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Effects of User's Hands on the Broadband Planar DTV Antenna in a Portable Media Player

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1. Introduction

Recently, a broadband planar shorted monopole antenna for DTV signal reception in the portable media player (PMP) has been studied [1]. The planar DTV antenna is protruded from the PMP casing in the operation condition and can be firmly attached onto the surface of the PMP casing when not in use. The broadband operation of the planar DTV antenna is achieved by using an internal matching circuit comprising mainly a chip capacitor [2]. The operating bandwidth of the planar DTV antenna can reach 340 MHz (about 53% centered at about 638 MHz) based on the 2.5:1 VSWR definition, making it very suitable for DTV signal reception in the 470 ~ 806 MHz band.

For practical applications, however, the user's hands are usually in direct contact with the PMP. This makes it necessary to include the user's hands in the study of the antenna performances, since it has been concluded that the user's hands function as a lossy medium and will affect the antenna performances significantly [3, 4]. For this consideration, we present in this paper the study of the planar DTV antenna in the PMP with the presence of the user's hands. Three different conditions of the right hand only, left hand only, and both hands of the user holding the PMP are studied. Effects of the three different user's hand conditions on the impedance and radiation characteristics of the planar DTV antenna in the PMP will be studied with the aid of the one-layer equivalent simulation hand model [4] incorporating the use of three-dimensional FDTD (Finite-Difference Time-Domain) simulation software, SPEAG SEMCAD (Simulation platform for EMC, Antenna design, and Dosimetry) [5]. Measured results on the impedance characteristics of the studied planar DTV antenna will also be presented to verify the simulation results.

2. Studied Planar Antenna with Proposed Simulation Hand Model

Fig. 1 shows the configuration of the simulation model of the studied DTV antenna in the PMP held by one-layer equivalent user's hand model (both-hands condition) and the experimental photo. The studied DTV antenna is a planar shorted monopole antenna mainly fabricated using a 0.2-mm thick brass plate and has a width of 17 mm and a length of 85 mm. Through an inverted-L shorting strip, the planar monopole antenna is integrated to the PMP ground plane of size 80×120 mm^2. In addition, with a simple internal matching circuit consisting of a 2.2-pF chip capacitor and two narrow strips, the planar shorted monopole antenna can achieve a wide operating bandwidth covering the DTV band of 470 ~ 806 MHz. Also note that in this study, in order to avoid the direct contact of the user's hands on the studied antenna and the PMP ground plane in the experiment, the studied antenna is covered by a 1-mm thick plastic casing of relative permittivity $\varepsilon_r = 3.5$ and conductivity $\sigma = 0.02$ S/m for protection. The outer thickness of the PMP casing is selected to be 27 mm in the study, which is a reasonable thickness for general PMP devices. With comparison to the condition without the plastic casing [1], the length of the antenna is reduced by 5 mm because of the substrate effect of the plastic casing. Fig. 2 shows the measured input impedance traces of the studied antenna with and without the chip capacitor in the condition of without the plastic casing and the user's hands in the frequency range of 300 ~ 1000 MHz in the Smith Chart. It is clearly seen that the impedance matching of the studied antenna is greatly enhanced over the DTV band, when the chip capacitor is added in the internal matching circuit.

For the one-layer simulation hand model, it is treated as a lossy medium represented by a relative permittivity of $\varepsilon_r = 33.5$ and a conductivity of $\sigma = 0.47$ S/m [6]. The conductivity will lead to a decrease in the antenna's radiation efficiency, while the permittivity can cause a large effect on the antenna's impedance characteristics. The corresponding values of the parameters ε_r and σ at different frequencies for different tissues such as skin, muscle, and bones are available in the open literature [6].

