Low SAR Antenna Design for Modern Wireless Mobile Terminals

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Abstract — The interaction between antenna and human body is claimed to introduce bad effect to human health, such as reduction in human cognitive function, brain tumor, and alteration of human DNA. This interaction also affects the antenna performances. The reduction of radiation efficiency and resonant frequency, and the increased bandwidth are the effects of the human body to the antenna. The antenna radiation to the human body can be expressed in terms of Specific Absorption Rate (SAR). In order to reduce SAR, vertical sidewalls are attached to the dual-band 900/1800 MHz mobile terminal antenna to increase antenna gain and reduce the radiation to human body. An additional layer is inserted between the patch and the chassis to reduce the current flowing on the chassis, which significantly contributes to the SAR. The simulated results show that the modification can decrease the SAR up to 60 % at 900 MHz and 40 % at 1800 MHz.

A. Introduction

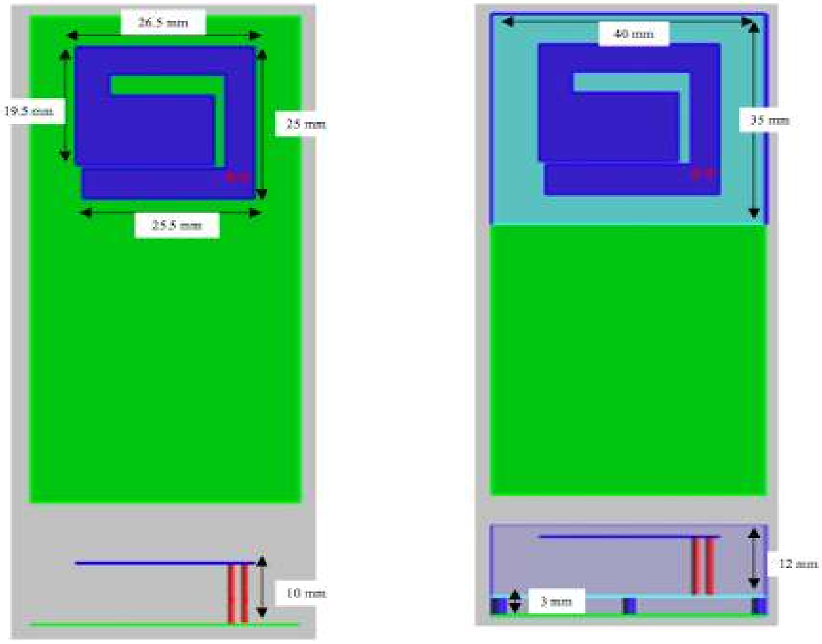
In modern environment, human body is constantly exposed by EM sources, such as power lines, electronic devices, and antenna. The effect of electromagnetic (EM) exposure to human body has been a hot issue in the past decade. Although it is still debatable, hazardous exposure from EM sources, like power lines, electronic devices, and antenna, is claimed to be able to reduce human cognitive function, cause brain tumor, and alter human DNA (Lin, 2003) and (Inskip, 2001). Despite of the health effects, the human body is proven to affect the antenna performances. The human body reduces radiation efficiency and resonant frequency, and increases antenna bandwidth (Diallo, 2007), (Nishikido, 2003), (Thiry, 1995) and (Sararaeh, 2004). In some cases, the human body also affects other parameters, such as antenna gain, return loss, radiation pattern, and input impedance (Thiry, 1995), (Eratuuli, 1998), (Cal, 2005), (Morishita, 2000), (Wei, 2005) and (Lazzi, 1998).

