A SURVEY ON RECENT APPROACHES OF ELECTROMAGNETIC ABSORPTION REDUCTION WITH RESPECT TO HUMAN HEAD EXPOSURE TO GSM FREQUENCY BANDS

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ABSTRACT: *The cellular phone usage has been growing dramatically over the last decade and became a crucial part of our life. One of the key components of mobile phone is the antenna that receives and transmits electromagnetic (EM) energy. The safety of human head exposure of electromagnetic (EM) waves emitted from cell phones has attracted public concern. A comprehensive review of recent approaches and techniques of electromagnetic absorption reduction over GSM bands are presented in this paper. Protection attachments between the antenna and the human head were proposed by many researchers. These distinct techniques have been classified in to 4 categories including the use of ferrite sheet, perfect electric conductor (PEC), electromagnetic band gap (EBG) structure and metamaterials. Few good papers were reviewed and evaluated in each group for proof of concept. Finally, a comparison between these techniques was done.*

Keywords: *Electromagnetic Absorption; GSM Frequency Bands; Survey Paper*

1. INTRODUCTION

Mobile phone technology had been introduced in the twenty first century and has been advancing subsequently to around the world. In the last decade, the mobile phone subscribers have increased dramatically around the globe. Consequently, the awareness of radiation effect of cellular phones towards the human health has spread. Since every cell telephone transmits a low level of radio frequency electromagnetic energy, the electromagnetic emission absorption affects human wellbeing. Because of their warming impacts, they can bring about biological harm to the body cells. Therefore, medical researchers are concerned that any related health dangers, even little ones could bring about noteworthy general health issues.

The fundamental parameter in the electromagnetic (EM) absorption is defined in terms of the specific absorption rate (SAR), or the absorbed power in unit mass of tissue [1, 2]. SAR values demonstrate the radiated power from cell telephone absorbed by the human over a specific volume of body tissue relating to 1g or 10 g of body tissues, and it is measured in watt per kilogram (W/kg) [3]. A specific safe limit of SAR is selected so that the most extreme EM radiation exposure could be managed without presenting biological changes onto the human health. These standards are regulated by world authoritative bodies such International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Federal Communications Commission (FCC) [4, 5]. As per the ICNIRP standard, the safe SAR limit is 2 W/kg for 10 g of body tissue. A few nations comply with these regulations including Australia, Japan, New Zealand and Brazil. Other countries, for example, Canada, South Korea, Bolivia and Taiwan followed the standard managed by FCC. As indicated by this standard, the safe limit of SAR is 1.6 W/kg over 1 g of body tissue [6, 7].

To reduce the specific absorption rate (SAR) created by cell telephone, numerous methods have been proposed. According to [8], there are primarily three strategies to reduce SAR of cellular telephone including changing the antenna position or the feeding point to the antenna, the incorporation of electromagnetic wave absorbers, and the utilization of special ground planes. However, the most used technique to deal with the electromagnetic problems is the inclusion of electromagnetic wave absorbers. In this approach, the applied techniques can be classified into four categories including using ferrite sheet [9, 10], perfect electric conductor (PEC) [11, 12], electromagnetic band gap (EBG) structure [13-15] and metamaterials [16-18].

During the next sections of this paper, an article review and comparison will be done to evaluate different electromagnetic absorption reduction techniques. This is to evaluate and realize the methods which are used by authors to reduce the electromagnetic radiation exposure to human body. It will be discussed four techniques including using perfect electric conductor, ferrite sheet, electromagnetic band gap and metamaterial structures. The geometry and some obtained results have been reported to reach this purpose.

2. ELECTROMAGNETIC-ABSORPTION REDUCTION TECHNIQUES

Perfect Electric Conductor (PEC)

In this design configuration, two shapes of perfect electric conductor shields are used. One shape has slit while the other is without as shown in figure 1. The purpose of the slit is to evaluate the effect of the shield and to improve the mobile phone antenna performance. The shields are made up of conductors such as Aluminum and Copper with and without slit. The thickness of the shields was taken as 0.1 cm. The separation between the cell telephone and the head is considered as 0.5 cm. The shield has been set in front of the cellular telephone, between the head and phone.

It is observed from the obtained results that the antenna reflection coefficient shifted to a higher frequency which is not suitable for the GSM mobile phone antenna use. The reflection coefficient increased up to 1.8 GHz as shown in figure 2. It is also observed that the radiation pattern of the antenna deteriorate due to the conductor shields. It is concluded in this study that the conductors are not suitable for mobile phone electromagnetic radiation because of bad signal reception and performance. This will cause signal attenuation and the desired radiation pattern of the mobile phone antenna changes. The effect of the conductor shield depends on their thickness. It doesn't matter if the shield interacts with the cellular telephone antenna or not; the signal quality will be decreased as it can't go through the protecting material. Therefore, a shield made up of a conductor can't be utilized for the cellular telephone radiation protection as they degrade the telephone antenna performance [11].

