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DUAL-BAND CPW-FED CIRCULARLY-POLARIZED SLOT ANTENNA FOR DMB/WIMAX APPLICATION

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Abstract—A novel dual-band circularly-polarized slot antenna fed by a coplanar waveguide (CPW) is presented for digital multimedia broadcasting (2.6 GHz) and Worldwide Interoperability for Microwave Access (3.5 GHz) application. The circular polarization in the lower band is achieved by the slots loaded in two opposite corners, and corner truncation of the square slot can offer a current path for the upper band. Experimental results show that the measured impedance bandwidths (VSWR $\leq$ 2) are 18.5% for the lower band and 19.1% for the upper band, and the measured 3 dB axial-ratio bandwidths are 22.3% and 18.3%, with respect to 2.6 GHz and 3.5 GHz, respectively.

1. INTRODUCTION

In order to reduce the loss caused by the misalignment between the signal and the receiving antenna and allow more flexible orientation of the transmitter and receiver antennas, CP antennas becoming more and more popular in the fields of radar, wireless communication, and navigational system [1]. Among various CP antennas, the microstrip patch antenna receives more and more attention for CP performance in wireless communication systems due to their compact profile, light weight, easy fabrication, and low production costs [2]. For generating CP radiation using single feed, various microstrip antenna designs have been introduced [3–6]. However, the related designs have narrow CP bandwidth (3 dB axial ratio bandwidth) which is lower than 10% [4–6], and all of them are coaxial probe-fed, which cannot be easily integrated with other RF front-end circuits. To achieve wideband CP performance, a coplanar waveguide (CPW) approach was adopted in

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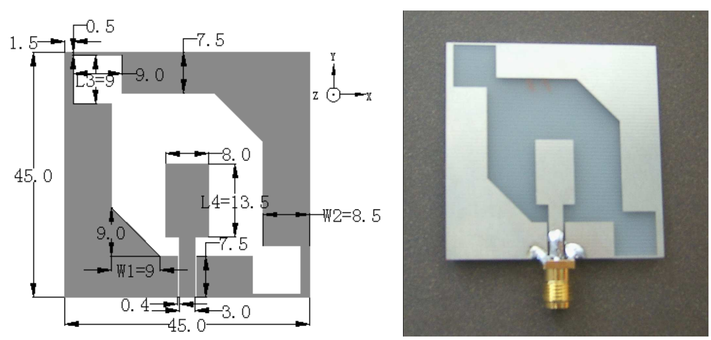
the CP slot antenna designs. In general, the wideband CPW-fed slot antenna can be developed by tuning their impedance value such as varying the slot dimensions. Also, the right-hand CP and the left-hand CP can be achieved simultaneously with various techniques in these antennas. One of the techniques that are usually used to design such CP slot antennas is embedding two inverted-L grounded strips around two opposite corners of the slot [7–9]. Embedding a spiral slot in the ground plane [10] or loading the slots in two opposite corners [11] with other techniques can provide dual-band dual-sense circularly-polarized CPW-fed slot antenna. However, the structure of these antennas is more complex and it is difficult to tune so many parameters and obtain a better design target. The truncated corner of the main slot together with the L-shaped strip is used to generate resonant mode for CP performance in [12], however, it only can provided one resonant mode results in one band CP operation.

This paper presents a dual-band CP antenna with compact size. In the proposed CP printed slot antenna, two square slots in the opposite corner of the ground plane and two truncated corner of the main slot is introduced to achieve dual-band CP performance. The dual-band antenna can work at the designated frequency band: digital multimedia broadcasting (DMB) system at 2.6 GHz; world interoperability for microwave access (WiMAX) service from 3.3 to 3.7 GHz. The achieved fractional 3-dB axial ratio (AR) bandwidth is up to 22.3% (from 2.36 to 2.94 GHz) for lower band and 18.3% (from 3.07 to 3.71 GHz) for upper band. Both the simulated and measured results are provided to validate the CP performance of the proposed antenna in the following sections.



