Progress In Electromagnetics Research Letters, Vol. 33, 101–108, 2012

DUAL-BAND CIRCULARLY POLARIZED SLOT ANTENNA FOR WIMAX/WLAN APPLICATION

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Abstract—A new antenna with dual-band circular polarization for the reception of WiMAX and WLAN is presented in this article. The circular polarization is achieved by a symmetrical U-slot together with an L-slot. The width of the signal strip is narrowed at the end of the feed point to widen the 3-dB axial ratio (AR) bandwidth and create a good impedance matching for the proposed antenna. A parametric study is conducted using a commercial simulation software based on the method of moments, and the antenna prototype is constructed and measured for providing the simulation validation. Experimental results show that the measured AR bandwidths are about 16.6% and 16.2% with respect to the center frequency at 3.5 GHz and 5.3 GHz. The radiation characteristics of the proposed antenna are also presented.

1. INTRODUCTION

In recent years, with the growth of the wireless communication and advancement in space telecommunication, circular polarization (CP) is becoming more and more popular for overcoming the multipath fading problem and allowing more flexible orientation of the transmitter and receiver antennas. As the interest of CP antenna design is increasing, the need for small antennas with dual-band CP behavior has greatly increased. A lot of work has been reported on modelling the dual-band CP antennas [1–5] in the open literature. Among various forms of the dual-band CP antennas, slot antennas have been concerned widely due to its well-known characteristics such as low profile, large impedance bandwidth, simple structure, and easy integration with other RF front-end circuits in a PCB. In a recent study, it was shown that the techniques of monofilar spiral [6] and crane-shaped strip [7] have been

Received 27 June 2012, Accepted 16 July 2012, Scheduled 17 July 2012
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employed to excite the circularly polarized radiation. The U-slot is also adopted in circularly polarized antenna design, but these patch antennas [8, 9] only can achieve single band CP performance. As for dual-band CP performance, an asymmetric U-slot [10] is employed to realize the design goal using stacked patches.

In this letter a novel symmetrical U-slot antenna optimized for simplicity in design and feeding is proposed for dual-band CP application. Compared to the previous U-slot CP antennas [8–10], the symmetrical U-slot is adopted, and it can achieve dual-band CP performance together with L-slot only using single metallic layer. Details of the proposed antenna design are described in the following section, the simulated results are carried out using a commercially available software package HFSS. Also the measured data of the obtained impedance and CP performance are presented and discussed. The dual-band antennas can work at the designated frequency band: world interoperability for microwave access (WiMAX) service from 3.3 to 3.7 GHz, and 5.15 to 5.35 GHz of the wireless local area network (WLAN) for IEEE 802.11a in the USA.

2. ANTENNA DESCRIPTION

The structure of the proposed simple antenna is shown in Figure 1. The antenna is fabricated on a square FR-4 substrate with dielectric

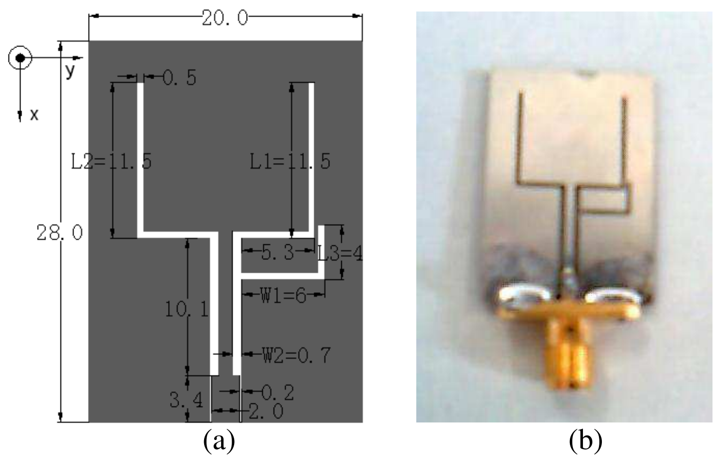

Figure 1. Geometry and dimensions of the proposed antenna: (a) design schematic figure, (b) photograph of the manufactured antenna.

constant of $\varepsilon_r = 4.4$, dielectric loss tangent $= 0.02$ and a thickness of 1 mm. The coplanar waveguide (CPW)-fed method is adopted due to simplified configuration with a single metallic layer, and the width of the feed line and the gap are 2 mm and 0.2 mm, respectively. The feed dimensions are fine designed to obtain $50\,\Omega$ impendence. The symmetric U-slot together with the L-slot is applied to generate a resonant mode for exciting two orthogonal E vectors to create the circularly polarization. The signal strip is narrowed to create a good impedance matching for the proposed antenna to attain 3-dB AR bandwidth enhancement.

