Study on EM Absorption Analysis of Mobile Handset Antenna

Touhidul Alam[1], Mohammad Rashed Iqbal Faruque[1], Mohammad Tariqul Islam[2]

[1]*Space Science Center (ANGKASA), Universiti Kebangsan Malaysia,43600UKM,Bangi,Selangor,Malaysia.*

[2]*Department of Electrical Electronic & System Engineering, Universiti Kebangsan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.*

touhid13@yahoo.com

***Abstract*—The development of the low SAR handset antenna with the apparition of advanced handset devices is presented in this paper. The main objective of the paper is to give an overview of the development of handset antenna with reducing specific absorption rate (SAR) and satisfying market demand in the last years. The development of handset antenna with higher efficiency, compact size, cost effective, multiband and Low SAR are studied for several types of antenna**.

***Index Terms*—Specific Absorption Rate (SAR); Antenna; Mobile Handset.**

I. INTRODUCTION

Communication system has been playing an important role in human civilization from ancient smoke signal to wireless signal through electromagnetic signal. The development of the communication system is the result of tremendous efforts of researchers. Now antenna researchers have given their concentration to develop biological friendly, compact, multifunction and low cost wireless devices together with satisfying the strict market demand. In this regard, the antenna researchers often have given emphasis on designing low cost, small and multiband antennas. Beside this, biological effect of electromagnetic absorption in the human body has drawn great concentration to researchers, which makes more complexity in antenna design.

The effects of Electromagnetic (EM) radiation from wireless devices have been investigated by various organizations, including world health organization (WHO). They have identified several short term and long term effects on human health [1]. International Commission on Non-Ionizing Radiation Protection (ICNIRP) and IEEE standard values of SAR is specified as 1.6 W/Kg for 1g tissues and 2 W/kg for 10g of human tissues [2 ,3]. In Malaysia, MCMC regulated the maximum allowable EM absorption onto humans. This authority body had abided to the standard of ICNIRP.

II. STUDY OF DIFFERENT METHODS OF SAR REDUCTION

In [2-11], the menacing effects on tissues due to electromagnetic radiation are discussed from various dimensions. Mobile handset antenna design is becoming very complex, because many conditions became to design. Such as the researchers have to fulfil the demand of present market with small dimension, multiband and less biological affect antenna. In this paper various attempts of the researcher to design low SAR handset antenna will be studied.

A. *Study on Handset antenna design for SAR reduction*

(a) *PIFA structure based antenna design for SAR value reduction*

Cabedo *et al.* Proposed an antenna combining slotted ground plane and a Planer Inverted-F Antenna (PIFA) with dimension of 40 x15x 6 mm^3 [12], which covers the GSM850, GSM900 bands, and from the DCS1800 to the Bluetooth bands.The antenna layout is shown in Fig. 1. Moreover, a slotted ground plane is used to increase the bandwidth without increasing the volume of the antenna.

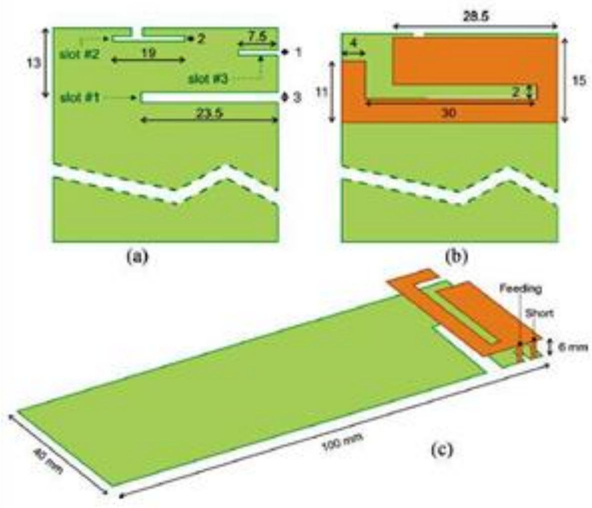

Figure 1: a) Front view of PCB, (b) front view of the antenna, and (c) 3D view of the antenna. PCB is 100 mmX40 mm. Height of the PIFA is 6 mm. [12].