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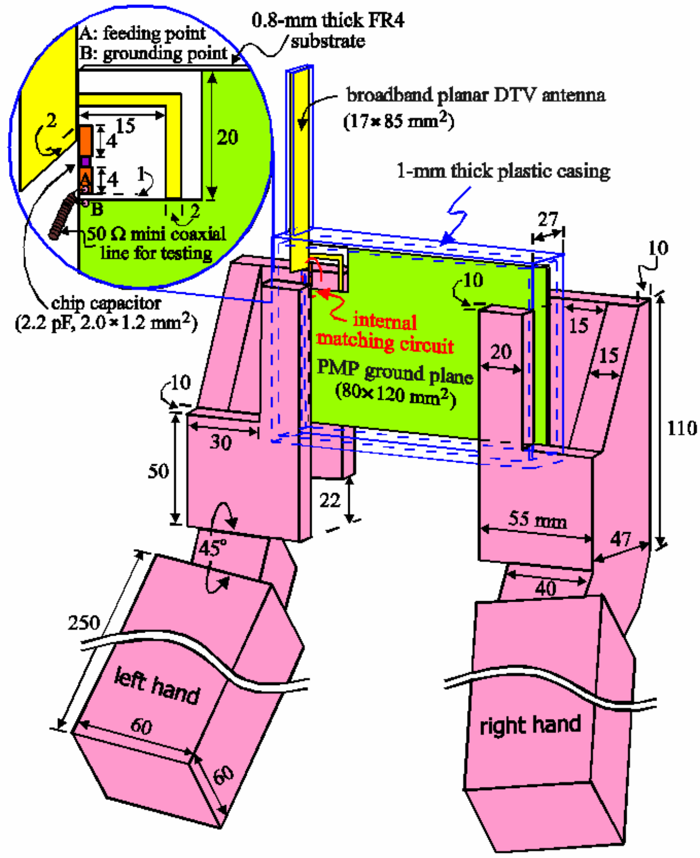
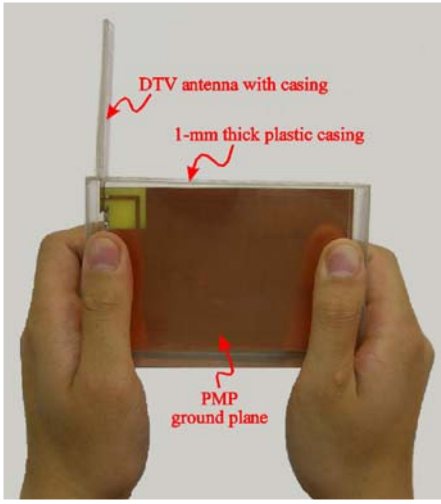
Owing to the bones occupying most volume of the user's hand, the equivalent parameters of the one-layer simulation hand model including the forearm arm in this study are selected to be close to those of the bones. With comparison to the multilayer simulation hand model [3], the use of the one-layer equivalent hand model can greatly reduce the simulation time [4]. This makes it possible for obtaining an efficient and reliable simulation study for the mobile antenna with the presence of the user's hand.





	ε_r	σ(S/m)
Casing	3.5	0.02
Hand Model	33.5	0.47

Figure 1: Simulation model and photo of the studied DTV antenna in the PMP held by the user's hands.

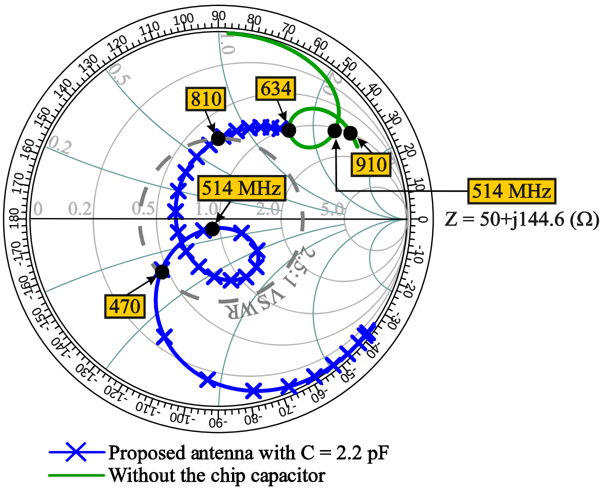


Figure 2: Measured input impedance in the Smith chart for the studied antenna with C = 2.2 pF and the case without the chip capacitor (the plastic casing and the user's hands are not present).

