BROADBAND PLANAR DTV ANTENNA IN THE PORTABLE MEDIA PLAYER HELD BY THE USER'S HANDS

Wei-Yu Li,[1] Kin-Lu Wong,[1] and Jeen-Sheen Row[2]
[1] Department of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung 804, Taiwan, Republic of China
[2] Department of Electrical Engineering, National Changhua University of Education, Changhua 500, Taiwan

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ABSTRACT: *Effects of the user's hands on the broadband planar DTV antenna in the portable media player (PMP) are studied. The antenna has a wide operating bandwidth covering the 470–806 MHz band for DTV signal reception and a one-layer equivalent simulation hand model including the user's forearm with a relative permittivity of 33.5 and a conductivity of 0.47 S/m is used for the simulation study. Three different conditions of the user's hands (right hand only, left hand only, and both hands) holding the PMP are studied, and their effects on the return loss, radiation efficiency, and radiation patterns of the studied DTV antenna are analyzed. In addition, effects of the user's hands holding the PMP at different positions relative to the studied DTV antenna are analyzed. Results have shown that, for the worst case, the radiation efficiency of the studied DTV antenna is still larger than 60% over the operating band, making the antenna very promising for practical applications.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1841–1844, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22639

Key words: *DTV antennas; planar antennas; portable media players; user's hand; user's hand including the forearm*

1. INTRODUCTION

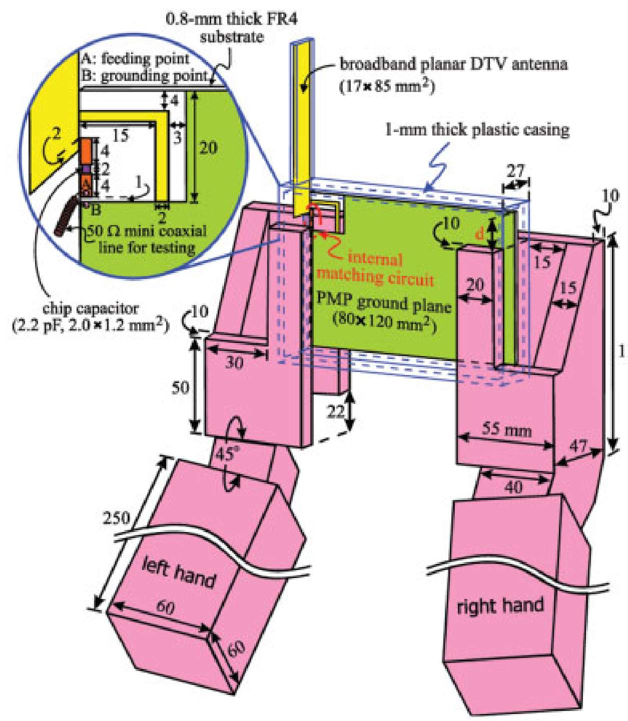
Recently, a broadband planar shorted monopole antenna for DTV signal reception in the PMP has been studied [1]. The planar DTV antenna is protruded from the PMP casing in the operation condition and can be firmly attached onto the surface of the PMP casing when not in use. The broadband operation of 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 [3-5].

However, for practical applications, 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 an effective lossy medium and will affect the antenna performances significantly [6, 7]. For this consideration, we present in this article 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 [7] incorporating the use of three-dimensional FDTD (Finite-Difference Time-Domain) simulation software, SPEAG SEMCAD (Simulation platform for EMC, Antenna design, and Dosimetry) [8]. Measured results on the impedance characteristics of the studied planar DTV antenna will also be presented to verify the simulation results.

2. SIMULATION HAND MODEL AND STUDIED PLANAR DTV ANTENNA

Figure 1 shows the configuration of the broadband planar DTV antenna in the PMP and the one-layer equivalent hand model holding the PMP in the both-hands condition. A photo of the user's hands holding the PMP with the studied DTV antenna is shown in Figure 2. The studied DTV antenna is a planar shorted monopole antenna [9] mainly fabricated using a 0.2-mm thick brass plate and has a width of 17 mm and a length of 85 mm, with 11 and 74 mm below and above the top edge of the PMP ground plane, respectively. The protruded length of 74 mm corresponds to only about 0.12 wavelength of the desired lower edge frequency at 470 MHz. 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 comprising mainly a 2.2-pF chip capacitor, the planar shorted monopole antenna can achieve a wide operating bandwidth covering the DTV band of 470–806 MHz. Detailed design considerations of the antenna have been described in [1]. Also note that in this study, the planar shorted monopole 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. In 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.