(a) (b)

Figure 1. Geometry and dimensions of the proposed antenna: (a) design schematic figure, (b) photograph of the manufactured antenna.

2. ANTENNA DESCRIPTIONS

Figure 1 shows the geometry of the dual-band dual-sense circularly polarized antenna. The proposed antenna is fabricated on a FR4 substrate with dielectric constant ε_r of 4.4, dielectric loss tangent of 0.02 and thickness of 1.6 mm.The CPW-fed technique is applied for their relatively wide bandwidth and simplified configuration with a single metallic layer. The feed dimensions are fine designed to obtain 50 Ω impendence, and the width of the feed line and the gap are 3 mm and 0.4 mm, respectively.

To better understand the excitation behavior of the two main structures, Figure 2 only shows the current distributions of phase 0° and 90° for the lower (2.6 GHz) and upper (3.3 GHz) frequencies since those of 180° and 270° are equal in magnitude and opposite in phase of 0° and 90°. Two square slots placed around two opposite corners with two truncated corner at other two opposite corners is applied to generate resonator for exciting two orthogonal modes with

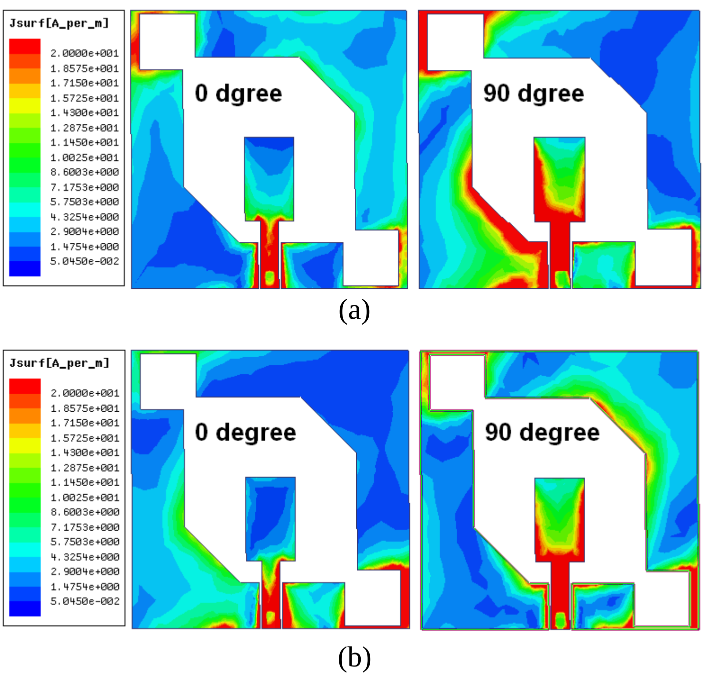


Figure 2. Simulated current distributions of the proposed antenna: (a) 2.6 GHz and (b) 3.3 GHz.

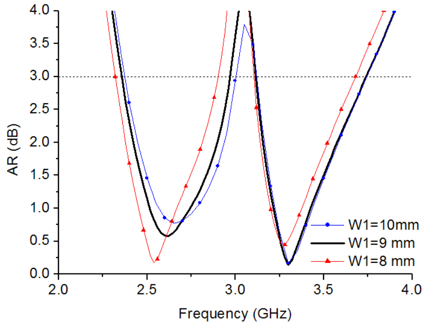


Figure 3. Simulated AR of the proposed antenna with different W_1 values.

