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Design of Handset Antenna with Low Electromagnetic Absorption

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Abstract: Cellular phone protection and the enforcement of pertinent exposure standards are issues in the current media, and regulatory agencies are motivated to ensure that compliance testing is acceptable. This is important because the electromagnetic radiation towards human being will heat the human tissue especially our brain as it is the most sensitive organ. In this project, the main objective is to design an antenna which has low SAR value than mentioned above. Besides that, the designed antenna will be operating at 2.4 GHz frequency for wireless local area network (WLAN) by considering some parameters that determine the performance of the antenna. The authors were carried out simulation by placing antenna at different position to determine which position are more suitable and effectively reduced the SAR level. The simulation results are compared and analyzed. The designed antenna operating at the range of frequency from 2373 MHz to 2435 MHz with 2.6% bandwidth and the radiation pattern is omni-directional. The handset antenna design has achieved 1.483 W/kg for 1 gm SAR and 1.192 W/kg for 10 gm SAR which has been reduction about 25.75% for 1 gm and 25.50% for 10 gm SAR value of the standard SAR level. It is demonstrated that the novel design of the low SAR antenna doesn't degrade its RF performance though has a great advantage of reducing the SAR value inside the user's head.

Key words: Patch Antenna, finite-difference time-domain method, Specific absorption rate, symmetry

INTRODUCTION

With the fast evolution of personal telecommunications, mobile handset antennas have been growing through a series of modifications and changes. Recently the design of mobile handset antennas begins to move away from an omnidirectional type to a selective directivity type or a low SAR type. This is driven mostly by public concerns of potential health hazards of RF radiation into a user's head. (Jensen et al, 1995; Hombach *et al,* 1996). The interaction of the cellular handset with the human head has been investigated by many published papers with considering; first, the effect of the human head on the handset antenna performance, including the feed-point impedance, gain and efficiency (Kouveliotis *et al,* 2006; Sulonen *et al,* 2003; Krogerus *et al,* 2005). Antenna performance can be optimize or evaluate through radiation pattern, return loss, voltage standing wave ratio (VSWR), gain, polarization, path loss, multipath, interference, polarization distortion, effects of earth and surroundings, antenna cost, antenna size and appearance. The above stated parameters and issues are equally important and take into consideration during the design process of an antenna. So an antenna type needs to be appropriate to the specifications that need to follow to design antenna. Therefore the antenna type should be taking into account before we start to design antenna for any application (Wong, *et al*, 2003).

The antenna size constraints imposed by mobile handset requirements and the availability of new dielectric materials has created much interest in dielectric loaded antennas (Bit-Babik *et al,* 2004; Wong *et al,* 2005). Tuning stability and good isolation from the handset and the human operator are cited as important features of dielectric loading which may enable a stand-alone ceramic chip antenna to be finally realized in practice over all the operating bands. There is also some expectation that somewhat less power is dissipated in the operator's head but the orientation of the dielectric antenna with respect to the head and the position of the antenna inside the handset in relation to the electronics are likely to remain the major influence on the specific absorption rate (SAR). Specific absorption rate are influenced by many parameters and it was handled and took into consideration three parameters to reduce the SAR level. Substrate permittivity, position of the antenna, type and size of the antenna are those factors that reduced the SAR level of this antenna.

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The use of ferrite material loading has previously been investigated (James *et al,* 1978) but it is only recently that the merits of equalizing the material relative permittivity and permeability values have been reported (James *et al*, 2002; Vardaxoglou *et al*, 2003; Kitra *et al,* 2003). The benefits include increased bandwidth (BW) and radiation efficiency (η). The influence of magnetic material on dielectric resonator antennas has also been investigated (James *et al,* 2004). A previous study (Islam *et al*, 2009) used a sheet attachment on the handset case to reduce SAR. Realizing ferrite material as a metamaterial has been considered (Buell *et al*, 2004; Islam *et al*, 2010). However, for handset compacted antenna applications the metamaterial heterogeneity and obtaining a small enough cell size are apparent difficulties with this concept. The expansion of wireless local area networks at home and work has also necessitated the demand for antennas that are compact and inexpensive. Wire antennas, such as whips and helical antennas are sensitive to only one polarization direction. As a result, they are not optimal for use in portable communication devices which require robust communications even if the device is oriented such that the antenna is not aligned with a dominant polarization mode. (Wong, *et al,* 2003). The protocol and procedures for the measurement of the peak spatial-average SAR induced inside a simplified head model of the cellular handset users are specified by IEEE standard-1528 [IEEE Standard-1528, 2005] and IEC 62209-1 [IEC 62209-1, 2005]. Anatomically correct head models of a nonhomogeneous human head at different ages were used to evaluate the performance of the handset on a human head phantom (Beard *et al,* 2006; Wang *et al*, 2006).