The studied DTV antenna is protruded from the left upper corner of the PMP casing. To avoid the direct contact of the user's hands on the studied antenna and the PMP ground plane in the experiment, a 1-mm thick plastic casing whose relative permittivity and conductivity are the same as those of the casing for the antenna is used as the PMP casing. Note that the outer thickness of



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

Figure 1 Configuration of the broadband planar DTV antenna in the PMP and the one-layer equivalent hand model holding the PMP (both-hands condition). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

the PMP casing is selected to be 27 mm in the study, which is a reasonable thickness for general PMP devices.

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 [10]. 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 [10]. 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 in this study are selected to be close to those of the bones. With comparison to the multilayer simulation hand model [6], the use of the one-layer equivalent hand model can greatly reduce the simulation time [7]. This makes it possible for obtaining an efficient and reliable simulation study for the mobile antenna with the presence of the user's hand.

Detailed dimensions of the one-layer simulation hand model including the forearm are shown in Figure 1. The hand model mainly consists of thumb, palm, fingers, and forearm portions [7], and their configurations are selected from simplifying the corresponding portions of the real user's hands holding the PMP. Also, the parameter *d* shown in Figures 1 and 2 indicate the distance from the user's hand to the top edge of the PMP ground plane. It is expected that the impedance and radiation characteristics of the antenna are strongly dependent on the distance *d,* and the results as a function of *d* will thus be analyzed in the study. For conducting the experiment, a 50-Ω mini coaxial line is used for testing the studied DTV antenna. The central conductor of the coaxial line is connected to the internal matching circuit of the antenna at point A (the feeding point), and the outer grounding sheath of the coaxial line is connected to the PMP ground plane.

3. RESULTS AND DISCUSSION

Figure 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. In this case, results for the distance $d = 0$ (i.e., the top edge of the user's hands is at the top edge of the PMP ground plane) are shown. It is first seen that the simulated results in Figure 3(a) in general agree with the measured data in Figure 3(b). 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 satisfactory for DTV signal reception in practical applications. Actually, it is also acceptable for the operating frequencies with 3:1 VSWR impedance matching.

