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A COMPACT SIZE AND SMALL FREQUENCY RATIO CPW-FED CIRCULAR SLOT ANTENNA FOR GPS/WLAN DUAL-BAND AND CIRCULAR POLARIZATIONS

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Abstract—This paper presents a novel dual-band circularly polarized CPW-fed circular slot antenna with two open-ground rings. The proposed antenna is constructed with two opened-ground rings facing in opposite directions and embedded in the circular slot and the enhanced feed strip of CPW. By way of adjusting the relevant parameters, we can obtain the dualband at 1.57 GHz and 2.46 GHz respectively. A smaller frequency ratio of 1.56 is presented. The measured −10 dB return loss impedance bandwidth are 380 MHz (24.68%) for 1.57 GHz band and 210 MHz (8.33%) for 2.46 GHz band. The measured −3 dB axial ratio bandwidth for 1.57 GHz and 2.46 GHz bands are 13.38% and 8.13%, the polarization of radiation patterns are RHCP and LHCP for each band and the antenna gain are 3.72 and 3.21 dBic respectively.

1. INTRODUCTION

Recently, coplanar waveguide (CPW) antenna has received considerable attention owing to its preferable characteristics, such as easy fabrication, low profile and wide bandwidths. For dual-band applications, several CPW-fed antennas have been developed [1–8]. The

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CPW monopole antennas present the two operating frequencies with a frequency ratio (FR) about 1.37 (2.45 GHz/1.781 GHz) [1], 2.08 (5.0 GHz/2.4 GHz) [2] and 2.79 (5.45 GHz/1.95 GHz) [3]. And the CPW slot antennas exhibit FR about 1.34 (2.475 GHz/1.845 GHz) [4], 1.87 (1.84 GHz/0.98 GHz) and 2.25 (5.35 GHz/2.38 GHz) [5], 1.36 (3.4 GHz/2.5 GHz) [6], 1.375 (2.2 GHz/1.6 GHz) [7] and 1.286 (1.98 GHz/1.54 GHz) [8] individually.

The circularly polarized (CP) antennas are required to implement polarization diversity, in order to prevent degradation due to multipath fading in the propagation environments. Recently, by using the self-similar iterative configuration of the fractal slot antenna, the dual-band and CP operations were obtained [5]. The CP operation was realized by taking a ground plane embedded with an inverted-L slit [6]. The two loaded spiral slots in the ground plane resulted in different senses of circular polarization [7]. A crane-shaped strip was placed in the ground plane to achieve circular polarization [8]. Therefore, a CPW-fed slot antenna designed with CP operation and dual-band is an attractive topic for applications

Since GPS and WLAN functionalities are becoming ubiquitous for the rapid growth of wireless communications. In applications, mobile phones, laptop computers, and PDA contain both GPS and WLAN simultaneously. A dual-band Hilbert slot antenna was supported the GPS and WLAN systems at 1.575 and 2.45 GHz (FR is 1.56) respectively [9]. However, the CP operation was not obtained in this works.

Based on the techniques of circular slot antenna [5], loaded spiral slots in the ground plane [7], crane-shaped strip in the ground plane [8] and the GPS and WLAN functionalities [9], the improved CPW-fed circular slot antenna embedded with two open-ground rings is designed for achieving dual-band and circular polarizations in this paper. The proposed circular slot antenna consists of two opened-ground rings and the enhanced feed strip of CPW. The two opened-ground rings facing in opposite directions can result in different senses of circular polarization. The dual-band operation is achieved by using the enhanced feed strip. Both simulated and experimental results show the performance of the proposed antenna. It is a simply structure and available CPW-fed slot antenna for GPS and WLAN systems.

2. ANTENNA CONFIGURATION AND BASIS

In Fig. 1, the proposed slot antenna is implemented on a commercial substrate. The ground plane under the substrate is square shape and dimension is $W \times L = 70 \times 70\,\mathrm{mm}^2$. The substrate is with enough

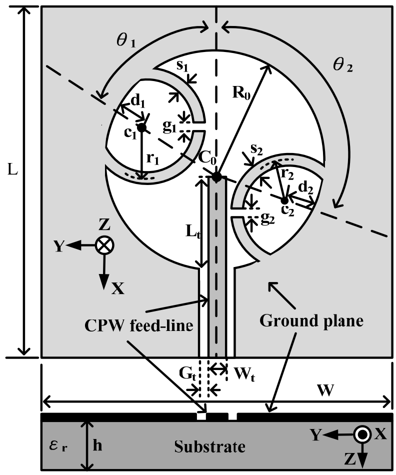


Figure 1. Configuration of the proposed CPW-fed slot antenna.