In this paper present that the above-established material loading techniques were brought together to create a multiband low SAR handset antenna. The continued reduction in the SAR is of interest to both manufacturers and users and is the central theme in our paper. This paper commences with the analysis of generic spherical shaped loaded monopoles and their extension to more realistic shapes. Optimal bandwidth, radiation efficiency and SAR properties are demonstrated by simulation using Flomerics' microstripes transmission line matrix (TLM) method and measurements. In particular, the influence of the choice of materials and the antenna excitation process on the near-fields and hence SAR, are considered. Retention of the antenna performance when embedded in a typical handset ground plane has received much attention in the present research and simulated results are included making available many design options to achieve the multiband low SAR operation. These are described in detail and final design recommendations are presented.

II. Handset Antenna Design and FDTD Simulation:

The SAR was simulated using a homogeneous spherical phantom of radius 75 mm. It has been established (Meier *et al,* 1997; Khalabatri S., 2006; Kim, 1998) that the use of a homogeneous spherical phantom gives worse-case simulation of the peak 10 gm SAR compared to an anatomically accurate heterogeneous phantom head. Computations times are also much less for the former. The phantom material parameters chosen were conductivity and density which resemble human tissue. The antenna radiating power external to the antenna was normalized at 125 mW. In all the simulations in this paper the sphere surface was placed 15 mm distant from the antenna surface of interest. Basically all patch antennas has common feature which is consist of four elements. Those four elements are:

- A very thin flat metallic region often called the patch
- A dielectric substrate
- A ground plane, which is usually much larger than the patch
- A feed, which supplies the element radio frequency (RF) power.

Microstrip elements are often constructed by etching the patch and sometimes the feeding circuitry from a single printed-circuit board clad with conductor on both of sides. The length of the patch (L) is typically about a third to a half of a free-space wavelength λ_0, while the dielectric thickness is in the range of $0.003\lambda_0$ to $0.5\lambda_0$. A commonly used dielectric for such antennas is polytetrafluoral ethylene (PTFE), which has a relative dielectric constant of about 2.5. Sometimes a low-density cellular material is used to support the patch.

This material has a relative dielectric constant near unity and usually results in an element with better efficiency and larger bandwidth but at the expense of an increase in element size. Substrate materials with high dielectric constants can also be used. Such substrates result in elements that are electrically small in terms of free-space wavelengths and consequently have relatively small bandwidth and low efficiency. In fig. 1 shows the proposed low SAR patch antenna elements typical structure and side view of rectangular patch antenna shows in fig. 2. Also fig. 3 and fig. 4 can be seen that how to build on patch antenna feed arrangement and how to develop on feed antenna arrangement. The geometric configuration of proposed antenna as shown as follows Table-1.

The substrate chosen for this project is Roger 4003(hydrocarbon Ceramic) which has dielectric constant, ε =3.38, and loss tangent 0.0022. The dielectric constant preferred to be less than 2.5 or otherwise smaller size patch is desired.

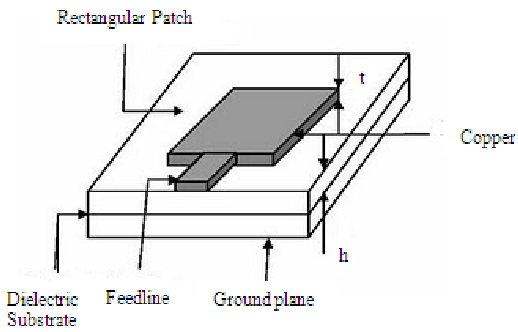

Fig. 1: A Typical rectangular patch antenna element.

