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COMPACT DUAL-BAND DUAL-SENSE CIRCULARLY-POLARIZED CPW-FED SLOT ANTENNA

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Abstract—A CPW-fed slot antenna for achieving dual-band dual-sense circular polarization is introduced. The dual-band circularly polarized operations are generated by the slots loaded in the two opposite corners and the halberd-shaped strip connected at the end of the signal line of the CPW. The left-hand and right-hand circularly polarized performances can be achieved simultaneously for the lower and the upper band, respectively. The measured impedance bandwidth for 10-dB return loss at 2.5 and 3.5 GHz operating bands can be up to 1100 MHz and 260 MHz, respectively. The measured 3-dB axial ratio bandwidths are 30.8% for lower band (LHCP) and 3.1% for upper band (RHCP), which are completely inside their respective impedance bands. The designed antenna has a simple uniplanar structure and occupies a compact size of $40 \times 40\,\mathrm{mm}^2$, including the finite ground CPW feeding mechanism. Moreover, the antenna gain variations across the two operating bands are less than 1 dB.

1. INTRODUCTION

Recently, the circularly polarized (CP) antennas have received considerable attentions in wireless communication systems owing to their advantages of reduction in multi-path reflections and flexibility in orientation angle between transmitter and receiver. With its prominent features such as wide bandwidth, low profile, simple structure, and easy fabrication, slot antenna is an attractive candidate for generating circular polarization. Several types of CP slot antennas have been reported, such as the slot antenna with four metallic strips in the four slot corner in [1], stubs and additional L-slot in [2], a grounded T-shaped metallic strip in [3], a cross patch in [4], a widened L-type strip

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in [5], and a pair of inverted-L grounded strips in [6]. However, those designs can only provide one operation band. As the growing interest in dual-band CP antennas, various designs of dual-band circularly polarized antennas have also been proposed in [7–9]. In [7], the antenna comprising a circular patch with two concentric annular-rings and an unequal cross-slot loading in the ground plane is demonstrated to produce dual-frequency circularly polarization, however, its dual CP bandwidths are only about 1%. In [8], although these antenna with the stacked-patch configuration can achieve the dual-band circularly polarization successfully, both the impedance bandwidths and CP bandwidths for the lower and upper bands are relatively narrow, and with the large ground plane, the antenna has a large size. The antenna in [9] has a complex structure and exhibit noticeable mutual coupling between its lower and upper band radiator.

In this paper, a uniplanar printed CPW-fed slot antenna with bandwidth enhancement and size reduction for dual-band dual-sense circular polarization is presented. The circular polarization in the lower band is excited by the slots loaded in two opposite corners, and the halberd-shaped strip connected at the end of the signal line of the CPW can provide a current path for the upper band. The proposed antenna can also generate the left-hand circularly polarized (LHCP) and the right-hand circularly polarized (RHCP) in the $+z$ direction, simultaneously. The measured 10-dB return loss impedance bandwidth for the lower and the upper band are 44% and 7.4%, respectively. The measured 3-dB axial ratio bandwidths are 30.8% for lower band and 3.1% for upper band, which are completely inside their respective impedance bands. Details of the antenna design and experimental results are presented and discussed.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed slot antenna. The antenna with a single-layered metallic structure is etched on one side of an inexpensive FR4 epoxy substrate with a relative permittivity of 4.6, a loss tangent of 0.02, a thickness of 1.6 mm, and with no metallization on the other side. The overall dimensions of the proposed antenna are only $40 \times 40\,\mathrm{mm}^2$.

A $50\,\Omega$ CPW feed line that has a signal strip width of W_f and a gap distance of g between the signal strip and the coplanar ground plane is used to excite the antenna. An $L \times L$ square slot is etched at the center of the ground plane. Two additional slots with the same size which consist of a pair of rectangular slots with the dimensions of U_x, U_y, D_x and D_y placed around the two opposite corners of the

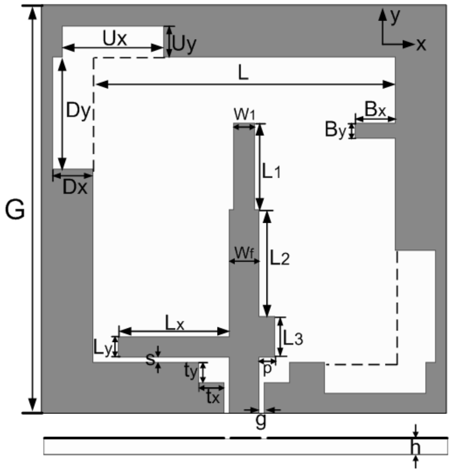


Figure 1. Geometry of the proposed antenna.

square slot. By adjusting the dimensions of the slots, the lower CP operation can be achieved. The signal line of the CPW is extended leftward along the $-x$ direction and upward along the y direction to form a halberd-shaped feeding signal line for generating the upper CP operation, and this halberd-shaped feeding line maintains a gap of s away from the lower edge of the slot. A tuning vertical stub is embedded in the feeding structure for enhancing the CP bandwidth. A pair of symmetrical rectangular slots etched on the lower edge of the ground plane plays an important role on impedance matching. By implanting a grounded rectangular strip with width B_y and length B_x on the right-hand side, a 10-dB return loss impedance bandwidth can be generated which completely covers the CP band.