SAR values for 830MHz, 900MHz, 1800MHz, 1900MHz and 2000MHz were investigated, but maximum reflection coefficient was achieved 9.4dB at 890MHz with efficiency 62% and minimum reflection co-efficient 5.1dB at 2000MHz with efficiency 46%.

Anguera *et al.* developed a multi-standard antenna with slotting radiators, where PIFA and slot radiators are excited in parallel [13]. Measured SAR value for 1g and 10g with reflection co-efficient is shown in TABLE. I. Kusuma *et al.* proposed a handset antenna to reduce the SAR value. The PIFA structure was used for operating at dual-bands of 0.9GHz and 1.8GHz in [14]. Antenna parameters were analysed with head model and without head model. The measured reflection co-efficient of the antenna without human head is 11dB at 902.5 MHz with 22 MHz bandwidth and 0.91dB gain and at 1703 MHz frequency reflection co-efficient is 11dB with 92MHz bandwidth and 1.76dBi gain. In the presence of human head reflection co-efficient is 13.5dB at 902.5MHz with 25 MHz bandwidth, gain 0.32dBi and at 1703MHz reflection co-efficient is 10dB with 92 MHz bandwidth, gain 2.03dBi.

Table 1
Measured Sar Value For 1g And 10g With Reflection Co-Efficient

Frequency (MHz)	S_{11}(dB)	SAR 1g(mW/g)	SAR 10g(mW/g)
900	-18.1	1.61	1.15
1710	-4.5	0.92	0.56
1800	-5.9	0.88	0.55
1900	-9.4	1.23	0.74
2000	-18.3	--------	--------

The maximum SAR (1g) of antenna is 0.97 W/kg at 0.9 GHz and 0.87 W/kg at 1.8 GHz and SAR (10 g) is 0.67 W/kg at 0.9 GHz and 0.58 W/kg at 1.8 GHz. The measured SAR reduction factor (SRF) of the antenna is over 10-g is more than 76% at 0.9GHz and 51% at 1.8GHz.

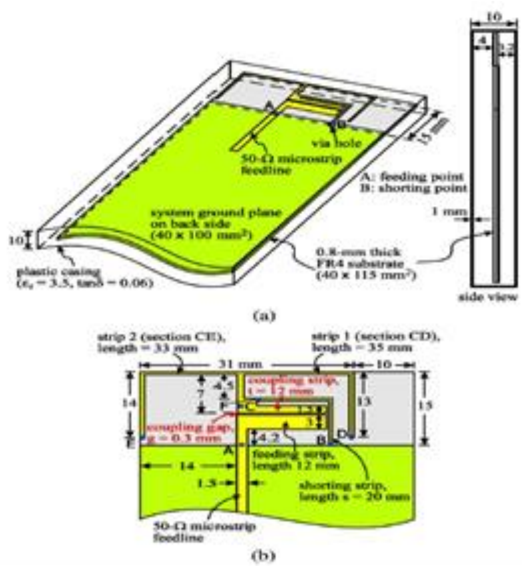

Figure 2: (a) printed PIFA antenna . (b) Dimensions of the PIFA.[15].

In [16], Zhan *et al.* Proposed a handset antenna for multiband commercial applications and the antenna consists of PIFA and side-mounted IFA antenna. The SAR value reduction of 30% was achieved than conventional PIFA antennas. On the other hand, maximum efficiency with phantom head is 38% at 1960MHZ and below 20% at 850MHz. Moreover, PIFA antennas have been developed for WLAN applications in mobile devices. As example, Chang *et al.* proposed a Penta band printed PIFA antenna, shown in Fig. 2. [15]. The antenna can operate in two wide bands at about 900MHz and 1900MHz. The antenna gain varies from 0.5 to 4.2 dB with 50 to 92% radiation efficiency for various frequency range was measured, but the SAR reduction result was not adequate at lower frequencies.

(b) Wipe type antenna for SAR reduction

Wang *et al.* presented FD-TD modelling of whip type handset antenna for SAR reduction [17] and showed total SAR reduced by 60% in the user's head without degrading RF performance. On the hand, the far-field pattern of presented wipe antenna is worse than the Conventional whip.

