Reducing the SAR Values of Mobile Terminal Antennas

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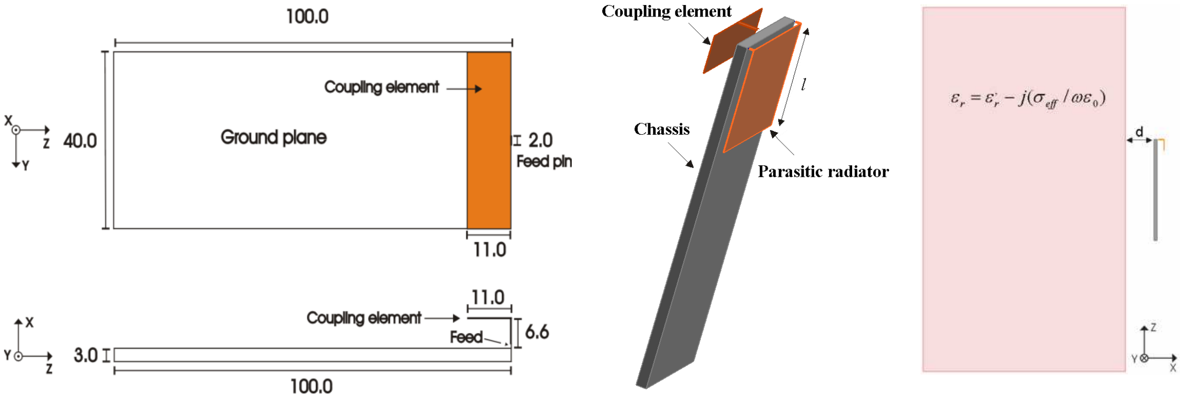
1. Introduction

Wireless communications has become an indispensable part in people's everyday life during the past decades. Examples of the most widely spread wireless applications are mobile phones, wireless internet access, and different Bluetooth devices. As a consequence, the hugely increased amount of electromagnetic radiation everywhere in the environment has increased the concern with possible health risks of wireless devices. In particular, the potential health hazards of mobile phones on human brain have been widely studied. Since a mobile phone is always in a close proximity of the user in a normal talk position, part of the energy radiated by its antenna is unavoidably absorbed by the user. It would be very beneficial if the amount the energy that is absorbed by the user could be reduced, since that would not only reduce any potential health risks but also enhance the total efficiency of the devices; this would improve network coverage and extend battery lifetime.

In this paper, we investigate the possibility of reducing the specific absorption rate (SAR) values of a mobile phone antenna by manipulating the dimensions of the display of the phone. The display is modeled by a conducting plate attached to the back side of a coupling element based antenna structure [1]. In addition to the SAR values, the effects of the display on the radiation efficiency and bandwidth potential of the antenna are studied. The results of this paper show that by optimizing the display dimensions the near fields of the antenna can be manipulated, and as a result, the SAR value of the used antenna structure in the user's head is reduced by up to 46 % at the GSM900 band. At the same time, a 16 %-unit increase in radiation efficiency is obtained.

2. Simulation Models

The used antenna model is a basic coupling element based antenna [1]. The dimensions of the ground plane, or the chassis, of the antenna are 40 mm × 100 mm; the coupling element is 11 mm long and located 6.6 mm above the chassis, see Figure 1(a). The display is modelled as a parasitic radiator attached to the chassis from two upper corners, as shown in Figure 1(b). A similar method was used in [2]. The user is first modelled by a simple rectangular block model having the dimensions of 200 mm × 320 mm × 360 mm; see Figure 1(c). The block is filled with material having the electrical parameters, i.e. the complex permittivity $\varepsilon_r = \varepsilon_r' - j(\sigma_{eff}/\omega\varepsilon_0)$, equivalent to those of the brain tissue; at 900 MHz, the parameter values are ε_r' = 45.8 and σ_{eff} = 0.77 S/m [3]. The user was modelled by as simple model as possible to ease the understanding on the physical phenomena. However, finally, the simulations are done also with an analytical head model. In all cases, the maximum cell size inside the simulation models was 1 mm. In addition, the SAR values are averaged over 10 g maximum with a normalized antenna input power of 1 W. One should note that in GSM900 and GSM1800 systems the maximum powers are 0.25 W and 0.125 W, respectively. All simulations were carried by commercial SEMCAD X simulation software.



(a) (b) (c)

Figure 1: Simulation models. (a) The used antenna model is a simple coupling element based antenna. (b) The display of the antenna is modelled by a parasitic radiator attached to the chassis of the antenna from two upper corners. (c) The user is modelled by a rectangular block model filled with material having the same dielectric properties than brain tissue.