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

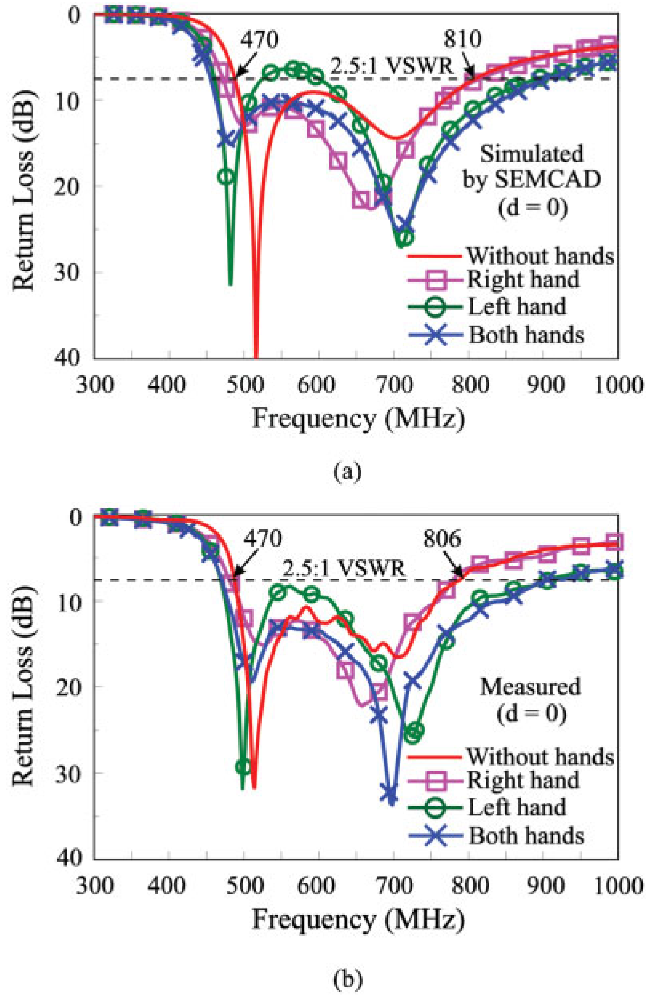


Figure 3 (a) Simulated and (b) measured return loss of the studied DTV antenna for three different user's hand conditions: right hand only, left hand only, and both hands; $d = 0$. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

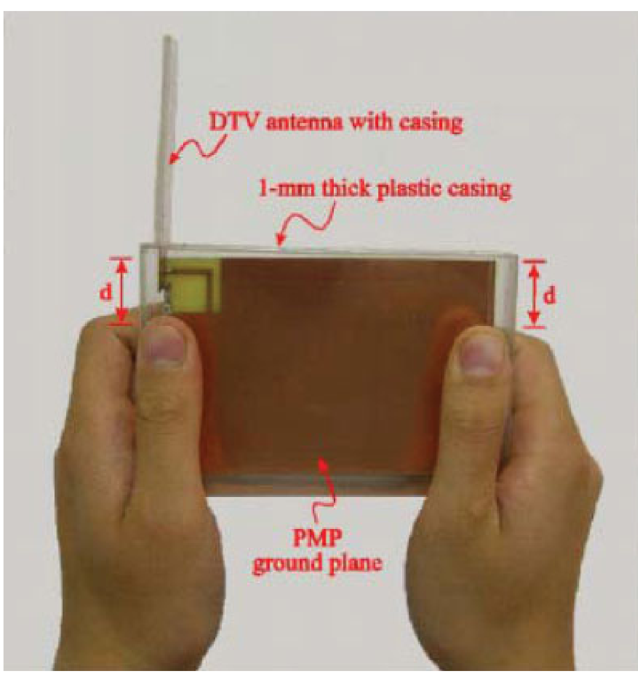


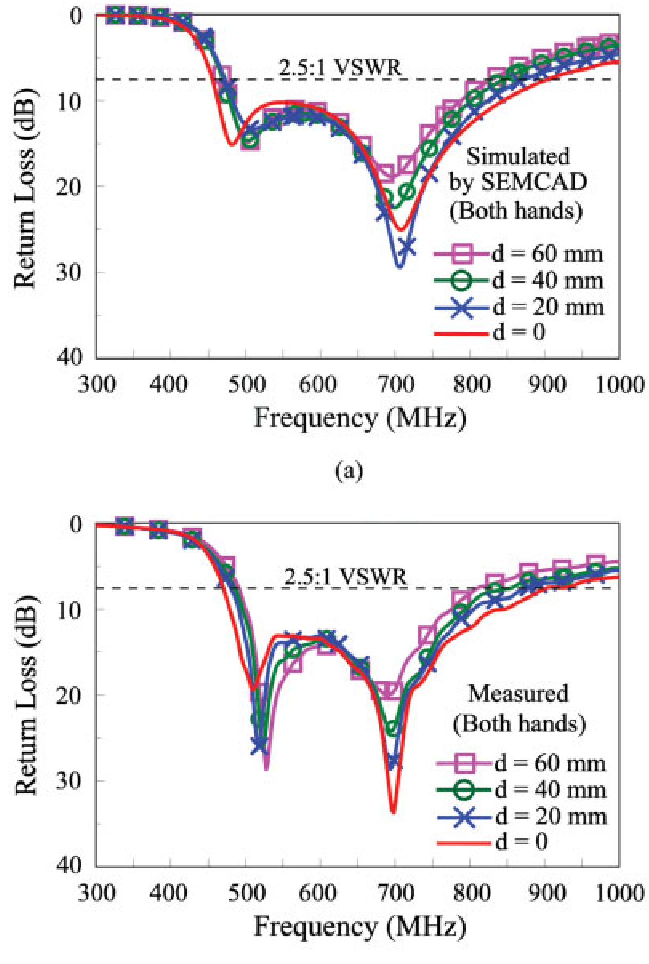
Figure 2 Photo of the user's hands holding the PMP with the studied DTV antenna in the experiment. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

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 4 shows the simulated radiation efficiency of the antenna for different user's hand conditions studied in Figure 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.