(c) Auxiliary antenna reflectors

In 1998 Tay et al. proposed reflector for efficiency improvements and SAR reductions towards the head [18]. Though, the techniques achieved 65-80% of peak SAR reduction, the major limitations of this technique is that an additional reflector element is required and cost increase. Moreover, the optimized procedure is required for antenna and reflector arrangement. Otherwise, poor efficiency could be expected

(d) Low SAR Monopole antenna

In [19], octaband monopole antenna has been proposed for commercially used multifunctional mobile communications with small size of 15x26 mm^2. The design layout is shown in Fig. 3. The measured minimum reflection coefficient is less than 6dB and satisfies the SAR limit for both 10g and 1g. But the peak gain in lower frequency is lower, such as at 860MHz the gain is 1.23dBi.

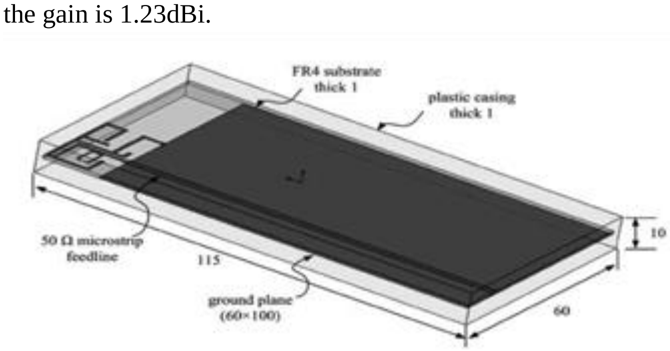

Figure 3: Monopole antenna for octaband mobile application [17].

B. Ferrite material based Handset Antenna for Peak SAR

In [20], Kitra *et al.* investigated on the advantages of ferrite material attachment with the antennas and designed a multiband antenna (Fig. 4), which covers the commercial mobile bands, with a 38% SAR reduction compared to conventional phones,but efficiency of the antenna is at 1.8 GHz.

The measured and simulated value of reflection co-efficient at 1.83GHz are 14.13dB with efficiency 15% and 12dB with efficiency 17% respectively, at 2.45GHz are 18dB with efficiency 63% and 12dB with efficiency 66.5%. Measured SAR value at 1.8GHz, 1.9GHz, 2.1GHz, and 2.45GHz are 0.078, 0.11, and 0.06, 0.0006 respectively. Moreover, for various values of permittivity and permeability the SAR value and efficiency with only head and with hand and head were studied.

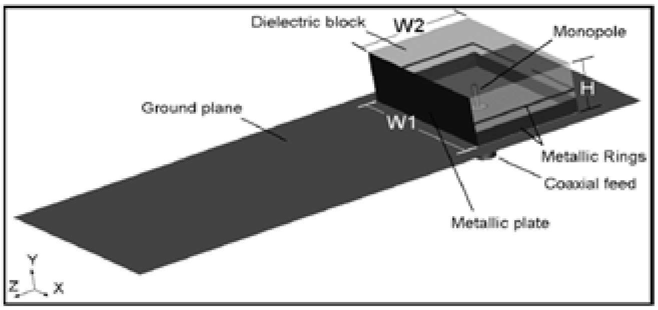

Figure 4: Layout of the material Coated antenna with central dipole excitation attached on 100 X 40 mm ground Plane.[20].

In addition, by attaching ferrite sheet the reduction of Specific Absorption Rate (SAR) was investigated in [21]. Moreover, the effects of attaching location, size distance and material properties of ferrite sheet on the SAR reduction were investigated and achieved 57.75% of reduction for 10g SAR values. The average SAR value with ferrite sheet is 0.676 for SAR 10 g.

Moreover, Augustine *et al.* investigated on the SAR measurements with a planar polymeric ferrite shielding and wearable antenna in [22]. Two different solid solution of ferric oxides based polymeric ferrite sheets (PFS), i.e. WDNRC and WDHTV were used as protective shielding for reduction of SAR at 2.4 GHz. Without using ferrite shielding the measured SAR for 10g is 7.23 W/kg. By attaching of WDNRC and WDHTV sheet on phantom the measured SAR values for 10g are 0.99 W/kg and 0.79 W/kg respectively. However, the reflection coefficients and efficiency of the antenna were not investigated together with SAR reduction.