To better understand the excitation behavior of the proposed antenna, the simulated surface current distributions are plotted in Figure 2 at phase $= 0°$ and $90°$ for the lower (3.5 GHz) and upper (5.3 GHz) frequencies, respectively. It can be observed that the U-shaped and L-shaped slot are introduced as perturbation segments for

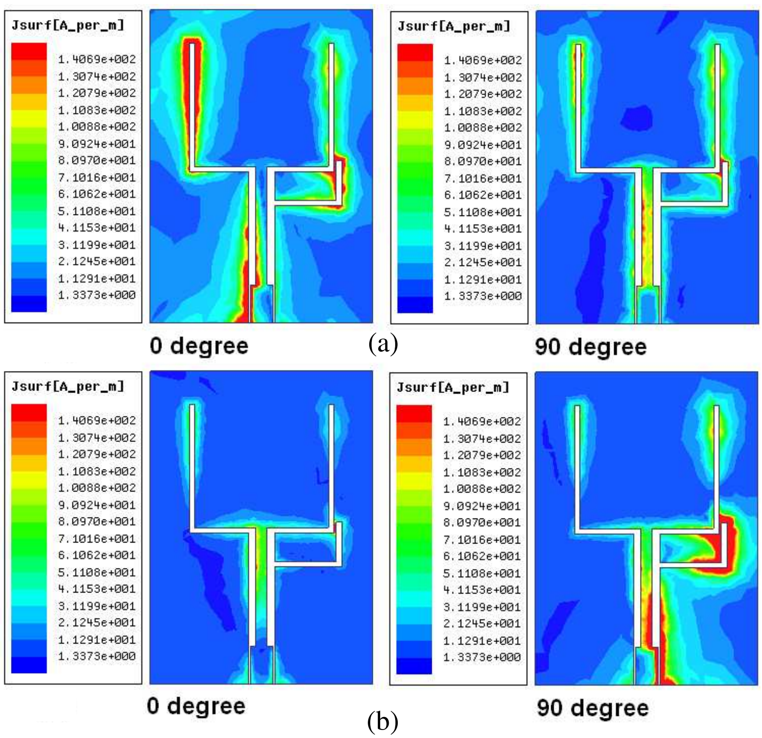

Figure 2. Simulated current distributions: (a) 3.5 GHz and (b) 5.3 GHz.

generating CP. To form circularly polarized radiation, the radiations from two slots must be 90° out of phase between each other with equal magnitude. It can be obtained by setting the length of two slots with a slight difference. For the lower band, the stronger current distributions occurs at phase = 0°, and the current distributions around the L-shaped slot are stronger at the upper frequency when phase = 90°. It is consistent with the fact that the proposed antenna radiates opposite-sense CP waves at the lower (3.5 GHz) and upper (5.3 GHz) frequencies, respectively.

In order to investigate the effects of key parameters on the antenna performance, a parameter studies based on the theory mentioned before has been carried out including both the AR and VSWR. Through out the parameters study presented in this section, all other parameters that have not been mentioned are fixed as shown in Figure 1. It can be seen from Figures 3 and 4 that the length of the U-slot arms has an obvious effect on both the AR and VSWR of the lower band operations. Also from Figures 3 and 4, if $L2$ is fixed, $L1$ mainly influences the performance of lower band. It is observed from Figures 5 and 6 that the length of the L-slot mainly determines the center frequency of the AR and VSWR for upper band, with the increase of the total length ($L3+W1$) of the L-slot, the center frequency of the upper band moves toward the lower band. Figures 5 and 6 also show that both the AR and VSWR in the lower operating band are almost stable, but both turned worse when the value of $W1$ is 7 mm. It is seen from Figure 3 to Figure 6 that the length ($L1$ and $L2$) of the U-slot arms and the length ($W1$ and $L3$) of the L-slot have a

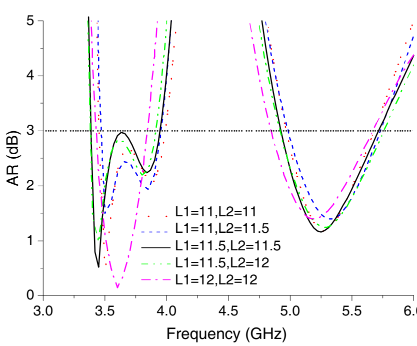

Figure 3. Simulated AR of the proposed antenna with different lengths of the U-slot arms.