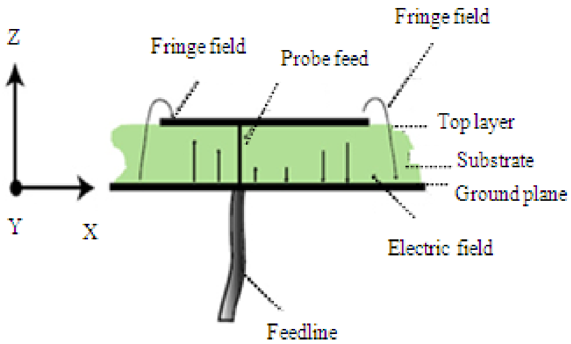

Fig. 2: Side view of rectangular patch antenna.

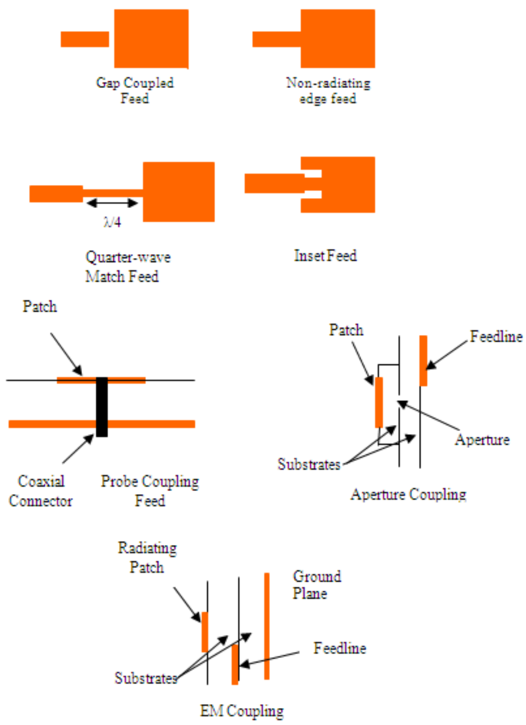

Fig. 3: Patch antenna feed arrangements.

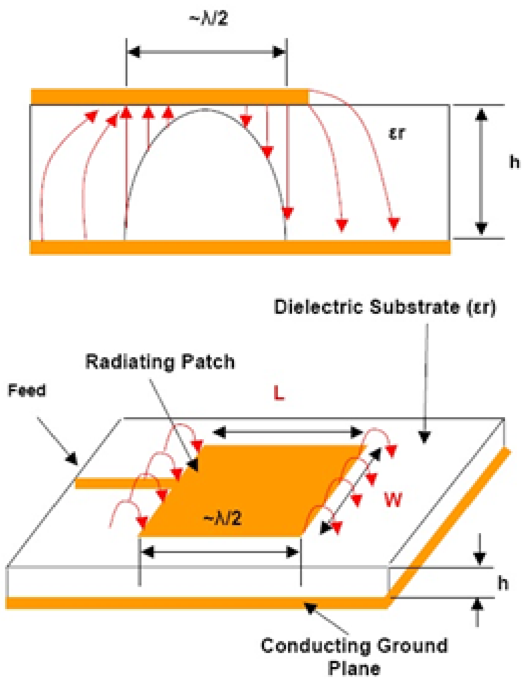

Fig. 4: Rectangular patch antenna electric field pattern.

Table 1: Antenna Specifications

Specifications	
Width	39.5 mm
Length	31.5 mm
Thickness	1.524 mm
Substrate	Rogers 4003
Ground plane	PEC
Operating frequency	2.4 GHz
Probe feed coordinate	(0, 9)

III. Specific Absorption Rate (SAR):

The use of mobile phones has augmented worldwide generating a public concern as to whether frequent utilization of such devices is unsafe. This provoked EMF researchers to find suitable techniques of assessing radiation blueprint and exposure hazards if any. Most of the research groups focused on two techniques, which are experimental measurements and finite difference time domain (FDTD) computations. Governments around the world have adopted comprehensive international safety guidelines, developed by independent scientific organizations, governing the exposure to RF energy. Antennas are designed to operate within these stringent limits which called as SAR. SAR is a measurement of the rate at which energy is absorbed by the body when exposed to a radio frequency (RF) electromagnetic field. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram. SAR is usually averaged either over the whole body, or over a small sample volume typically 1 gm or 10 gm of tissue. SAR is used to measure exposure to fields between 100 kHz and 10 GHz. The SAR can be calculated according to the equation SAR = $\sigma E^2/\rho$. Where σ is the electric conductivity and ρ is mass density. The (root mean square) rms value of the electric field strength in the x, y, z point, E is defined by:

$$E = (Ex^2 + Ey^2 + Ez^2)^{1/2} \qquad (1)$$

where the *Ex*, *Ey* and *Ez* are the rms values of the x, y, and z components of the electric field.