C. Electromagnetic Band Gap (EBG) structure for SAR reduction

Ikeuchi *et al.* used EBG Substrate above dipole antenna for local SAR reduction [23] and found 84% reduction of SAR value,with improved the radiation efficiency by 10% . The feeding positions of the dipole antenna with head model was investigated, which is shown in Fig. 5 and 10-g averaged SARs for these positions were measured. Such as at position 'a' peak 10-g average SAR for dipole with PEC and dipole with EBG are 1.4 W/Kg and 1.2 W/Kg respectively. However, the reduction of SAR by using the EBG structure with varying antenna to head distance variation was not analysed.

Another experiment has been performed to reduce SAR on mobile phone by using EBG structure in [25]. The size of EBG structure was 31×8mm2 and inserted it between PIFA antenna and Circuit board. The unit cells of Integrate Patch and Square Patch. The SAR value reduced by using Integrate Patch and Square Patch structure are 31% and 43% respectively compare with conventional PIFA antenna.

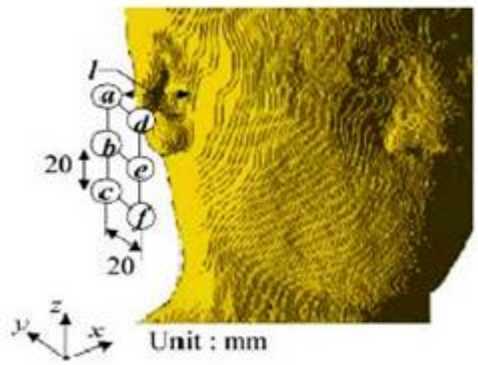

Figure 5: Feeding positions of the dipole antenna with head model [23]

D. Design handset antenna with Metamaterial attachment for Low SAR

The reduction of SAR value with materials and metamaterial was investigated in [24-29]. The achieved SAR reduction by metamaterial is 42.12% and by Materials 47.18%,which provide information to design metameterial based antenna for minimize biological effect on human body due to EM radiation [26]. In [25], metameterial based Split Ring Resonators was proposed for SAR reductionshown in Fig. 6. The measured SAR value 0.692 W/Kg for 10g is and 1.0923W/kg for 1g was achieved .that means 63.40% of the SAR value is reduction by using Metamaterials.

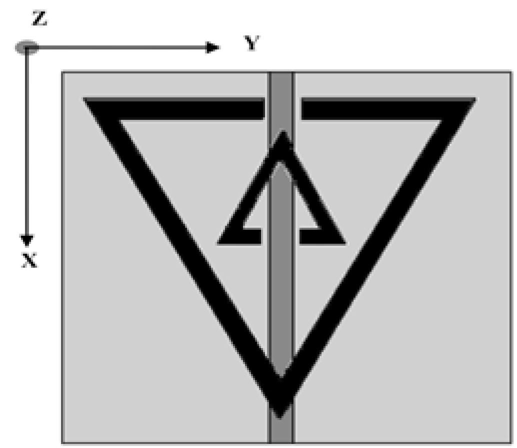

Figure 6: Metamaterials based triangular split ring resonators [28]

In sequence development of research Faruque *et al.* developed a design of square Metamaterials (SMMs) resonator for SAR reduction by which 53.06% of SAR reduction was achieved [28].

Alam *et al.*. developed Metamaterials inspired patch antenna for SAR reduction [24], which has decreased 75.53% of SAR values compare with conventional patch antenna. The developed antenna design is shown in Fig. 7. The SAR values for different finger position was investigated also.

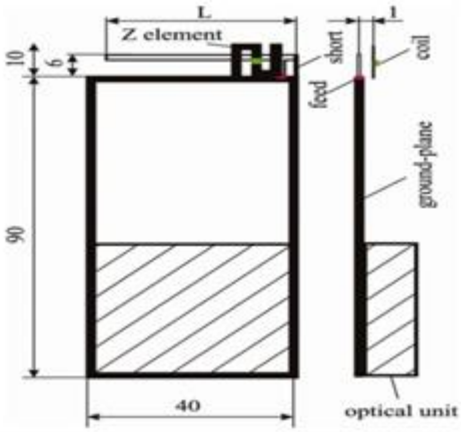

Figure 7: Metamaterials inspired inverted F antenna (MIIFA) [28].

In [31], suggested an antenna for WiMAX mobile communication with low SAR value and minimize physical size.