Many researches have been performed in order to reduce the antenna radiation towards human body. It is found that the antenna position is an important parameter to reduce the SAR value. The minimum SAR can be achieved by mounting the antenna on the back side of the mobile terminal or profiling the handset (Amos, 1999). Planar Inverted F-Antenna (PIFA) has attracted many researchers to reduce SAR due to low profile, simple structure, reasonable antenna performance, and half-space radiation characteristics (Lazzi, 1998) and (Park, 2003). There are a lot of modifications performed to the PIFA to reduce radiation towards human body. The arm width, patch shape, and the feed and shorting pin position can be modified and optimized to maximize the SAR reduction. Some structures can also be attached to reduce the SAR. In 2006, Chan, et al tried to investigate the effect of sidewall attachment of internal patch antenna ground plane on SAR (Chan, 2006). It is found that the sidewall attachment not only greatly reduces the SAR, but also significantly reduces the radiation efficiency. The current flowing on the chassis has dipole-like current distribution. Therefore, the chassis can also be considered as resonating element, which contributes to SAR value in the human body.

In this paper, the mobile terminal antenna is designed in order to reduce antenna radiation towards human body. The vertical sidewalls are attached to barricade the radiation to human body. It can also increase the gain and direct the radiation in the opposite direction from the human body. The contribution of the chassis is reduced by decreasing the current flowing on the chassis. An additional layer is inserted between the patch and the chassis to reduce the current flowing on the chassis.

B. Antenna Structure

The geometry of the original PIFA is shown in Fig. 1a. The PIFA is designed to operate at 0.9 GHz and 1.8 GHz. A dual band patch is placed 10 mm above chassis. The total dimension of the patch is 25 x 26.5 mm and the dimension of the chassis is 40 x 80 mm. The patch and the chassis are made from copper. Coaxial probe is used to feed the antenna. Fig. 1b shows the geometry of the modified PIFA. An additional layer is inserted between the patch and the ground plane. This layer behaves as new ground plane of the PIFA. The gap between this layer and the chassis is 3 mm. Three vertical sidewalls are also attached at top, left, and right side of the ground plane. The height of the sidewalls is 15 mm. The sidewalls are also made from copper.



(a) (b)

Fig. 1. Antenna Structure
(a) Original PIFA
(b) Modified PIFA

C. Health Effect of Radio Frequency Radiation

For temperature elevation below 0.1 °C RF radiation could be considered physiologically and biologically insignificant. Exposure limits are given in terms of the specific absorption rate (SAR) to limit temperature increase in the human tissues. SAR defines the absorbed dose rate and it is thus the time derivative of the incremental energy absorbed by or dissipated in an incremental mass, which given as:

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dv}\right) \quad (1)$$

Where m is the mass, V is the volume and ρ is the density.

One way of determining the SAR is by measuring the electric field (E) inside the tissue-simulating material. SAR will be given in terms of conductivity σ and density ρ as

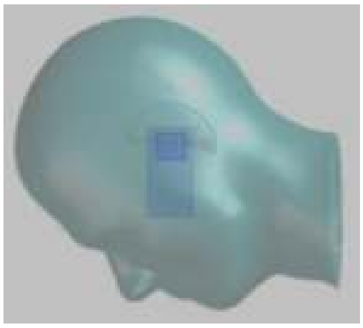
$$SAR = \frac{\sigma |E|^2}{\rho} \quad (2)$$

D. Simulation Results and Discussion

The antenna is simulated using SEMCAD simulation tools. This software uses the Finite-Difference Time-Domain (FDTD) method and is specialized in SAR computation. Simulation is performed of the antenna in free space as well as close to Specific Anthropomorphic Mannequin (SAM) model of the human head. A model is built as shown in Fig. 2, of the antenna next to the left ear on SAM model. SEMCAD is chosen due to its SAR simulation features. The features provide the head model and enable the user to get accurate SAR values. The shape of the head model is similar with real human head shape. The head model consists of homogenous dielectric representing the human tissue with relative permittivity ε_r = 41.5 and electric conductivity 0.97 S/m.

The antenna is positioned in cheek mode as shown in Fig. 2. It means that the antenna touches the ear and cheek.

(a)



(b)

Fig. 2. PIFA and SAM Position
(a) Front view
(b) Side view

The simulated return loss of the original PIFA is shown in Fig. 3. The resonant frequencies of the original PIFA without human head model at the first and second bands are 977 MHz and 1874 MHz, respectively. The bandwidths of this PIFA at the first and second bands are 26.25 MHz and 105 MHz, respectively. As expected, the resonant frequencies of the original PIFA are decreased to 964 MHz for the first band and to 1843 MHz for the second band. The antenna bandwidths are increased to 32 MHz for the first band and to 121 MHz for the second band.