The simulated surface current distributions of 0° and 90° at the lower and upper frequencies are plotted in Fig. 2. It can be observed that the slots placed around two opposite corners act as a slight perturbation segments to excite the two orthogonal modes with a 90 phase-shift and equal amplitude for CP operation at the lower-band. On the other hand, the current distributions on the halberd-shaped strip connected at the end of the signal line of the CPW are stronger at the upper frequency which implies that the upper-band radiation mainly comes from the halberd-shaped strip.

Figure 3 illustrates the influence of t_x on the impedance matching and the 3-dB AR bandwidth. It is observed that the impedance matching of the dual-band slot antenna is very sensitive to this parameter. However, there is no significant influence on the AR

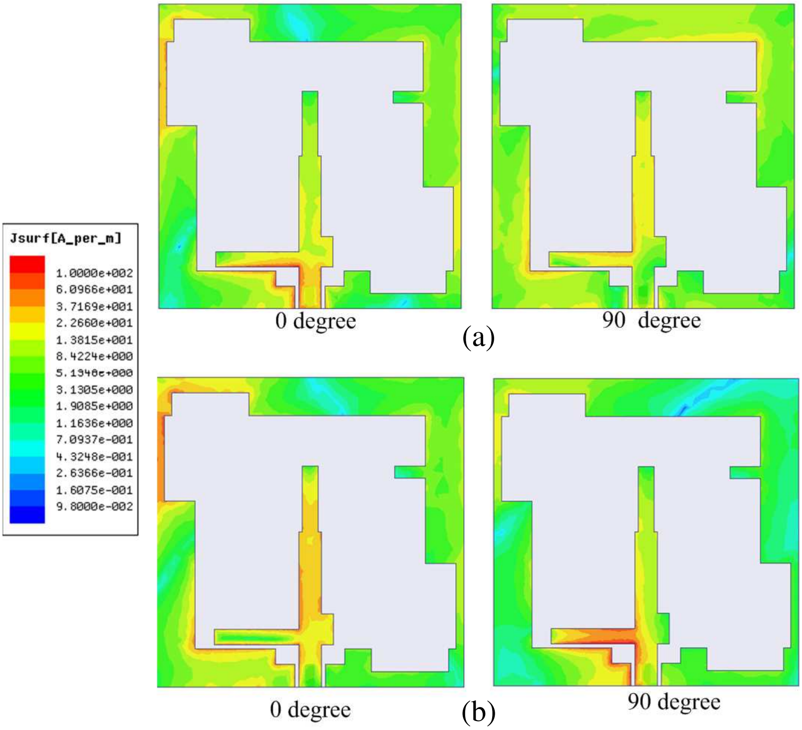


Figure 2. Simulated current distributions: (a) 2.5 GHz and (b) 3.5 GHz.

characteristic. Therefore, the length of the rectangular slots etched on the lower edge of the ground plane needs to be optimized for providing dual-band impedance matching. Furthermore, the optimum matching condition can be obtained, when t_x is about 2.5 mm.

In addition, the effect of the rectangular slot height U_y on the performance of the proposed dual-band CP antenna is presented in Fig. 4. As shown in the figure, varying U_y from 2.5 mm to 3.5 mm with an increment of 0.5 mm and keeping the other parameters unchanged, the center frequency of the upper AR band shifts to the lower frequencies, while the increase has no significant effect on the lower AR band. Meanwhile the increasing the height of the rectangular slot will lower the center frequencies of both impedance bands, but the change of the upper band is more obvious than that of the lower band. It is also worthwhile to point out that the 3-dB AR bandwidths for the dual band can be completely enclosed by the 10-dB return loss impedance bandwidths.