3. Results and Discussion

Fig. 3 shows the simulated and measured return loss of the studied DTV antenna for three different user's hand conditions of right hand only, left hand only, and both hands (the top edge of the user's hand is at the top edge of the PMP casing). It can be seen that the simulated results in general agree with the measured results. This ensures reliable simulated results obtained in this study. It is also observed that, for the condition of right hand only, the obtained impedance bandwidth (2.5:1 VSWR) is about the same as that of the case without the user's hands. This is largely because the user's right hand holding the PMP at the opposite side to the studied DTV antenna. Thus, smaller effects of the user's hand on the antenna performances can be expected. Also note that the bandwidth definition of 2.5:1 VSWR is generally acceptable for DTV signal reception in practical applications. Conversely, for the conditions of left hand only and both bands, the obtained impedance bandwidths are seen to be larger than that of the case without the user's hands. This behavior indicates that, when the user's hand is close to the studied DTV antenna, there will be large effects on the antenna performances. For the widening of the obtained bandwidth, it is largely because that the user's hand is mainly a lossy medium, which can thus lead to a lowering of the quality factor of the antenna. This in turn leads to the widening of the antenna's impedance bandwidth. However, over the bandwidth, the radiation efficiency of the antenna is expected to be decreased owing to the absorption of the radiation power by the user's hands.

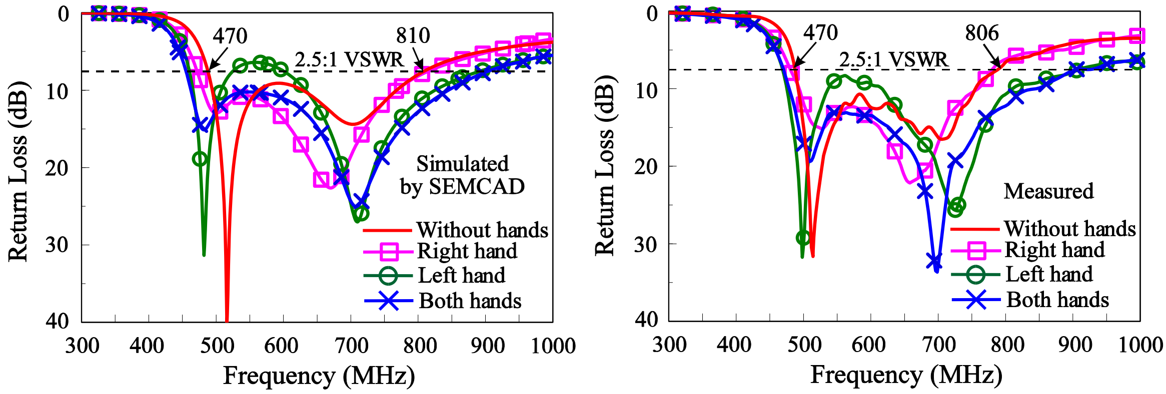


Figure 3: Simulated and measured return loss for different user's hand conditions.

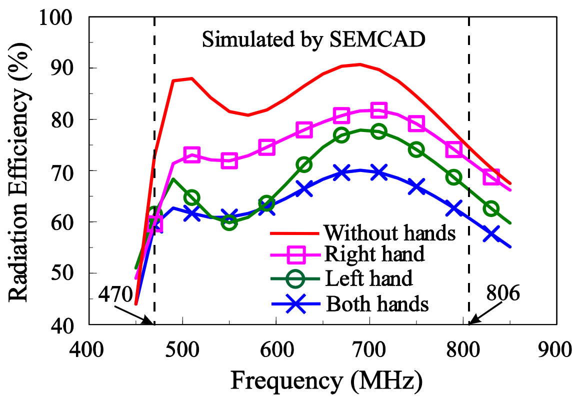


Figure 4: Simulated radiation efficiency for different user's hand conditions.