E. Electroencephalography (EEG) Electrode Caps for SAR reduction

Hamblin *et al.* investigated the effect of EEG electrode caps on Specific Absorption Rate reduction for GSM900 mobile phone in [32]. The SAR value was compared and investigated for three different phantom arrangement as, no cap, 64-electrode “Electro-Cap”and “Quick-Cap” for the whole head and for the temporal region. The reduction of SAR(10g) was achieved by 14% and 18% for the whole head and for the temporal region respectively. And presented a mathematical model to identify the reason of SAR reduction. The effects of the presence of electrode leads is the primary cause of SAR reduction and the orientation of electrode leads varies the effect.

III. CONCLUSION

The advancement in wireless communication makes complexity in handset antenna design. By fixing the SAR value, small size, cost effective, multiband antenna design becoming a challenge for researchers. From above study it seems that, metameterials and EBG structure play a great role in reducing the SAR value with minimizing Physical size. The maximum SAR reduction of 84% was achieved by using EBG structure and 63.40% of the SAR reduction was achieved by using Metamaterials. The use of EBG and Metameterials have a prospective aspect to design handset antenna.

REFERENCES

[1] W. H. Organization, "Electromagnetic fields and public health: mobile phones. October 2014," ed.

[2] "IEEE Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," IEEE Std C95.1-2005 (Revision of IEEE Std C95.1-1991), pp. 0_1-238, 2006.

[3] "International Non-Ionizing Radiation Committee of the International Radiation Protection Association, “Guidelines on limits on exposure to radio frequency electromagnetic fields in the frequency range from 100kHz to 300 GHz," Health Physics, vol. 54 p. 9, 1988.

[4] P. J. Riu and K. R. Foster, "Heating of tissue by near-field exposure to a dipole: a model analysis," Biomedical Engineering, IEEE Transactions on, vol. 46, pp. 911-917, 1999.

[5] M. D. Samsuzzaman, M. T. Islam, and J. I. T. Mandeep Singh, "Ceramic material based multiband patch antenna for satellite applications," Revue Roumaine des Sciences Techniques Serie Electrotechnique et Energetique, vol. 59, pp. 77-85, 2014.

[6] C. C. Davis, B. B. Beard, A. Tillman, J. Rzasa, E. Merideth, and Q. Balzano, "International intercomparison of specific absorption rates in a flat absorbing phantom in the near-field of dipole antennas," Electromagnetic Compatibility, IEEE Transactions on, vol. 48, pp. 579-588, 2006.

[7] C. Kwok-Chi, K. C. L. Chan, and R. D. Murch, "Investigating the impact of smart antennas on SAR," Antennas and Propagation, IEEE Transactions on, vol. 52, pp. 1370-1374, 2004.

[8] R. O'Donnell, "Prolog to EM interaction of handset antennas and a human in personal communications," Proceedings of the IEEE, vol. 83, pp. 5-6, 1995.

[9] S. Fiocchi, I. A. Markakis, P. Ravazzani, and T. Samaras, "SAR exposure from UHF RFID reader in adult, child, pregnant woman, and fetus anatomical models," Bioelectromagnetics, vol. 34, pp. 443-452, // 2013.

[10] J. C. Lin, "Specific absorption rates (SARs) induced in head tissues by microwave radiation from cell phones," Antennas and Propagation Magazine, IEEE, vol. 42, pp. 138-139, 2000.

[11] M. Okoniewski and M. A. Stuchly, "A study of the handset antenna and human body interaction," Microwave Theory and Techniques, IEEE Transactions on, vol. 44, pp. 1855-1864, 1996.

[12] A. Cabedo, J. Anguera, C. Picher, M. Ribo, and C. Puente, "Multiband Handset Antenna Combining a PIFA, Slots, and Ground Plane Modes," Antennas and Propagation, IEEE Transactions on, vol. 57, pp. 2526-2533, 2009.

[13] J. Anguera, I. Sanz, J. Mumbru, and C. Puente, "Multiband Handset Antenna With a Parallel Excitation of PIFA and Slot Radiators," Antennas and Propagation, IEEE Transactions on, vol. 58, pp. 348-356, 2010.

[14] A. H. Kusuma, A.-F. Sheta, I. M. Elshafiey, Z. Siddiqui, M. A. Alkanhal, S. Aldosari, *et al.*., "A new low SAR antenna structure for wireless handset applications," Progress In Electromagnetics Research, vol. 112, pp. 23-40, 2011.