area of one wavelength square. The $50\,\Omega$ microstrip feed-line is excited with a SMA connector. The FR4 substrate with thickness 0.8 mm and relative permittivity 4.4 is used. The detail dimensions in Fig. 1(b) are $R_0 = 25.0$ mm, $L_t = 25.0$ mm, $W_t = 4.2$ mm, $G_t = 0.3$ mm, $r_1 = r_2 = 13.0$ mm, $s_1 = s_2 = 2.0$ mm, $g_1 = g_2 = 2.0$ mm, $d_1 = 3.86$ mm, $d_2 = 5.14$ mm and $\theta_1 = 57.0°$ and $\theta_2 = 116.5°$.

Since the frequency responses of dual-band are decided by the feed strip and slot dimensions, and the CP characteristics are mainly related to the two opened-ground rings, the variations of the parameters are investigated in Figs. 2(a) and (b). After the second band is determined by the diameter of the circular slot, the first band is related the feed strip. Inspecting the results, Fig. 2(a), the length (L_t) of feed strip increases, the fractional BW in the first band increases slightly, and $L_t = 25.0$ mm is chosen. Analogized to the crane-shaped strip used in the conventional CPW-fed CP antennas [8], and bending the arms of the crane-shaped strip, two open ring-shaped strips designated as opened-ground rings are adopted for modification. The dimensions of the two opened-ground rings are related to the CP characteristics. The radius and the open gap of the opened-ground rings are adjusted to obtain the CP operation. In the results of Fig. 2(b), as the radius of d_1 decreases and the radius of d_2 increases, the AR BW in the dual-band increases, and $d_1 = 38.6$ mm and $d_2 = 51.4$ mm are determined. Inspecting the results of Fig. 2(c), as the gaps of g_1 and g_2 increase, the AR responses in the dual-band shift, and $g_1 = g_2 = 2.0$ mm are used.