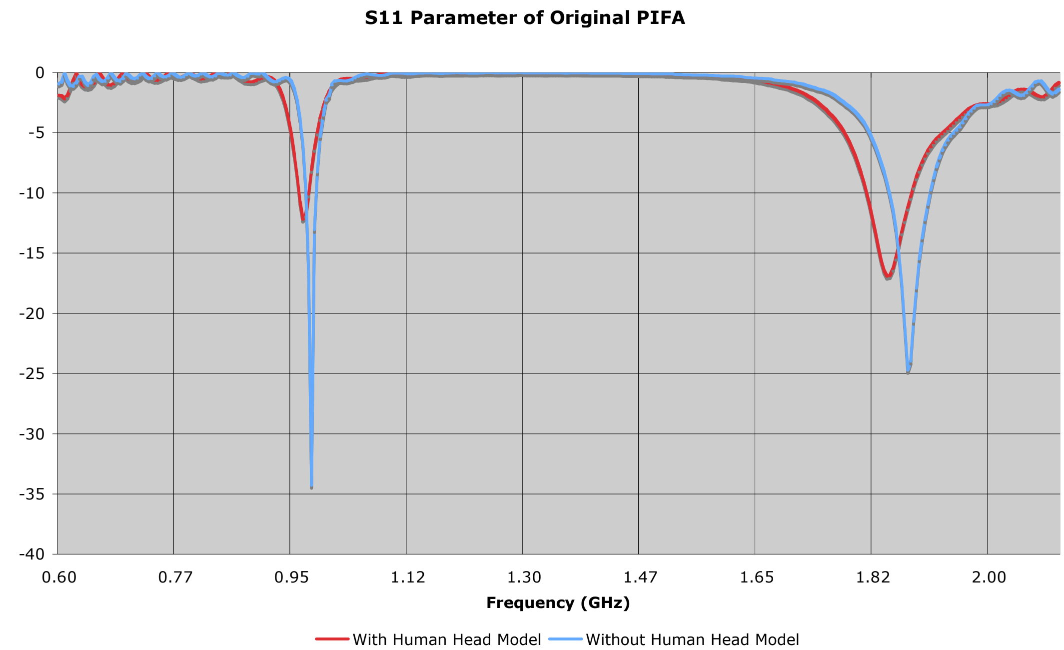


Fig. 3. Simulated Return Loss of Original PIFA

The return loss of the proposed modified PIFA structure in Fig. 1b is shown in Fig. 4. The resonant frequencies without human head model for the first and second bands are 951 MHz and 1795 MHz, respectively. The antenna bandwidths and return loss magnitudes are greatly decreased. The resonant frequencies as well as the bandwidth at the first and second bands of the modified PIFA with and without the human head model are almost unchanged. This means that the effect of the human head on the antenna performances is not significant. This means also that little power is directed toward the human head and so low power will be absorbed in the head.

