. I. Faruque, M. T. Islam, and N. H. M. Hanafi, “Application of auxiliary antenna elements for SAR reduction in the human head,” *Advanced Materials Research*, vol. 974, pp. 288-292, 2014.

[3] M. R. I. Faruque, N. A. Husni, M. I. Hossain, M. T. Islam, and N. Misran, “Effects of mobile phone radiation onto human head with variation of holding cheek and tilt positions,” *Journal of Applied Research and Technology*, vol. 12, no. 5, pp. 871-876, 2014.

[4] Federal Communications Commission, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Field, 2001.

[5] IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz - Amendment 1: Specifies ceiling limits for induced and contact current, clarifies distinctions between localized exposure and spatial peak power density, IEEE Std. C95.1a-2010 (Amendment to IEEE Std. C95.1-2005), pp. C1-9, 2010.

[6] O. Kivekas, J. Ollikainen, T. Lehtiniemi, and P. Vainikainen, “Bandwidth, SAR, and efficiency of internal mobile phone antennas,” *Electromagnetic Compatibility, IEEE Transactions on*, vol. 46, pp. 71-86, 2004.

[7] K. Yanase and A. Hirata, “Effective resistance of grounded humans for whole-body averaged SAR estimation at resonance frequencies,” *Progress In Electromagnetics Research B*, vol. 35, 2011.

[8] H. Y. Chen and W. Y. Chiou, “Material studies on cellular phones for reducing SAR in a human head model,” in *Antennas and Propagation Society International Symposium, 2002. IEEE*, pp. 448-451, 2002.

[9] K. Chan, K. Chow, L. Fung, and S. Leung, “Effects of using conductive materials for SAR reduction in mobile phones,” *Microwave and Optical Technology Letters*, vol. 44, pp. 140-144, 2005.

[10] J. Pretorius, “Design and manufacture of a ferrimagnetic wave absorber for cellular phone radiations,” in *Electron. Devices for Microwave and Optoelectronic Applications, 2004 EDMO 2004, 12th International Symposium on*, pp. 119-123, 2004.

[11] M. I. Kitra, C. J. Panagamuwa, P. McEvoy, J. Vardaxoglou, and J. R. James, “Low SAR ferrite handset antenna design,” *Antennas and Propagation, IEEE Transactions on*, vol. 55, pp. 1155-1164, 2007.

[12] M. T. Islam, M. R. I. Faruque, and N. Misran, “Design analysis of ferrite sheet attachment for SAR reduction in human head,” *Progress In Electromagnetics Research*, vol. 98, pp. 191-205, 2009.

[13] S. il Kwak, D. U. Sim, J. H. Kwon, and H. Do Choi, “Comparison of the SAR in the human head using the EBG structures applied to a mobile handset,” in *Microwave Conference, 2007, European*, pp. 937-940, 2007.

[14] R. Ikeuchi, K. H. Chan, and A. Hirata, “SAR and radiation characteristics of a dipole antenna above different finite EBG substrates in the presence of a realistic head model in the 3.5 GHz band,” *Progress In Electromagnetics Research B*, vol. 44, pp. 53-70, 2012.

[15] M. I. Hossain, M. R. I. Faruque, M. T. Islam, and M. H. Ullah, “A new wide-band double-negative metamaterial for C- and S-band applications,” *Materials*, vol. 8, no. 1, pp. 57-71, 2014.

[16] M. R. I. Faruque, M. Islam, and M. Ali, “A new design of metamaterials for SAR reduction,” *Measurement Science Review*, vol. 13, pp. 70-74, 2013.

[17] G. F. Pedersen and J. B. Andersen, “Integrated antennas for hand-held telephones with low absorption,” in *Vehicular Technology Conference, 1994 IEEE 44th*, pp. 1537-1541, 1994.

[18] J.-N. Hwang and F.-C. Chen, “Reduction of the peak SAR in the human head with metamaterials,” *Antennas and Propagation, IEEE Transactions on*, vol. 54, pp. 3763-3770, 2006.

[19] C. H. Li, E. Ofli, N. Chavannes, and N. Kuster, “Effects of hand phantom on mobile phone antenna performance,” *Antennas and Propagation, IEEE Transactions on*, vol. 57, pp. 2763-2770, 2009.

[20] CST Microwave Studio, 3D EM Simulation Software [Online], available: https://www.cst.com/Products/CSTMWS.[Accessed:01-Nov-2014].

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