3. Simulations with a block model

3.1 SAR

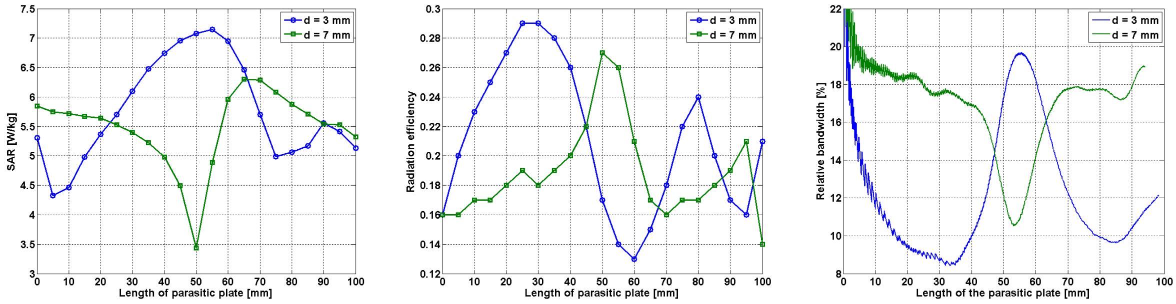
The simulations were done by placing the antenna at two different distances from the dielectric block, i.e. d = 3 mm and d = 7 mm. One should note here, that the respective distances between the parasitic plate and the dielectric block are 1 mm and 5 mm, since the distance between the chassis and the plate is 2 mm. Figure 2(a) shows the SAR value of the antenna as the function of the length of the display. With d = 7 mm, SAR decreases from about 5.9 W/kg to about 3.4 W/kg when the length of display changes from 0 mm to 50 mm. The reduction in SAR is thus approximately 42 % compared to the reference case (l = 0 mm, i.e. antenna without the display). With display lengths larger than 50 mm, SAR increases rapidly, being even higher than the original one already with a 60 mm display. With d = 3 mm, the behaviour in SAR is quite different when compared to the case when d = 7 mm. First of all, with display lengths 0...20 mm, SAR is somewhat lower with d = 3 mm; in addition, SAR reaches maximum approximately with the same display length where SAR had a minimum with d = 7 mm.

3.2 Radiation efficiency

By comparing Figures 2(a) and (b), it can be seen that radiation efficiency and SAR are closely related: whenever SAR decreases, the efficiency increases and vice versa. For instance, with d = 7 mm, the radiation efficiency increases from 16 % to 27 % when the display is lengthened from 0 mm to 50 mm. As somewhat interesting result it can also be seen that in many cases the efficiency is actually higher with d = 3 mm than with d = 7 mm.

3.3 Bandwidth potential

Figure 2(c) shows the achievable bandwidth in [%] relative to the 900 MHz center frequency. The curves were obtained by first matching the impedance of the antenna (critical coupling) at a point frequency with two lumped elements and then calculating the relative bandwidth according to - 6 dB matching criterion. This procedure was repeated separately for each display length. It should be noted that in this way we apply a single resonant matching and that larger bandwidths could be easily obtained by utilizing multiple resonances. However, this way we can see the trends in the behavior of the achievable bandwidth in a simple manner. Figure 2(c) shows that whenever the SAR decreases, and the efficiency increases, the bandwidth potential decreases.

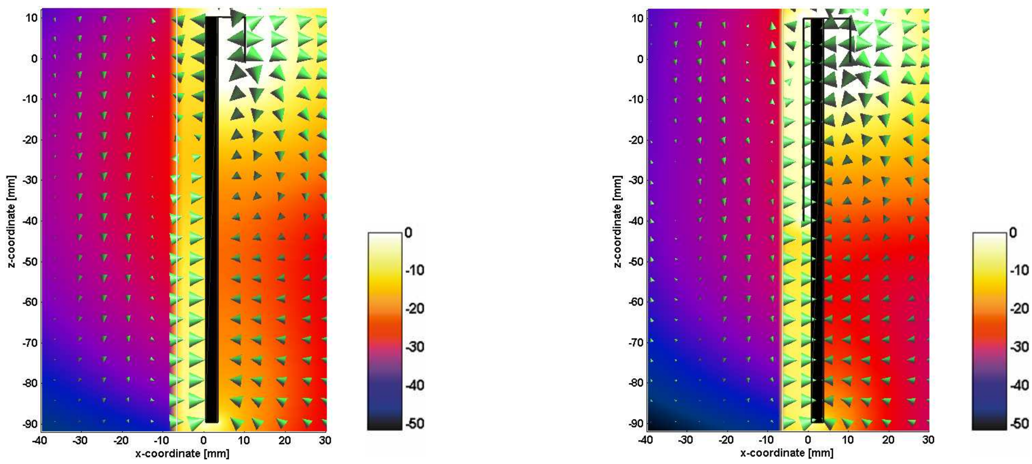


(a) (b) (c)

Figure 2: (a) SAR, (b) radiation efficiency, and (c) bandwidth potential of the antenna with different lengths of the display.