Radio-frequency electrical currents in the antenna and in the casing of a handheld mobile phone will induce RF electric fields in tissue. As a result of this a part of the radiated energy will be absorbed into tissue causing an increase in the tissue temperature. The absorption is caused by the power loss involved with dielectric polarization. Vibrations of water molecules, movements of free ions and movements of bound charges attached to macro-molecules contribute most to the dielectric polarization in biological material in radio frequencies. In practice SAR is always determined as an average value in the finite tissue volume. The whole body average, SAR was simply gives the power absorbed into the whole human body divided by the mass of the body. In order to avoid the exposure of human to radiation, internal antenna can be used. They are placed on the backside of the phone thus avoiding human interference. Fig. 5 shows that the electromagnetic absorption of radiation pass through the head model to cellular phone.

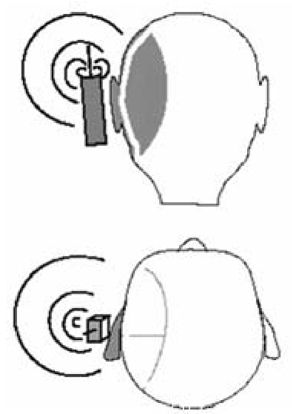

Fig. 5: Head model electromagnetic absorption of radiation.

IV. *Handset Antenna Results and Discussions:*

The handset antenna design and the development process of the patch antenna and specific absorption rate level, the results for the simulations by using CST Microwave Studio can now be presented and discussed. Antenna designs was simulated and optimized over and over again until satisfactory results are obtained. Based on these results, discussions will be made on the specific absorption rate level and performance of the antenna. The accomplished results such as return loss curves and radiation patterns and specific absorption rate level for designed antenna will be discussed. In addition, analysis of the results of the designed patch antenna will be made to find out if it fulfills the basic criteria for operation in the proposed wireless communication networks or systems with lower SAR level. A return loss plot indicates how well the link and channel's impedance matches its rated impedance over a range of frequencies. High return loss values mean a close impedance match, which results in greater differentiation between the powers of transmitted and reflected signals.

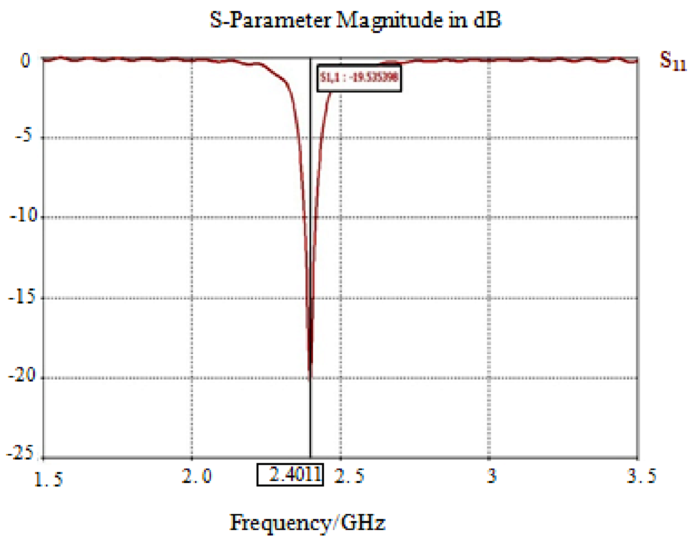

Fig. 6: Simulated return loss of new designed of patch antenna.

As can be seen from this fig. 6, the resonant frequency of the antenna is 2400 MHz. The return loss of the antenna is –19.53 dB at 2400MHz for VWSR is 2 is as shown in fig. 6. The simulated result shown that, the antenna covering the frequency ranges from 2373MHz to 2435MHz. Antenna has 2.6% (62MHz) bandwidth which is suitable for wireless local area network (WLAN) applications. Even though the designed antenna gave a much narrower bandwidth but it is
applicable for WLAN applications which are operating at centre frequency 2400MHz. The antenna can be modifying to give a better return loss at 10dB and at 14dB by optimizing the slots to excite at a closer resonance frequency without sacrificing the bandwidth requirement of the WLAN band.