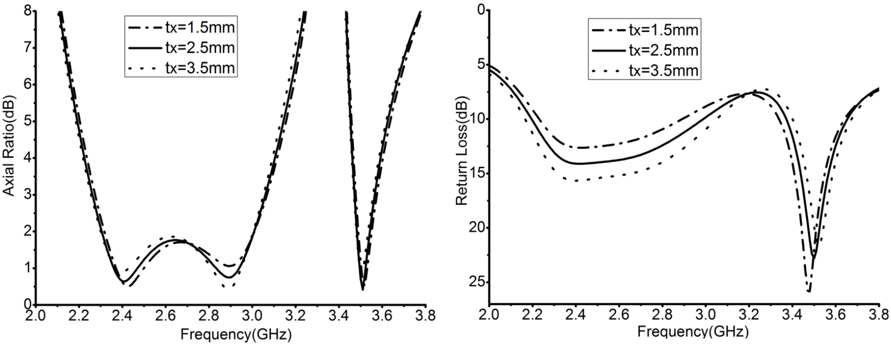


Figure 3. Simulated return loss and axial ratio of different values of t_x.

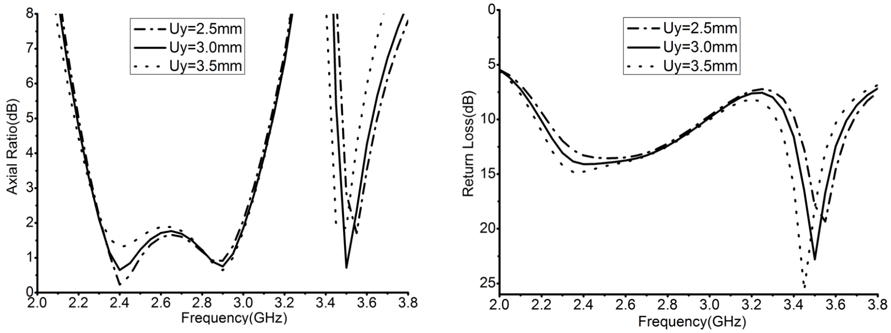


Figure 4. Simulated return loss and axial ratio of different values of U_y.

The mainly optimized parameters of the proposed antenna are as follows: $G = 40.0\,\text{mm}$, $L = 30.0\,\text{mm}$, $U_x = 10.0\,\text{mm}$, $U_y = 3.0\,\text{mm}$, $D_x = 4.0\,\text{mm}$, $D_y = 11.0\,\text{mm}$, $B_x = 4.0\,\text{mm}$, $B_y = 1.5\,\text{mm}$, $L_1 = 8.5\,\text{mm}$, $L_2 = 10.5\,\text{mm}$, $L_3 = 4.0\,\text{mm}$, $L_x = 11.0\,\text{mm}$, $L_y = 2.0\,\text{mm}$, $W_1 = 2.0\,\text{mm}$, $W_f = 3.0\,\text{mm}$, $S = 0.5\,\text{mm}$, $t_x = 1.5\,\text{mm}$, $t_y = 2.0\,\text{mm}$, $p = 1.5\,\text{mm}$, $g = 0.5\,\text{mm}$.

3. RESULT AND DISCUSSION

According to the designing dimensions given above, a prototype of the proposed antenna has been fabricated and measured. The photograph of the prototype for the proposed antenna is shown in Fig. 5. Fig. 6 describes the simulated and measured return loss against the frequency

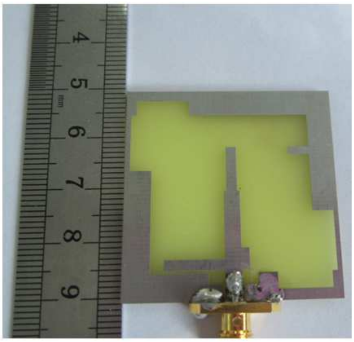
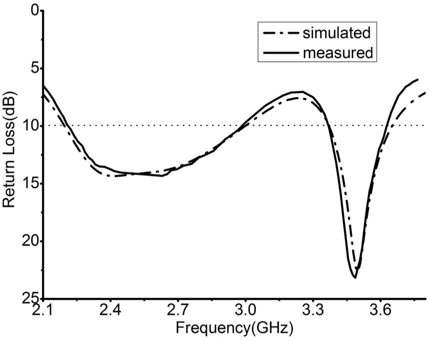


Figure 5. Photograph of the proposed antenna.