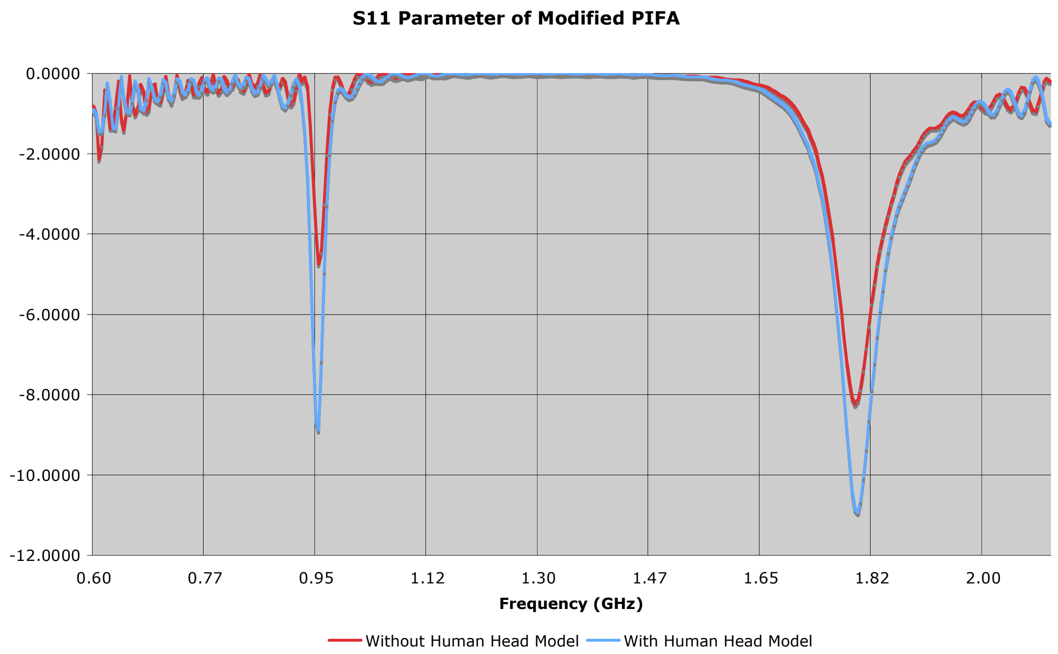


Fig. 4. Simulated Return Loss of Modified PIFA

Table 1. Simulation Results

	Original PIFA		Modified PIFA	
	0.9 GHz	1.8 GHz	0.9 GHz	1.8 GHz
Gain	-1.73 dBi	0.64 dBi	-0.7 dBi	1.24 dBi
Radiation Efficiency	37.03 %	59.1 %	49.19 %	59.25 %
Max Avg SAR (10 gr)	5.25 W/kg	2.75 W/kg	2 W/kg	1.68 W/kg
Max Avg SAR (1 gr)	7.63 W/kg	3.77 W/kg	2.86 W/kg	2.25 W/kg

Delivered Power = 1 W

Table 1 shows the simulated gain, radiation efficiency, and maximum averaged SAR. The gains and radiation efficiencies of the modified PIFA are increased. The increased gains direct the radiation in the opposite direction of the human head. Since the radiation is directed to the opposite direction of the human head, the absorbed radiated power is decreased and causing increased radiation efficiencies. The increased gains also lead to decreased SAR. At 900 MHz, the maximum averaged 10 gr and 1 gr SAR are decreased by 61.9 % and 62.5 %. While for 1800 MHz band, the maximum averaged 10 gr and 1 gr SAR are decreased by 38.9 % and 40.3 %, respectively. The great reduction of SAR is also associated with significant reduction of current flowing on the chassis as shown in Fig. 5. The reduced current flowing on the chassis greatly decreases the contribution of the chassis to the SAR in the human head. Therefore, the modified PIFA has a very low SAR values compared to the original PIFA.