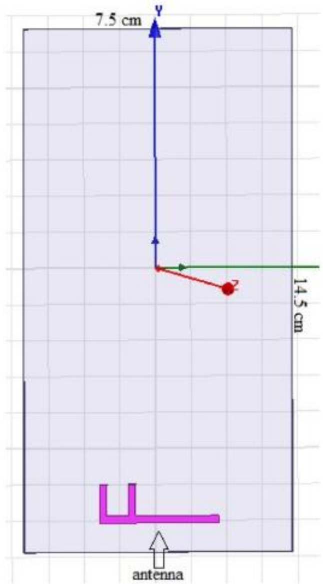


Figure (1) Conductor shield [11]

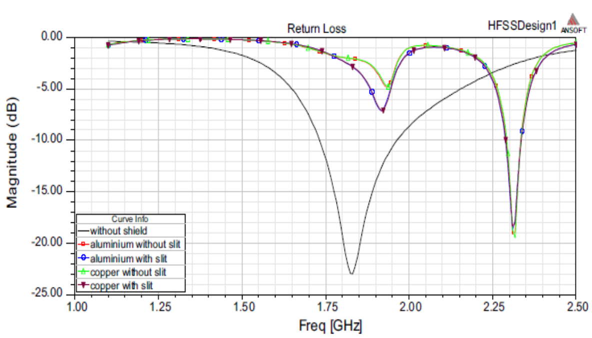


Figure (2) Reflection coefficient of mobile phone antenna with shields made up of conductors [11]

3. Electromagnetic Band Gap (EBG) Structure

Figure 3 shows the proposed design of EBG structure. The EBG structure is consists of several unit cells. And every unit comprises of a rectangular metallic patch, via connector, dielectric substrate, and metallic ground. It is understood that EBG structure works as filter and can provide filtering characteristic for its equivalent inductance and capacitance structure. In this manner it will reduce the surface waves that create EM waves going toward the human head, and after that reduces the top SAR of the cell telephone.

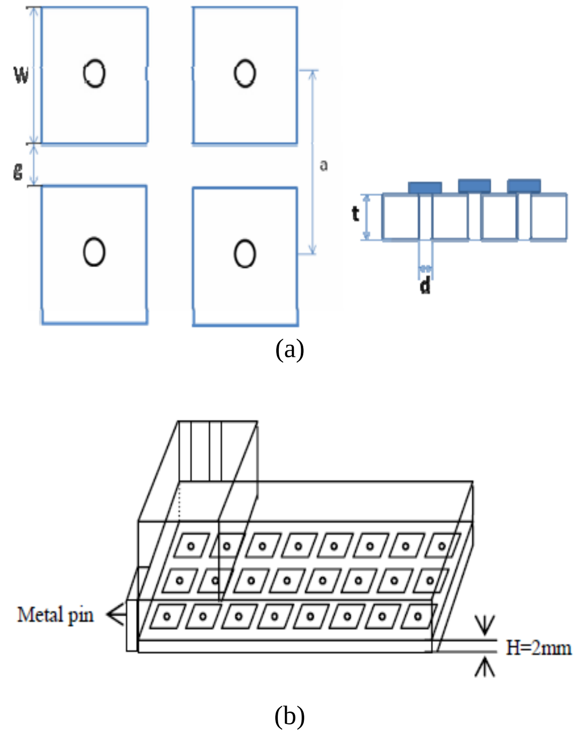


Figure (3) the proposed EBG structure, (a) the proposed unit cell design, (b) antenna with EBG structure [13]

The EBG structure was inserted between human head and PIFA antenna. The EBG unit cells are fabricated on Taconic CER-10 substrate (ε_r = 10.2) with a physical thickness of 2 mm. According to the authors the EBG structure was inserted between the radiated antenna of the mobile phone and PCB board. Therefore, the signal radiation towards the human head is suppressed as shown in figure 4. Hence, the electromagnetic peak SAR is reduced up to 0.448569 W/kg. And this result is lower than the peak SAR without any suppression technique [13].