3.4 Near field distributions

The results shown so far indicate that the SAR and efficiency of a coupling element based antenna can indeed be controlled by optimizing the dimensions of the display. However, the behaviour seems to be quite sensitive at least to the distance between the antenna and the dielectric material. In order to better understand what causes the decrease in the SAR values, the electric field is plotted in Figure 3 without the display and with a 50 mm long display in the case where the distance between the antenna and the dielectric block was 7 mm. As shown above, the SAR value decreased by approximately 42 % when the display was attached to the antenna compared to the antenna without the display. Looking at the electric fields in Figures 3(a) and (b) it can be seen that when the plate is added to the antenna (Figure 3(b)), the electric field is much stronger than when there is no display attached to the antenna (Figure 3(a)). However, we know from Maxwell's equation that at a dielectric boundary, the field components normal to the surface can be written as $\varepsilon_1 \vec{E}_{1,\mathrm{n}} = \varepsilon_2 \vec{E}_{2,\mathrm{n}}$ and the components tangential to the surface as $\vec{E}_{1,\mathrm{t}} = \vec{E}_{2,\mathrm{t}}$. Since the strong electric field between the antenna with the 50 mm long display and the dielectric block comprises mainly field components that are normal to the surface of the dielectric material, the field cannot penetrate to dielectric material; see Figure 3(b). In the case when there is no display added to the antenna, field components parallel to the surface of the dielectric block exist around z = -20 mm, which causes also the SAR values to be higher; see Figure 3(a).



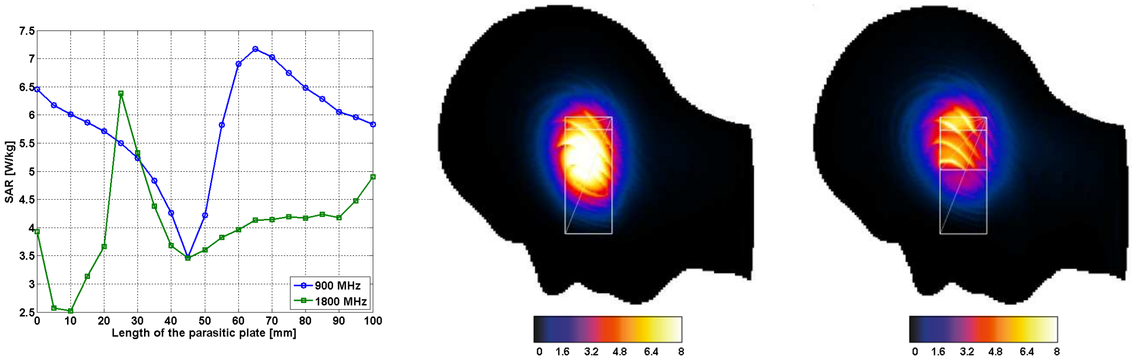
(a) (b)

Figure 3: The electric near field in the proximity of the antenna. In this case, the distance between the chassis of the antenna and the dielectric block was 7 mm. (a) Antenna without the display attached to the chassis and (b) antenna with a 50 mm display.

4. Simulations with an anatomical head model

In order to see how the introduced method works in a more realistic situation, the method was finally tested by replacing the block model with an anatomical head model. In the simulations with the head model, the distance between the head and the chassis of the antenna was fixed to $d = 3$ mm. It should be noted that the distances that were used in the previous section in the case of the block model ($d = 3$ mm and $d = 7$ mm) are not straightforwardly comparable with the distance that is used with the head model. At first, the surface of the head is not completely flat, which means that the distance between the head and the antenna changes slightly depending on the location. In addition, in the block model the high-permittivity brain tissue starts immediately at the surface, while in the head model the brain tissue starts after a few millimeter-thick low-permittivity shell.

Figure 4(a) shows the SAR values at different display lengths simulated at both GSM900 and GSM1800 bands. The SAR curve at 900 MHz closely resembles the behavior with the block model with $d = 7$ mm. At this time, the minimum SAR was achieved with a 45 mm long display, and the reduction was from about 6.5 W/kg to 3.5 W/kg, i.e. approximately 46 %. Simultaneously, radiation efficiency increased from 23 % to approximately 39 %, i.e. 16 %-units. Figures 4(b) and (c) show the SAR distribution on the surface of the brain tissue without the display and with a 45 mm long display. The reduction in SAR values can be clearly observed.



(a) (b) (c)

Figure 4: SAR simulated in the head model with different display lengths. (a) SAR values at 900 MHz and 1800 MHz. (b) SAR distribution without the display and (c) with a 45 mm long display.

5. Conclusion

In this paper, we have studied the possibility of reducing the SAR values of mobile terminal antenna by optimizing the dimensions of the display of the phone. The results show that by changing the length of the display, the near field of the antenna can be manipulated; as a result, the SAR value of a coupling element based antenna was reduced by 46 % at GSM900 band in the best case. Simultaneously, the radiation efficiency was increased by 16 %-units.

References

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