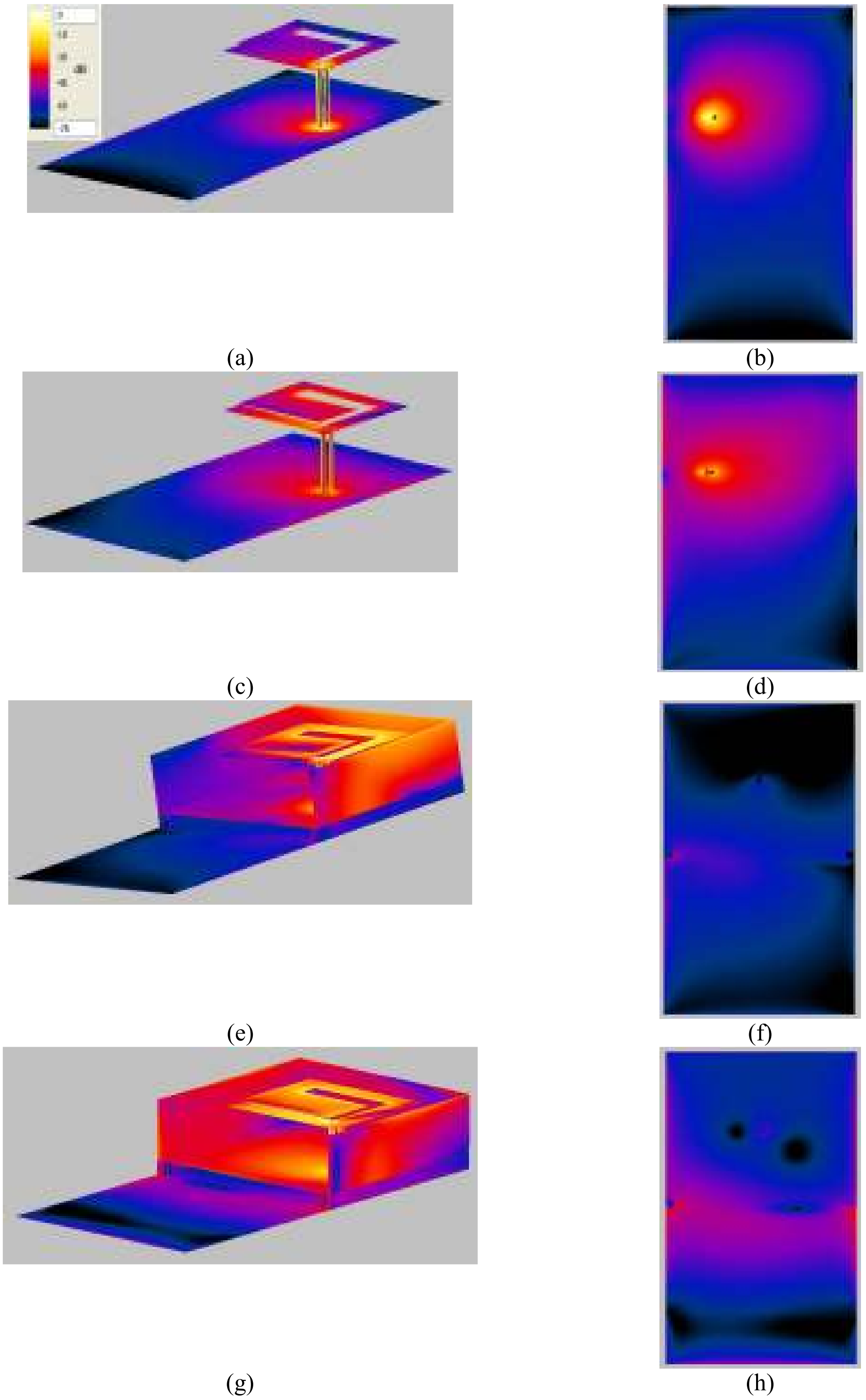


Fig. 5. Current Distribution
(a) Front Side of Original PIFA at 900 MHz
(b) Back Side of Original PIFA at 900 MHz
(c) Front Side of Original PIFA at 1800 MHz
(d) Back Side of Original PIFA at 1800 MHz
(e) Front Side of Modified PIFA at 900 MHz
(f) Back Side of Modified PIFA at 900 MHz
(g) Front Side of Modified PIFA at 1800 MHz
(h) Back Side of Modified PIFA at 1800 MHz

E. Conclusion and Future Works

A low SAR mobile terminal antenna is designed and implemented. Three vertical sidewalls are attached to the antenna to increase the gain and reduce the radiation towards human head. An additional layer is also inserted between the patch and the chassis to reduce the current flowing on the chassis. The reduced current flowing on the chassis decreases the radiation toward the human head and so reduces the SAR value. The simulated results show that the proposed structure decreases the SAR by about 60 % at 900 MHz and 40 % at 1800 MHz. More effort is still needed in order to overcome some disadvantages such as the insufficient matching and bandwidth.

Acknowledgment

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