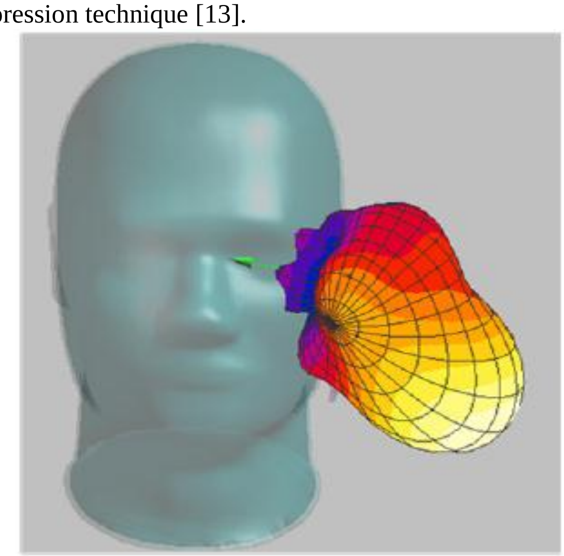


Figure (4) Antenna suppressed pattern [13]

The authors calculated the total radiated power (TRP) of the mobile phone in order to validate effectiveness of this technique. They found that this method reduced the peak SAR while maintaining the TRP of mobile phone. Besides, a comparison of this method and conductor reflector is provided for further understanding. And according to the obtained results the EBG structure is better than the conductor reflector for suppressing the peak SAR of the mobile phone.

4. Ferrite Sheet Attachment

In this design, a ferrite sheet was placed between antenna and a human head in order to reduce the SAR value. As shown in figure 5, a handset with monopole type of helix antenna model was simulated by using CST software. The antenna was organized in parallel to the head axis; the separation is varied from 5mm to 20 mm; lastly 20mm was decided for comparison with ferrite sheet. Other than that, the output power of the cellular telephone model should be set before SAR is simulated. In this case the output power of the mobile phone is 500 mW at operating frequency of 0.9 GHz. Generally, the output power of the cellular phone won't surpass 250 mW for typical application, while the most extreme output power can reach till 1W or 2 W.

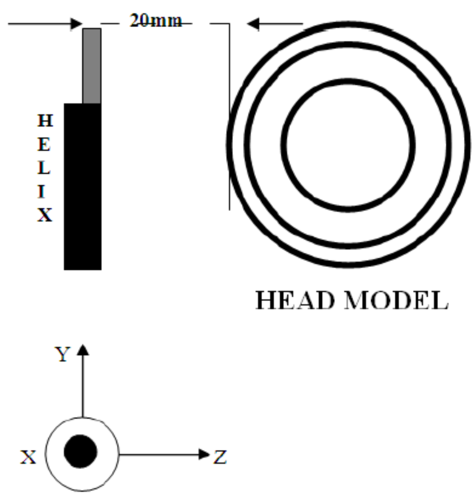
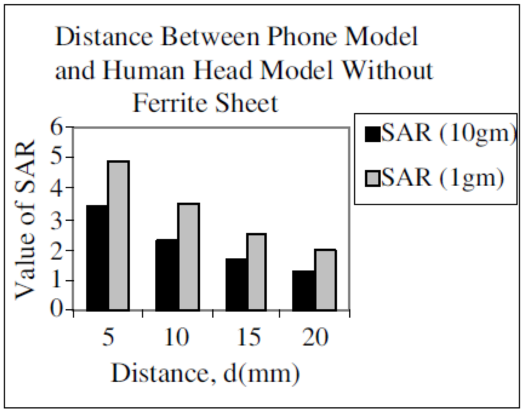
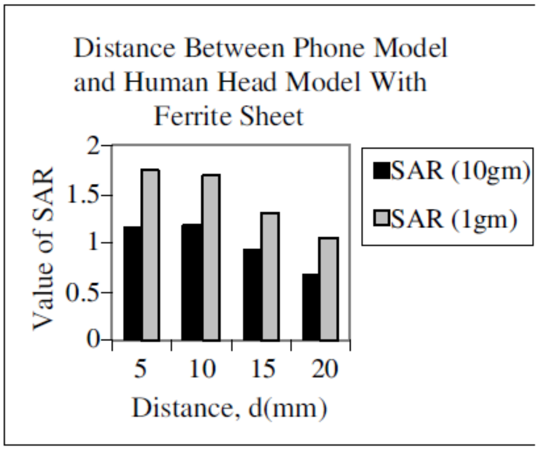


Figure (5) the head and antenna models for SAR calculation [10]

The obtained simulated SAR was compared with other related papers results for validation. The ferrite sheet material is used in the middle of the telephone and head models, and it is found that the simulated value of SAR 1gm and SAR 10gm are 1.043 W/kg and 0.676 W/kg respectively. A SAR reduction of about 57.75% was observed in this study when a ferrite sheet is appended between telephone and human head models for SAR 10 gm. This SAR decrease is better than the outcome reported in related research papers. Figure 6 illustrates the simulated SAR value of the phone with and without ferrite sheet versus the distance between phone and head model.