While consideration of the antenna performance in terms of efficiency by analyzing return losses, there is another main property that must be analyzed when considering the viability of the antenna is the radiation pattern. The radiation pattern of the antenna which is operating at 2400MHz is shown below in 3D pattern view in shown in figs. 7 (a), 7(b), and 7(c) and 2D pattern view's shown in fig. 7(d).

Based on the graph and pictures above, the gain of antenna influence by the dominant E-Theta field is vertical polarization. The radiation pattern is omnidirectional which is perfectly suitable for wireless local area network. Even though it is omnidirectional radiation pattern but the radiation is not fully occupied the 360^0 region in far field radiation pattern. There was a very slight drop in the electric field strength in direction of the two ends of the antenna.

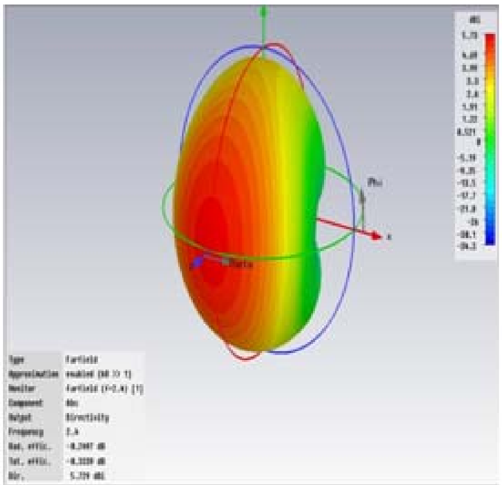

Fig. 7(a): Overall far field radiation patterns.

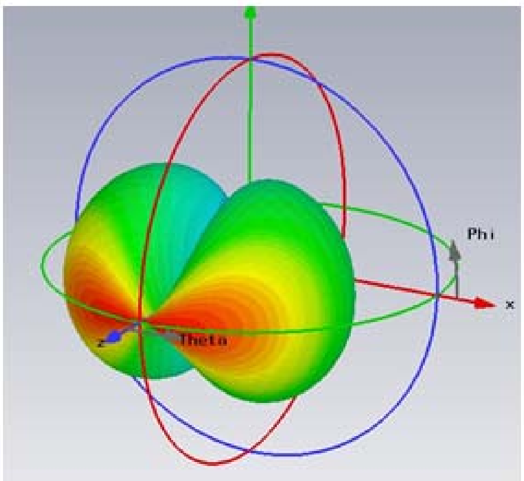

Fig. 7(b): Phi view of far field radiation pattern.

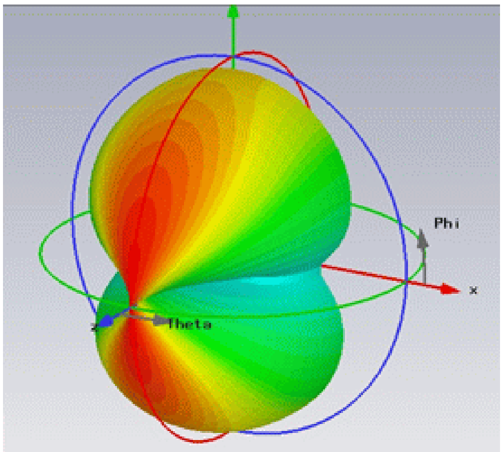

Fig. 7(c): Theta view of far field radiation pattern.