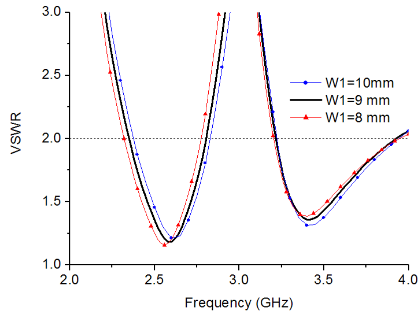


Figure 4. Simulated VSWR of the proposed antenna with different W_1 values.

equal amplitude and 90° phase difference for both the lower and upper frequency to create dual-band circular polarization, as illustrated in Figure 2. Both the two elements work as perturbation structures to distort the surface current and help to realize circular polarization. The CP operation for lower band is achieved by introducing two square slots placed around two opposite corners. The corner truncated square patch is the conventional technique to produce degenerate modes necessary for realizing broadband CP. Based on this theory, truncated corner at two opposite corners of the proposed antenna is tried to realize CP performance for upper band in this paper. The main slot is a corner truncated rectangular slot with a dimension of 28 mm × 30 mm, the truncation of $W_1 = 9$ mm and the square slot of $L_3 = 9$ mm embedded in the coplanar ground plane. To find optimized parameters of the proposed antenna structure, numerical work was carried out using a commercially available software package HFSS and included a SMA feed connector model.

The success of the CP antenna design mainly relies on whether the entire 3-dB AR band can be completely enclosed by the voltage standing wave ratio VSWR band, so the parameter studies including both the AR and VSWR are presented. By properly varying the key parameters of W_1, W_2, L_3 and L_4, a wider 3-dB ARbandwidth and better impedance matching are achieved. Figure 3 shows that as the truncation W_1 increasing the resonant mode for 2.6 GHz CP performance moves to upper band. It is seen from Figure 7 that the resonant frequency moves to lower band for 3.5 GHz CP performance as the slot length L_3 increases. The width W_2 of the ground plane plays an important role on the center frequencies of 2.6 GHz and 3.5 GHz for

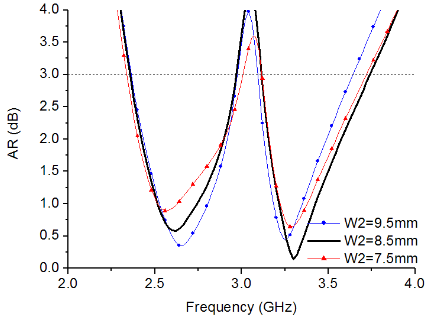


Figure 5. Simulated AR of the proposed antenna with different W_2 values.

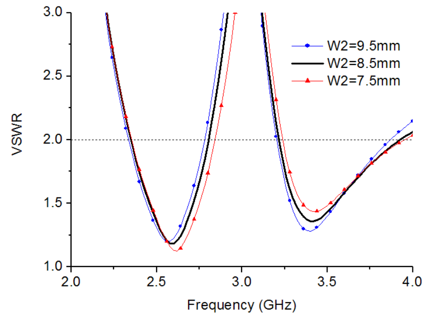


Figure 6. Simulated VSWR of the proposed antenna with different W_2 values.

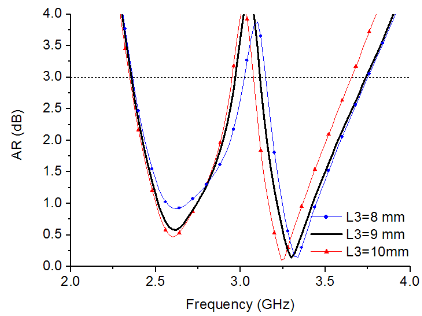


Figure 7. Simulated AR of the proposed antenna with different L_3 values.

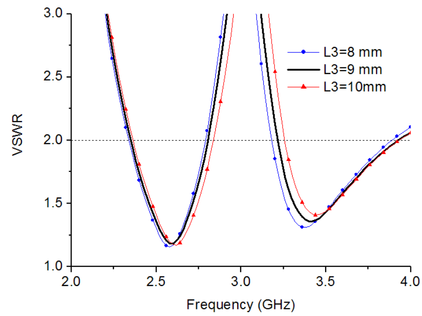


Figure 8. Simulated VSWR of the proposed antenna with different L_3 values.