The antenna performances as a function of d are also studied. For this study, results for the both-hands condition are presented. Figure 5 shows the simulated and measured return loss for the studied DTV antenna as a function of d. Results for $d = 0$, 20, 40, and 60 mm are presented. Again, the simulated results in Figure 5(a) in general agree with the measured data in Figure 5(b), and the obtained results indicate that the impedance bandwidth is larger for smaller values of d. This behavior also agrees with the expectation, because smaller values of d indicate that the user's hands are closer to the studied DTV antenna. In this case, larger effects of the user's hands on the antenna performances are expected. For the simulated radiation efficiency as a function of d shown in Figure 6, it also indicates that the largest efficiency decrease is seen for the case of $d = 0$. However, from the results shown in Figures 4 and 6, it is seen that, for the worst case, the radiation efficiency of the antenna is still larger than 60% over the 470–806 MHz band for DTV signal reception. That is, acceptable radiation efficiency is still obtained for the studied DTV antenna with the presence of the user's hands.

Finally, effects of the user's hands on the three-dimensional radiation patterns of the studied DTV antenna are analyzed. Figure 7 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. The simulated radiation patterns for the both-hands condition with $d = 0$, 20, 40, and 60 mm are plotted in Figure 8. In this case, no large variations in the radiation patterns are seen. This indicates that the radiation patterns are mainly affected by how the user's hands holding the PMP. For the variation in the distance d, it will mainly



(a)

(b)

Figure 5 (a) Simulated and (b) measured return loss for the studied DTV antenna as a function of d; both-hands condition. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

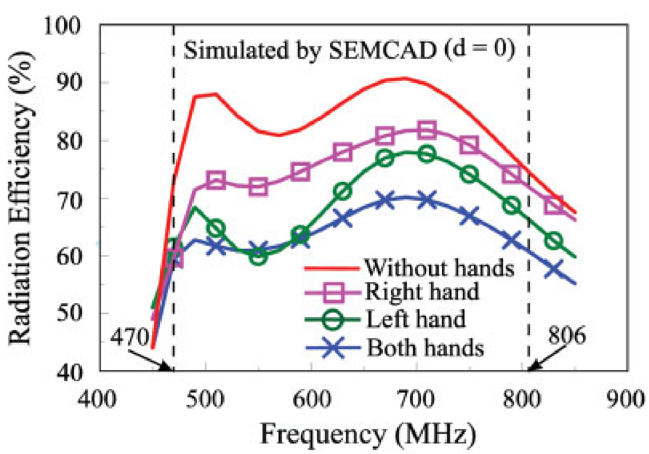


Figure 4 Simulated radiation efficiency for different user's hand conditions; $d = 0$. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

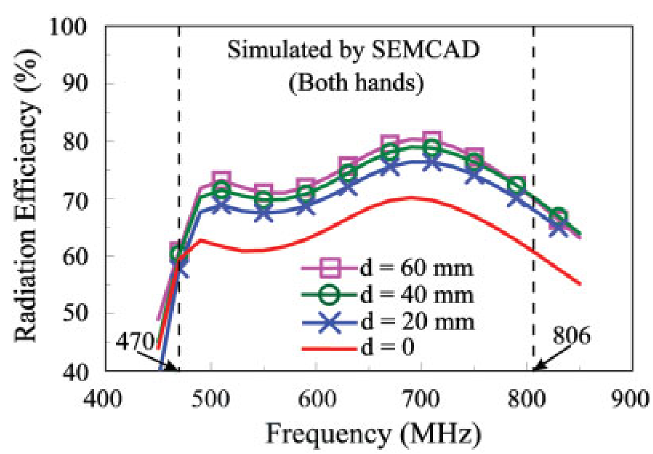


Figure 6 Simulated radiation efficiency as a function of d; both-hands condition. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