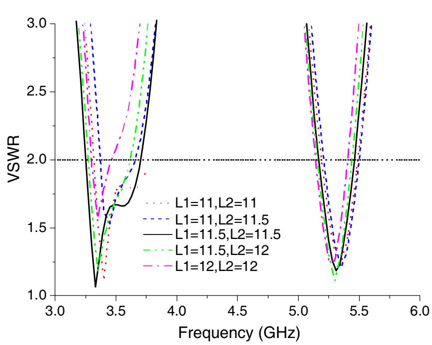

Figure 4. Simulated VSWR of the proposed antenna with different lengths of the U-slot arms.

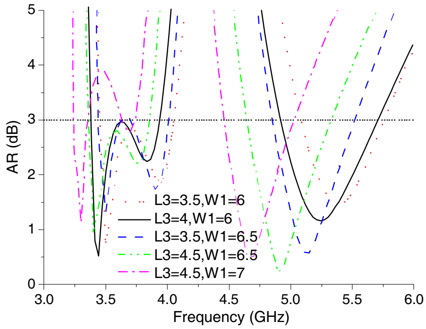

Figure 5. Simulated AR of the proposed antenna with different lengths of the L-slot.

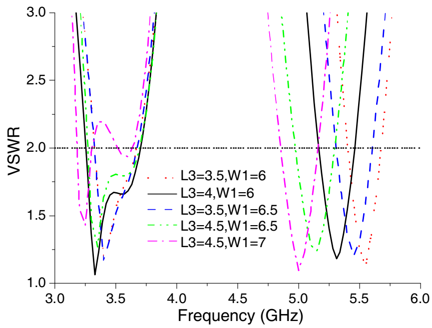

Figure 6. Simulated VSWR of the proposed antenna with different lengths of the L-slot.

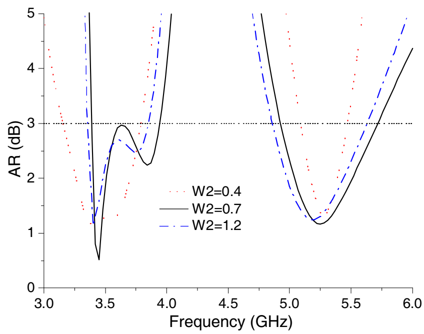

Figure 7. Simulated AR of the proposed antenna with different $W2$ values.

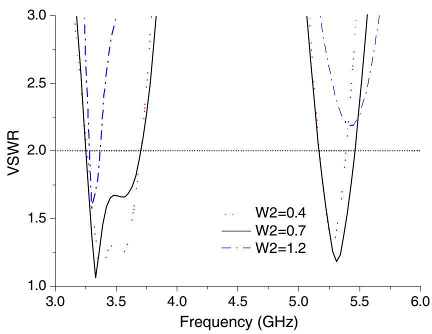

Figure 8. Simulated VSWR of the proposed antenna with different $W2$ values.

remarkable influence on both the AR and VSWR for lower and upper band. We can see from Figures 7 and 8 that the width of the signal strip mainly determines the width of the 3-dB AR and VSWR. By properly varying the key parameters of $W1$, $W2$, $L1$, $L2$ and $L3$, a wider 3-dB AR-bandwidth and better impedance matching are achieved.

3. ANTENNA PERFORMANCES

The proposed dual-band CP antenna is measured by a Wiltron-37269A network analyzer to evaluate its performance. In this section, simulated and measured VSWR, axial ratio and radiation patterns of the proposed antenna are presented. Figure 9 shows impedance

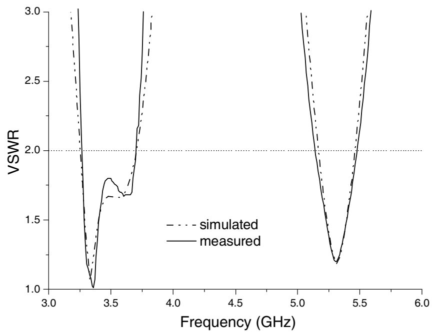

Figure 9. Measured and simulated VSWR for the proposed antenna.