CP operation, as shown in Figure 5. However, Figures 4, 6, and 8 show that the effect of W_1, W_2 and L_3 on the VSWR of both band is relative little. As can be seen from Figure 9 the signal strip length L_4 has little effect on AR, while it is the key parameter to determine the impedance matching bandwidth. It is apparent that as L_4 increases, the center frequencies of both the lower and upper VSWR bands shift to the lower frequencies, and the VSWR bandwidth of the upper band becomes narrower in Figure 10. In this paper, the appropriate value of these four parameters for the proposed antenna is selected as $W_1 = 9\,\text{mm}$, $W_2 = 8.5\,\text{mm}$, $L_3 = 9\,\text{mm}$ and $L_4 = 13.5\,\text{mm}$.

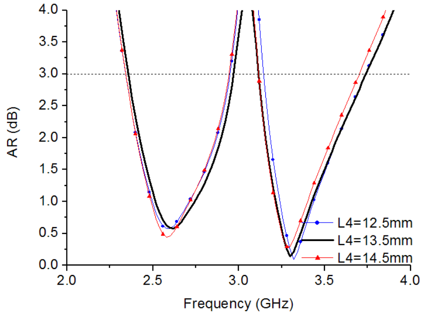


Figure 9. Simulated AR of the proposed antenna with different L_4 values.

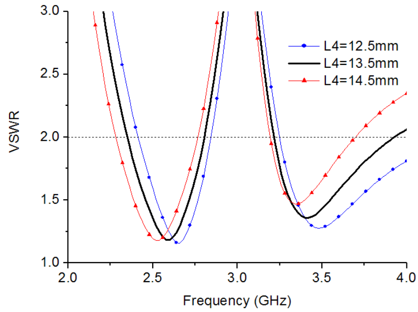


Figure 10. Simulated VSWR of the proposed antenna with different L_4 values.

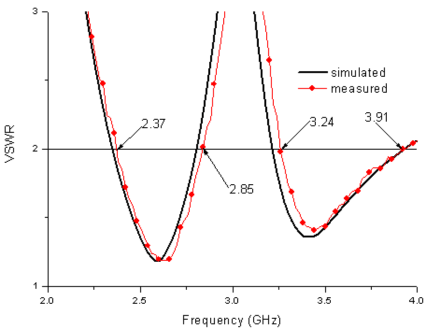


Figure 11. Measured and simulated VSWR for the proposed antenna.

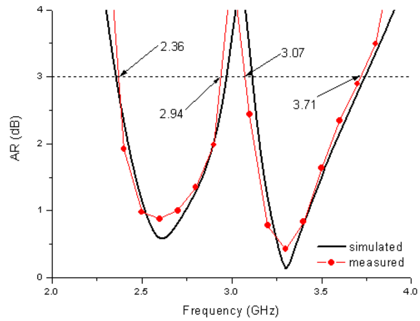


Figure 12. Measured and simulated AR for the proposed antenna.

3. ANTENNA PERFORMANCES

The proposed antenna has been constructed and electrical characteristics such as VSWR of the implemented antenna were measured by using a Wiltron-37269A network analyzer. Figure 11 illustrates the simulated and measured impedance bandwidths (VSWR ≤ 2) are 0.48 GHz (from 2.37 to 2.85 GHz) for 2.6-GHz band and 0.67 GHz (from 3.24 GHz to 3.91 GHz) for 3.5-GHz band, approximately 18.5% and 19.1% for lower and upper band respectively. The measured data agree well with the simulated results. The discrepancy is due to tolerances in the dielectric constant and difference between the simulated and the measured environments. Figure 12 presents the simulated and measured variations of the axial ratio as a function of frequency at broadside direction. As illustrated in Figure 12, the measured axial ratio attains minimum value at resonance frequency of 2.6 GHz and 3.5 GHz with 3-dB AR-bandwidth of 0.58 GHz (from 2.36 to 2.94 GHz) approximately 22.3% and 0.64 GHz (from 3.07 to 3.71 GHz) approximately 18.3% respectively. There is a little frequency discrepancy between the AR bandwidth and the impedance bandwidth as seen from Figure 11 and Figure 12. That is because the truncated corner of the main slot influences the impedance matching when it works to realize circular polarization. The measured data of AR and radiation patterns are all obtained through phase-amplitude method. The LHCP and RHCP radiation patterns were measured in the XZ-plane and YZ-plane at frequencies of 2.6 GHz and 3.5 GHz. It can be seen from Figure 13 that in the boresight direction, the patterns are mainly LHCP for $Z > 0$ and RHCP for $Z < 0$, and cross-polarization is more than 15 dB lower than the co-polarization in each plane. Further more, the radiation patterns in both sides are almost the same for printed slot antenna