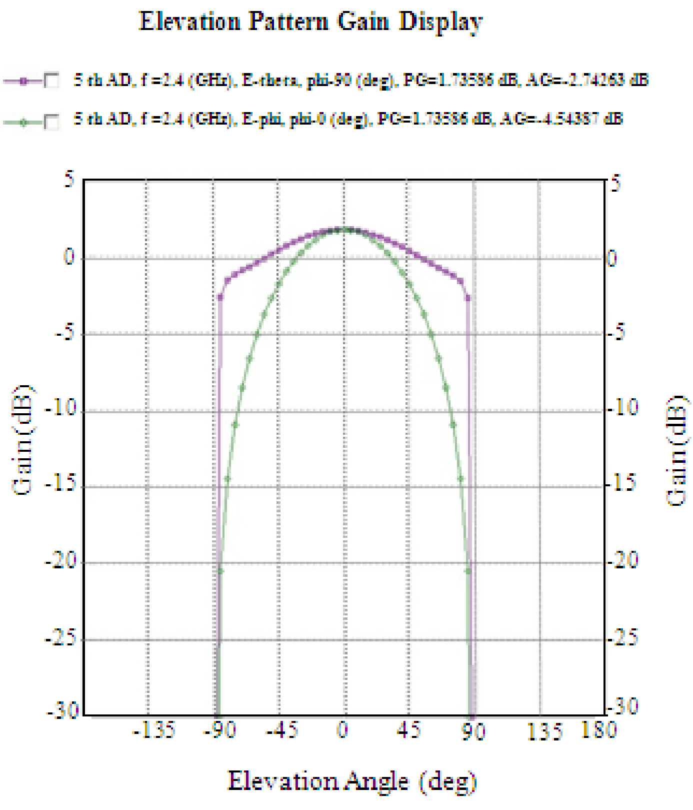

Fig. 7(d): 2D view of far field radiation pattern.

V. SAR Reduction with Handset Antenna:

Before starting on the reduction of the specific absorption rate level of antenna, it is necessary to determine and verify the three methods effectiveness or influence in SAR reduction. As mentioned earlier, the size of antenna has influence on the reduction of SAR value, so the size of antenna was varied to analyze the size effect. The main dimensions are the thickness, width and length. In this case, the thickness of the antenna was adjusted according to the SAR reductions effectiveness and also according to the dimension of the cellular phone model, so that antenna fit on the phone case. The substrate has many influences in designing an efficient antenna. The thicker substrate is mechanically strong, increase the radiated power, reduce conductor loss and improve impedance bandwidth. The disadvantages of thicker substrate are increase dielectric loss, increase weight, increase surface wave loss and extraneous radiations from the probe feed which will increase the SAR level. The width and length of the antenna was maintained at constant value and varied the thickness value to identify the effectiveness of thickness on SAR reduction. The width and length value is smaller than the calculated value to make it fit into the phone case and to improve the performance of antenna.

In fig. 8 shows that that, SAR value is increases as the thickness of the substrate increases. Only at thickness of the 1.5 mm, the antenna is below the specific absorption rate and following the SAR standard. At the thickness of 2.0 mm, the SAR value for 10 gm is satisfying but the 1gm of SAR value is exceeds the SAR limit. Substrate which has thickness greater than 2mm are exceeds the SAR limit for both 1 gm and 10 gm of SAR. Position antenna has influence in reducing the specific absorption rate. This fact also needs to analyze before designing a low specific antenna for wireless local area networks. To analyze this factor, initially a standard size phone case was created to place antenna at different places. The phone case with length 100mm, width is 40mm and the height of 18mm phone case is created. The position of the antenna has influence in SAR reduction. Antenna which is close to the head has higher SAR value compared to the antenna far away from head which is placed at backside of phone case and at the bottom of the phone case. After analyzed parameters that has influence in reduction of specific absorption rate of antenna, now by using those methods the antenna was designed to get low specific absorption rate value. The antenna was designed by using Roger 4003 loss free substrate and with appropriate size especially by reducing the thickness of substrate. So in the following the numerical results and discussions are limited to category 2. Since the antenna is an EM absorptive one, the attaching positions and size of antenna may be an important factor for the reduction of EM absorption is shown in Table-2. Finally the antenna simulated at 2.4GHz frequency by selecting E-field, H-field, power flow, current density, power loss density (SAR), electric energy density, magnetic energy density and far field. After the simulation completed, the SAR value was calculated for both 1gm and 10gm of tissue sample. By using these methods, the SAR value for the antenna which is operating at 2.4GHz was successfully reduced. Figs. 9(a) and 9(b) shows the simulated SAR distribution for the case of handset antenna designed.

As a result, substrate, size and position of the antenna have influence in reducing specific absorption rate of an antenna. Even though, all three methods decreasing the SAR level but substrate thickness is the most influential factor in reducing specific absorption rate of antenna. When the thickness of the substrate increase, there is drastic increase in SAR value too compare to the placement of the antenna inside the phone case. Although, the antenna placed far away from head inside phone case, the SAR values just decrease in small value. When the thickness of the substrate increase, it will emit extraneous radiation from probe feed which increase the specific absorption rate. Substrate thickness is directly proportional to the specific absorption rate.