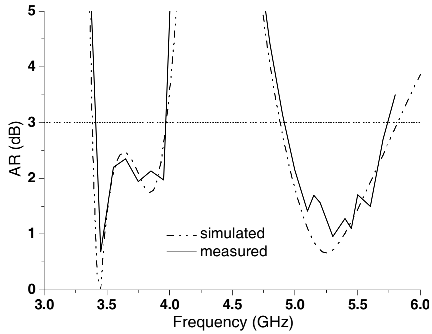

Figure 10. Measured and simulated AR for the proposed antenna.

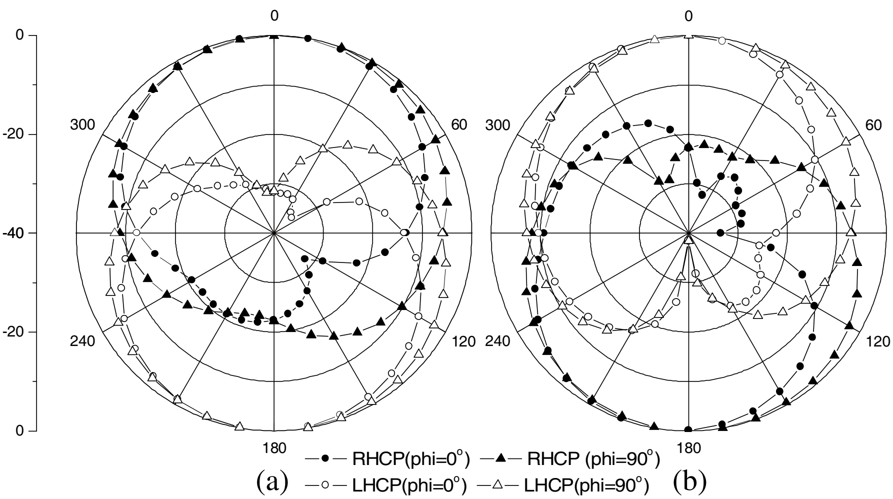

Figure 11. Radiation pattern of the proposed antenna (in dB): (a) 3.5 GHz,(b) 5.3 GHz.

bandwidths (VSWR $\leq$ 2) are 0.44 GHz for 3.5-GHz band and 0.36 GHz for 5.3-GHz band. It can be seen that the measured VSWR reasonably agrees with the simulated results with an acceptable frequency discrepancy, which may be referred to the difference between the simulated and the measured environments. Figure 10 shows AR at boresight direction obtained in the two frequency bands, both the lower and the upper band centered at 3.5 and 5.3 GHz respectively, and with 3-dB AR-bandwidth of 0.58 GHz (166%) and 0.86 GHz (16.2%).

Measured AR is also in agreement with the simulated, which changes rapidly with frequency.

Figure 11 presents the measured radiation patterns in x-z plane (phi $= 0^{\circ}$) and y-z plane (phi $= 90^{\circ}$) at two resonant frequencies selected in the corresponding 3-dB AR band mentioned earlier. The measured results are normalized to absolute gain of antenna. It can be found that in the boresight direction, cross-polarizations can keep more than 15 dB lower than the co-polarizations. Note that the proposed antenna is a bidirectional radiator and the radiation patterns in both sides are almost the same the patterns are mainly RHCP for $Z > 0$ and LHCP for $Z < 0$ at 3.5 GHz, but it radiates opposite-sense CP waves at 5.3 GHz frequencies.

4. CONCLUSION

A novel design of a dual-band CP slot antenna with CP performance at 3.5 GHz and 5.3 GHz frequencies is proposed and verified with simulation and measurement. It is observed that dual-band CP operation can be achieved by inserting the U-slot and L-slot into the metallic patch. The proposed antenna can provide 3-dB AR bandwidths of 16.6% for lower band and 16.2% for upper band, respectively. This design example offers advantages in structure, size weight, fabrication and performances, which demonstrate that it is very suitable for commutation system.

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