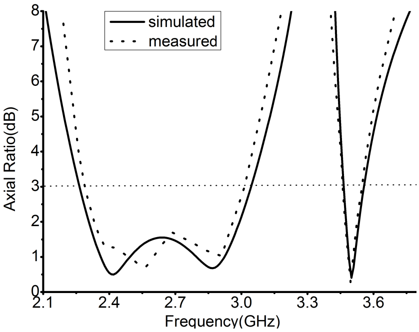
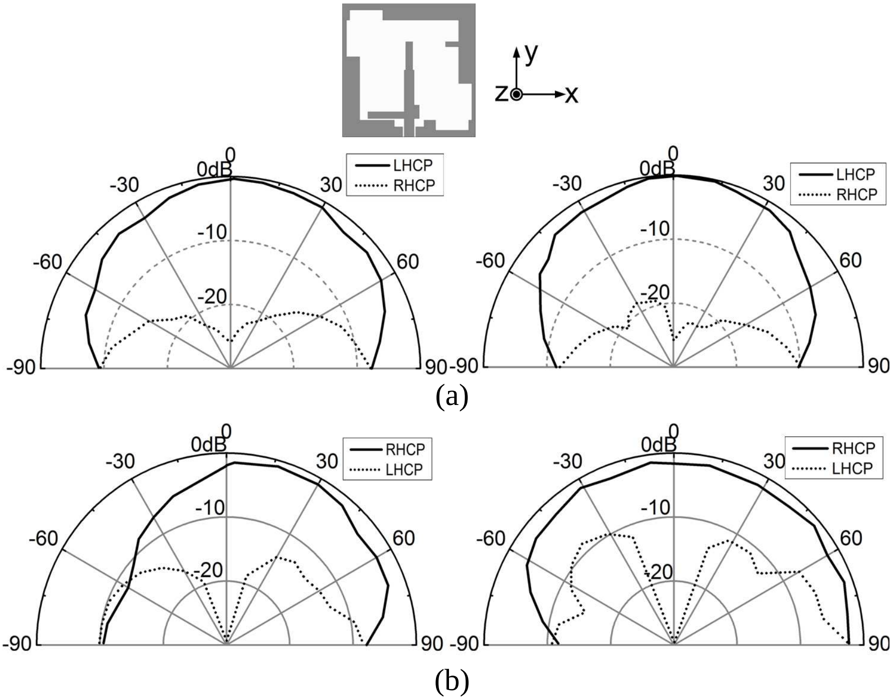


Figure 6. Measured and simulated return loss of the proposed antenna.

Figure 7. Measured and simulated axial ratios of the proposed antenna.

for the fabricated prototype antenna, and there are some slight discrepancies between simulated and measured results mainly due to errors in fabricating process and the effects of the SMA connector which introduces a varying reactance. The measured impedance bandwidths for the lower frequency is about 1100 MHz from 2.20 to 3.30 GHz, representing 44% with respect to 2.5 GHz, and the bandwidth of the upper frequency is about 260 MHz from 3.37 to 3.63 GHz, representing 7.4% with respect to 3.5 GHz. Fig. 7 illustrates the simulated and measured results of axial ratio of the antenna. The measured 3 dB axial ratio bandwidths are 30.8% (2.28–3.05 GHz) for the lower band (LHCP) and 3.1% (3.35–3.56 GHz) for the upper band (RHCP), which are completely inside their respective impedance bands.

The measured far-field radiation patterns of the fabricated



(a)

(b)

Figure 8. Measured radiation patterns of the proposed antenna at different frequencies. (a) Measured radiation patterns at 2.5 GHz. (b) Measured radiation patterns at 3.5 GHz.

prototype at 2.5, and 3.5 GHz in x-z plane and the y-z plane are shown in Fig. 8. Apparently, the proposed antenna radiates LHCP at the lower frequency (2.5 GHz) and RHCP at the upper frequency (3.5 GHz). It can also be found that the cross-polarizations can keep 20 dB lower than the co-polarizations in the bore sight direction at the dual frequencies. However, the patterns at the upper band show a slight deviation from the broadside direction, which is primarily due to the effect of asymmetric antenna structure.

Finally, the measured gains against the frequency for the proposed antenna across the dual bands are shown in Fig. 9. As can be seen, stable gain variations across the dual bands have been achieved and the maximum measured gain is 3.63 dBi at the lower band and 3.86 dBi at the upper band.

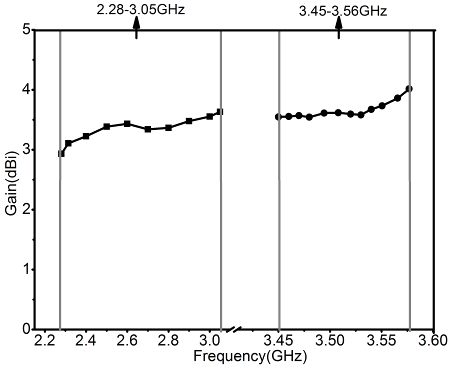


Figure 9. Measured gains of the proposed antenna.

4. CONCLUSION

A dual-band dual-sense circularly polarized CPW-fed slot antenna has been proposed. The proposed antenna can provide impedance bandwidths of 44% for lower band and 7% for upper band, respectively. The 3-dB axial-ratio bandwidths are 30.8%, and 3.1% for the lower (LHCP) and upper band (RHCP) respectively. The compact size, simple structure, multiband coverage, and stable antenna gains across the operating bands make the proposed antenna an attractive candidate for practical applications in the multiband multipolarized systems to mitigate interference effects.

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