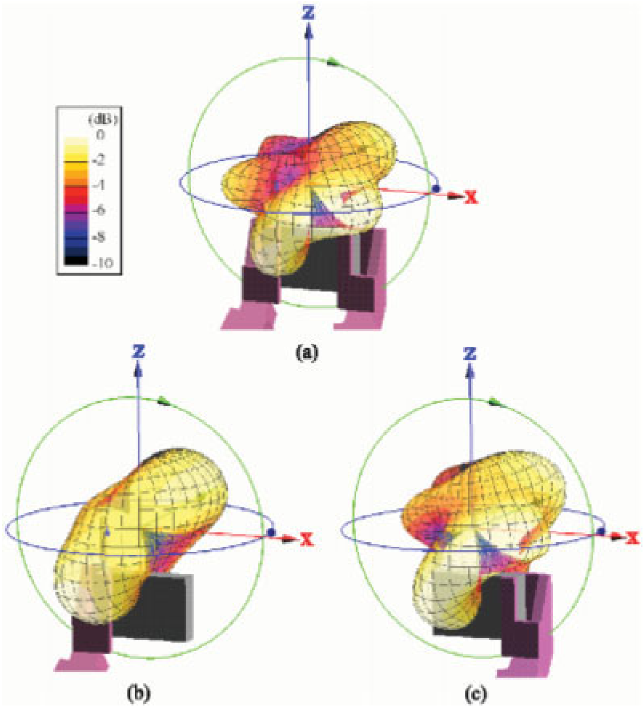


Figure 7 Simulated three-dimensional radiation patterns for the studied DTV antenna with different user's hand conditions at 630 MHz. (a) Both hands. (b) Right hand only. (c) Left hand only. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

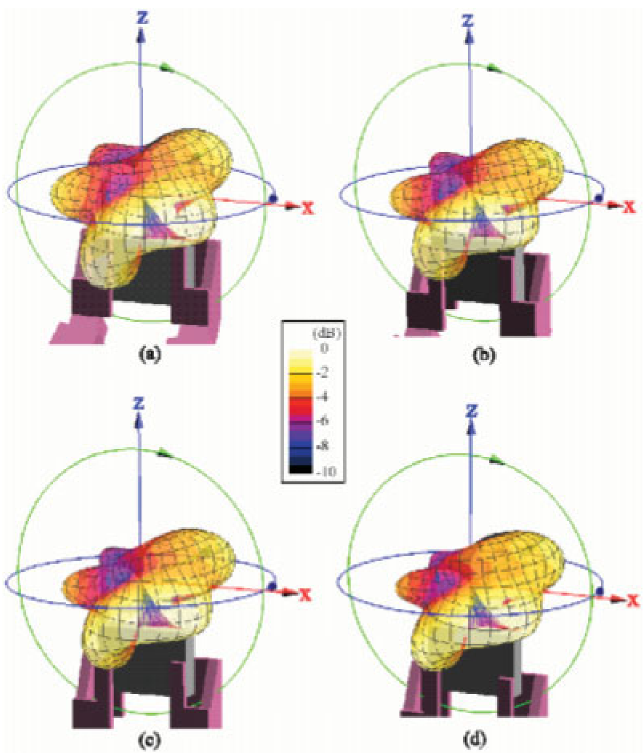


Figure 8 Simulated three-dimensional radiation patterns for the studied DTV antenna with the both-hands condition at 630 MHz. (a) $d = 0$. (b) $d =$ 20 mm. (c) $d = 40$ mm. (d) $d = 60$ mm. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

affect the radiation efficiency of the studied antenna; for d increased from 0 to 60 mm, the radiation efficiency can be increased by about 10% (see the results shown in Fig. 6).

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 on the antenna performances, especially for the condition of the user's both hands holding the PMP. 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 (both-hands condition with the user's hand at the top edge of the PMP casing), 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.

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