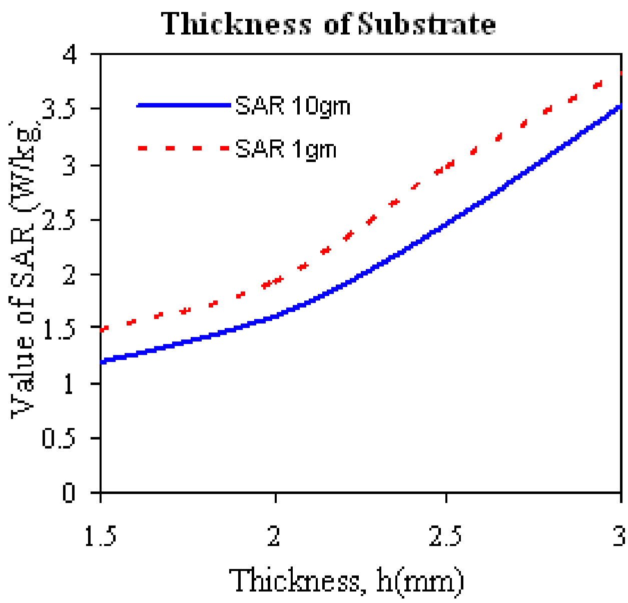

Fig. 8: SAR value compared with thickness of substrate.

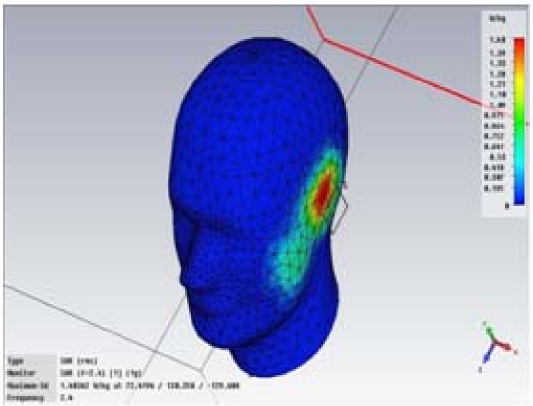

Fig. 9(a): SAR distributions for 1gm sample in head tissue.

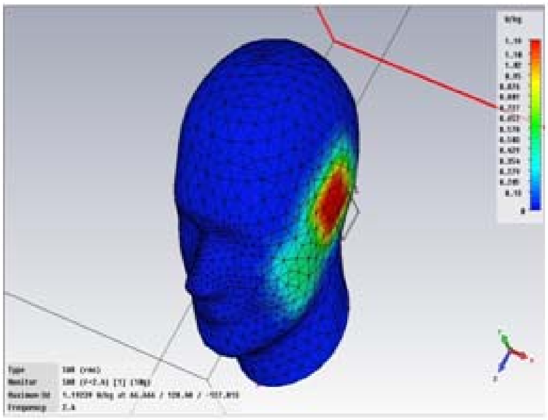

Fig. 9(b): SAR distributions for 10gm sample in head tissue.

Table 2: Effects of attaching locations of antenna on SAR reduction at 2.4 Ghz

	Category 1	Category 2	Category 3
SAR 1 gm (W/kg)	2.058	1.483	1.608
SAR 10 gm (W/kg)	1.708	1.192	1.299

Conclusion:

The low specific absorption rate antenna successfully designed by using proper methods. The factors that influence the specific absorption rate were analyzed and by considering those factors, the SAR level of the antenna was reduced. The designed antenna also operating at 2.4GHz frequency and has an Omni directional radiation pattern. In addition, this antenna is suitable for wireless local area networks applications. As a result, by implementing these simple and easy methods, the specific absorption rate of an antenna can be reduced and it is possibly could be implementing to the mobile devices in the market. This methods obviously will fulfill the requirements of the public and organization who are wants to reduce the electromagnetic radiation effects as minimum as possible and to avoid from disease such as brain cancer, insomnia and migraine. Numerical results can provide useful information in designing safety mobile communication equipment compliance.

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