[15] C. Chih-Hua and W. Kin-Lu, "Printed <formula formulatype="inline"> <img src="/images/tex/18921.gif" alt="\lambda /8"> </formula>-PIFA for Penta-Band WWAN Operation in the Mobile Phone," Antennas and Propagation, IEEE Transactions on, vol. 57, pp. 1373-1381, 2009.

[16] L. Zhan and Y. Rahmat-Samii, "Optimization of PIFA-IFA combination in handset antenna designs," Antennas and Propagation, IEEE Transactions on, vol. 53, pp. 1770-1778, 2005.

[17] Z. Wang and X. Chen, "A low SAR whip type mobile handset antenna," in Antennas and Propagation, 2001. Eleventh International Conference on (IEE Conf. Publ. No. 480), 2001, pp. 352-355 vol.1.

[18] Tay, R. Y.-S., Q. Balzano & N. Kuster. Dipole configurations with strongly improved radiation efficiency for hand-held transceivers. Antennas and Propagation, IEEE Transactions on vol.46(6), pp. 798-806, 1998.

[19] M. Jie, Y. Ying-Zeng, G. Jing-Li, and H. You-Huo, "Miniature Printed Octaband Monopole Antenna for Mobile Phones," Antennas and Wireless Propagation Letters, IEEE, vol. 9, pp. 1033-1036, 2010.

[20] 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.

[21] 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.

[22] R. Augustine, T. Alves, T. Sarrebourse, B. Poussot, K. T. Mathew, and J. M. Laheurte, "Polymeric ferrite sheets for SAR reduction of wearable antennas," Electronics Letters, vol. 46, pp. 197-198, 2010.

[23] R. Ikeuchi and A. Hirata, "Dipole Antenna Above EBG Substrate for Local SAR Reduction," Antennas and Wireless Propagation Letters, IEEE, vol. 10, pp. 904-906, 2011.

[24] Alam, T., Faruque, M. R. I., & Islam, M. T. (2016). Specific absorption rate analysis of broadband mobile antenna with negative index metamaterial. Applied Physics A, 122(3), 1-6.

[25] S. I. Kwak, D. U. Sim, J. H. Kwon, and H. D. Choi, "Experimental tests of SAR reduction on mobile phone using EBG structures," Electronics Letters, vol. 44, pp. 568-569, 2008.

[26] M. A. Antoniades and G. V. Eleftheriades, "A Compact Multiband Monopole Antenna With a Defected Ground Plane," Antennas and Wireless Propagation Letters, IEEE, vol. 7, pp. 652-655, 2008.
[27] Alam, T., Faruque, M. R. I., & Islam, M. T. (2015). A double-negative metamaterial-inspired mobile wireless antenna for electromagnetic absorption reduction. Materials, 8(8), 4817-4828.
[28] M. Faruque, M. Islam, and M. Ali, "A New Design of Metamaterials for SAR Reduction," Measurement Science Review, vol. 13, pp. 70-74, 2013.
[29] T. Alam, M. R. Faruque, and M. T. Islam, "A Corded Shape Printed Wideband Antenna Design for Multi-standard Mobile Applications" Telecommunication Systems (In press).
[30] L. Xue-jie, Y. Hong-chun, and H. Na, "An improved dual band-notched UWB antenna with a parasitic strip and a defected ground plane," in Intelligent Signal Processing and Communication Systems (ISPACS), 2010 International Symposium on, 2010, pp. 1-4.
[31] K. Sungtek, K. Kyungseok, E. Dajeong, L. Boram, M. Segyoon, Y. Seongryong, *et al.*., "A metamaterial-inspired handset antenna with the SAR reduction," in Electromagnetic Compatibility (EMC), 2012 IEEE International Symposium on, 2012, pp. 307-310.
[32] D. L. Hamblin, V. Anderson, R. L. McIntosh, R. J. McKenzie, A. W. Wood, S. Iskra, *et al.*., "EEG Electrode Caps Can Reduce SAR Induced in the Head by GSM900 Mobile Phones," Biomedical Engineering, IEEE Transactions on, vol. 54, pp. 914-920, 2007.