Fig. 4 shows the simulated radiation efficiency of the antenna for different user's hand conditions studied in Fig. 3. It is seen that, for the three different user's hand conditions, the radiation efficiency is all decreased, with the largest decrease (about 20%) observed for the both-hands condition. This agrees with the expectation that the user's hands are a lossy medium and will thus absorb some of the antenna's radiated power, which leads to a decrease in the antenna's radiation efficiency.

Finally, effects of the user's hands on the three-dimensional radiation patterns of the studied DTV antenna are analyzed. Fig. 5 shows the simulated radiation patterns for the three different user's hand conditions at 630 MHz, the center frequency of the desired operating band. Large variations in the obtained radiation patterns for the three different user's hand conditions are seen. This indicates that the radiation patterns are mainly affected by how the user's hands holding the PMP.

4. Conclusion

The user's hand effects on the broadband planar shorted monopole antenna for DTV signal reception in the PMP have been studied. Although the studied DTV antenna is protruded from the PMP casing, obtained results indicate that there are large user's hand effects, especially for the condition of the user's both hands holding the PMP, on the antenna performances. For the both-hands condition, large distortion in the antenna's radiation patterns has been observed, and a large decrease of about 20% in the radiation efficiency has been seen, with comparison to the condition of without the user's hands. However, obtained results also indicate that, even for the worst case the radiation efficiency of the studied antenna is still larger than 60% for frequencies over the 470 ~ 806 MHz band for DTV signal reception. This radiation efficiency level makes the studied DTV antenna very promising for practical PMP applications.

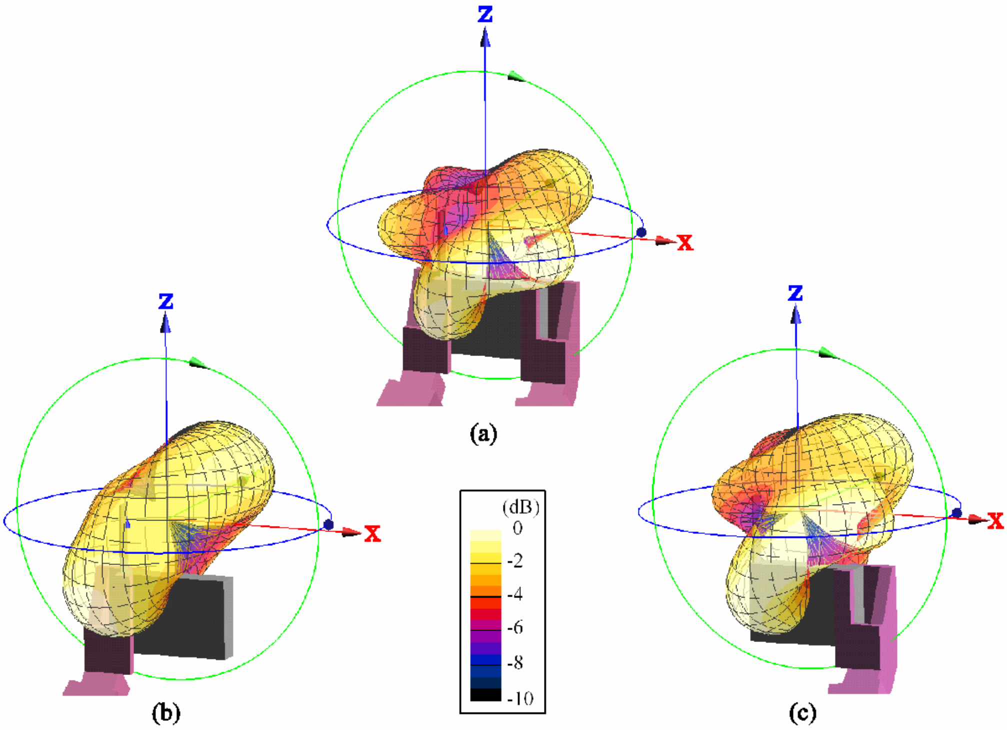


Figure 5: Simulated 3D radiation patterns for the studied DTV antenna with different user's hand conditions at 630 MHz. (a) Both hands. (b) Right hand only. (c) Left hand only.

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