(a)



(b)

Figure (6) SAR value versus the distance between phone model and human head model, (a) without ferrite sheet, (b) with ferrite sheet [10]

5. SAR Reduction using Metamaterial

A coplanar wave guide (CPW) fed printed monopole antenna structure was proposed and reported in [18] to reduce peak SAR value. Using metamaterial the radiation hazards for mobile phone can be reduced when a human head is near around. In addition to this, when an antenna with the metamaterial is in free space, the metamaterial should not affect the antenna performance, such as radiation pattern or total radiated power. This antenna design resonates at 1.8 GHz when printed on a substrate of dielectric constant (εr) 4.4 and thickness 1.6mm.

Split ring resonator (SRR) with dimension of r1 (outer ring radius) = 6.3 mm, Width of the ring W = 0.9 mm, distance between the two rings d = 0.6 mm, split gap (t) = 0.5mm is offset by a distance (a) = 1.7mm from the right edge of the feed and b = 1.3mm from the top edge of the right ground is printed at back side. The geometry of the proposed antenna and the associated parameters are shown in figure 7.

Larger pulse number lead to a smaller particle size due to the fragmentation effect as shown in the following figure 6 where (60) laser pulse was used to prepare ZnO NPs at (71) J/cm2 laser fluency average particle diameter found to be about (31.75 nm) as shown below.

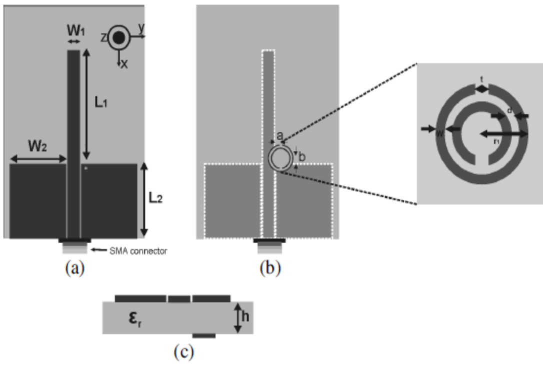


Figure (7) Geometry of the proposed antenna, (a) front view, (b) bottom view, (c) side view [18]

The planar monopole antenna with and without printed SRR for a distance of 10mm from head model is simulated using a SAM phantom head model provided by CST Microwave Studio software. The obtained results are shown in figure 8.

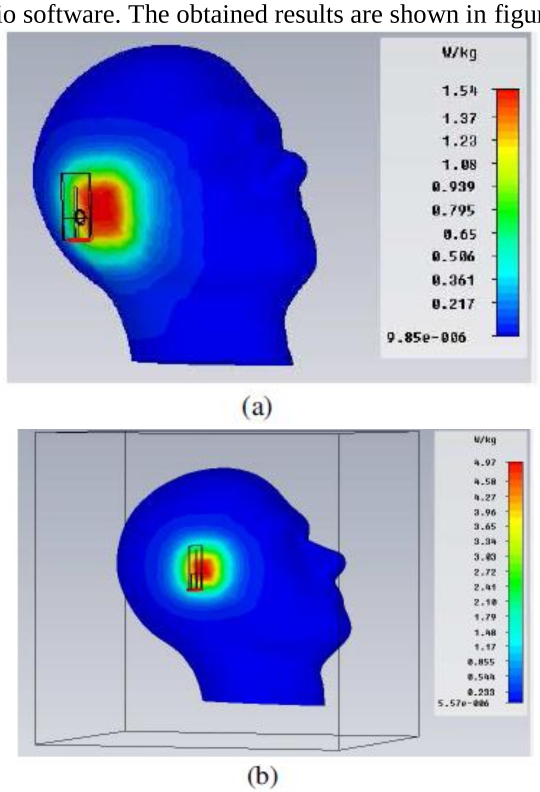


Figure (8) Planar monopole antenna with (a) and without (b) printed SRR for a distance of 10mm from head model [18]

The obtained results demonstrate that the SAR value reduces with distance and for this antenna design the SAR value is less than the FCC regulated value even for a distance of 10 mm as shown in Table 1.

Table 1: Simulated SAR value of the antenna with distance [18]

Distance from phantom model to antenna	SAR W/kg (1 gm) Planar monopole antenna	SAR W/kg (1 gm) Planar monopole antenna with printed metal SRR at the back
10 mm	4.97	1.54
20 mm	2.616	1.22
30 mm	1.074	0.623
40 mm	0.707	0.509

6. CONCLUSIONS

This paper presents a comprehensive review of recent approaches of electromagnetic absorption reduction techniques and their performances. It focuses on the recent method used to reduce the radiation hazard and peak SAR value reduction using perfect electric conductor, electromagnetic band gap, ferrite sheet and metamaterial structures. These methods are proposed by numerous researchers to investigate suitable techniques for solving radiation concerns on human health. Several good and published articles about these techniques were analysed and compared.

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