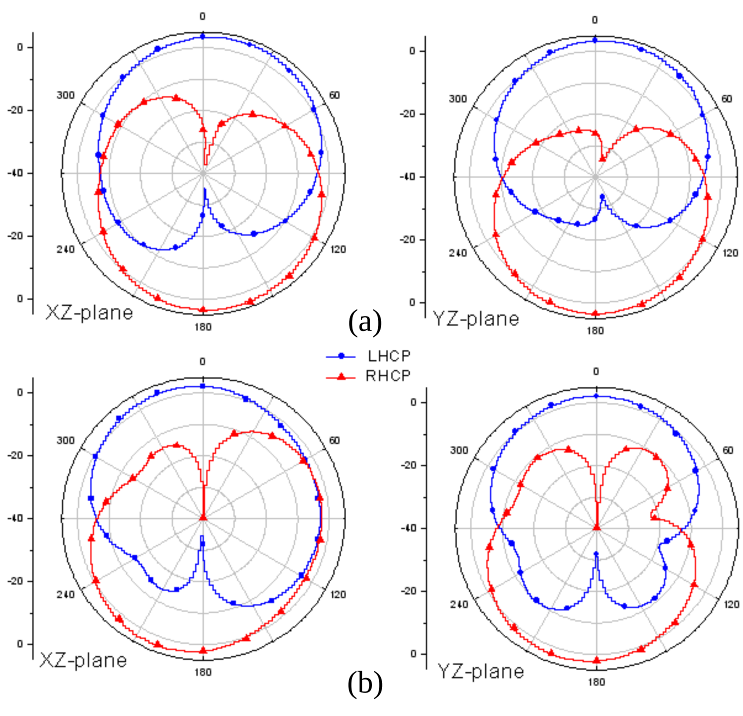


Figure 13. Radiation pattern of the proposed antenna (in dB): (a) 2.6 GHz, (b) 3.5 GHz.

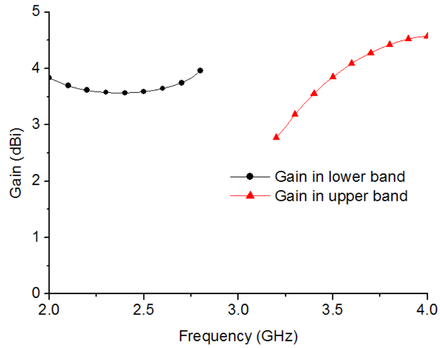


Figure 14. Measured gains in the lower and upper bands.

is a bidirectional radiator. Also note that the radiation patterns at other operating frequencies within the circularly polarized bandwidth performance in a similar fashion to those plotted here, i.e., stable radiation patterns have been obtained for the dual-band CP antenna. As can be seen from Figure 14, there exhibits peak gains of around 3.95 and 4.58 dBi in the lower and upper CP bands.

4. CONCLUSIONS

The characteristics of a dual-band CPW-fed slot antenna with CP performance at 2.6 GHz and 3.5 GHz frequencies have been proposed and verified with simulation and measurement. By introducing two truncated corners and two square slots in the ground plane, dual-band circular polarization can be achieved. The proposed antenna can provide 3-dB AR bandwidths of 22.3% for lower band and 18.3% for upper band, respectively. The implemented antenna has a good radiation pattern characteristic therefore the proposed dual-band CP antenna can be applicable for the reception of DMB and WiMAX signals.

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