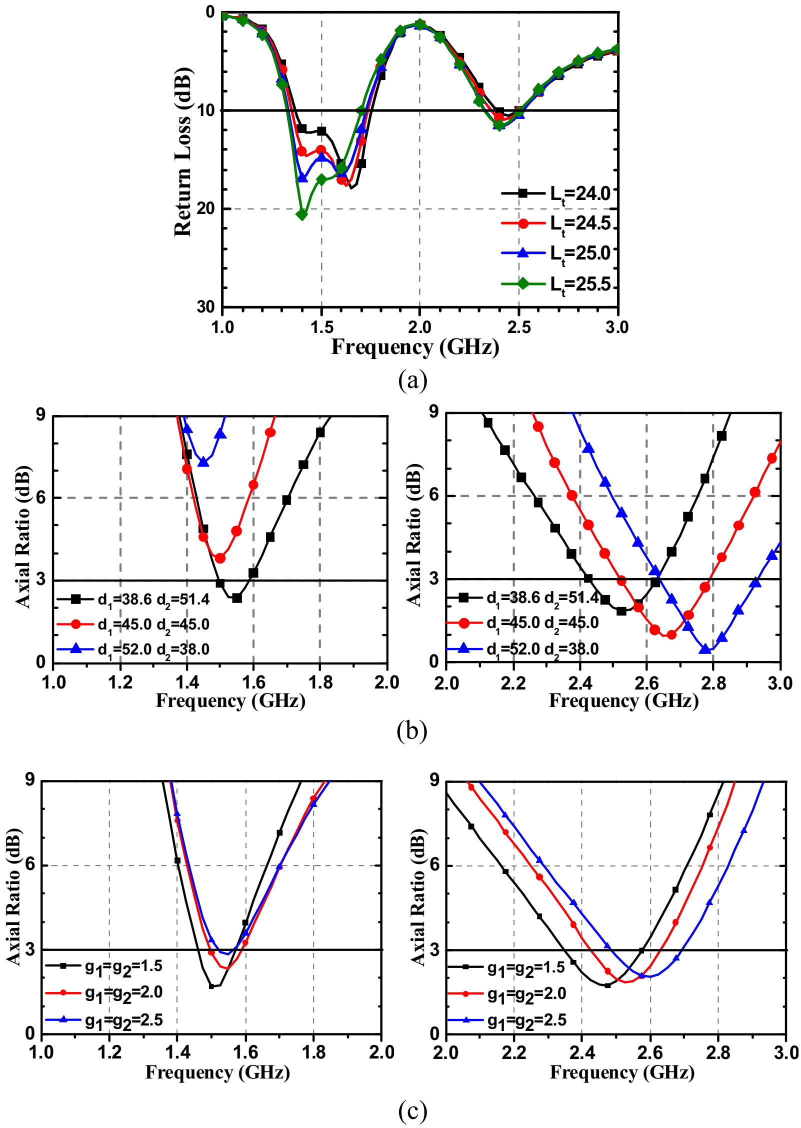


Figure 2. Characteristics of the parameter variations. (a) Variation of feed strip length. (b) Variation of radius of two opened-ground rings. (c) Variation of gaps of two opened-ground rings.

3. SIMULATION AND MEASUREMENT

The spectrums and radiation patterns are simulated by using commercial software of Ansoft HFSS [10]. The return loss spectrums of the proposed antenna are shown in Fig. 3. It is evident that the simulated and measured results of frequency responses are in good agreement. In measurement, while the reflection coefficient is smaller than −10 dB, the frequency responses cover two bands of 1.35 to 1.73 GHz (bandwidth = 380 MHz, 24.68%) and 2.32 to 2.53 GHz (bandwidth = 210 MHz, 8.32%).

Figure 4 illustrates the axial ratio (AR) spectrums. The measured AR −3 dB bandwidths are 13.38% (from 1.45 to 1.66 GHz) and 8.13% (from 2.39 to 2.59 GHz) for each band. CP characteristics are achieved.

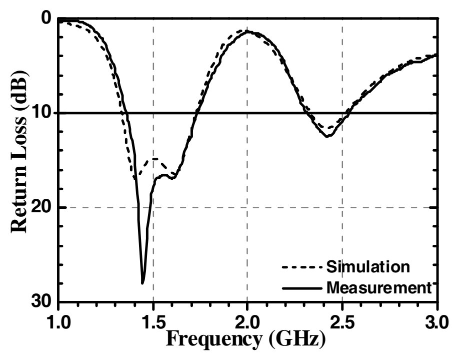


Figure 3. Return loss spectrums of the proposed antenna.

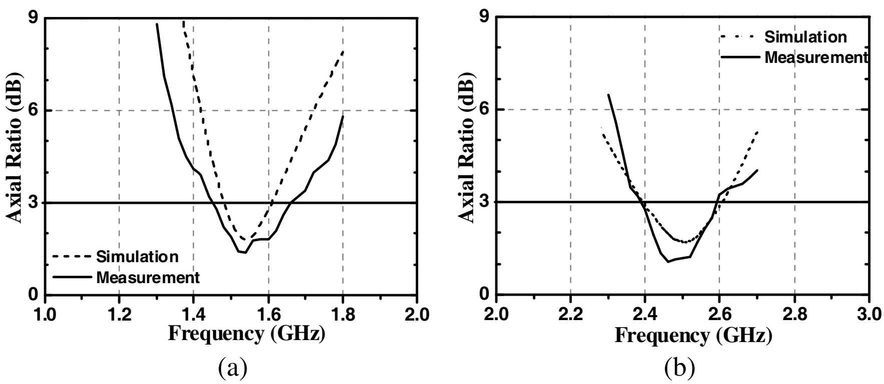
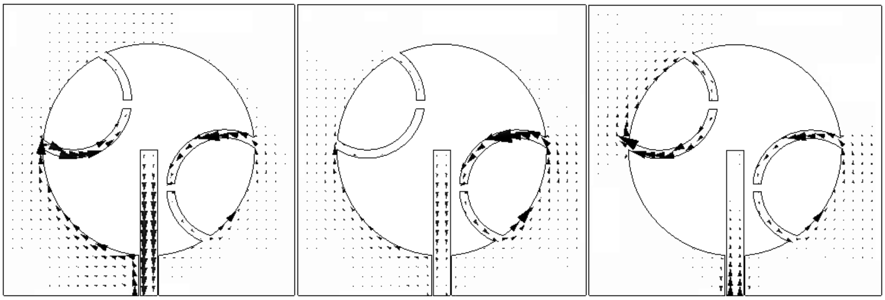
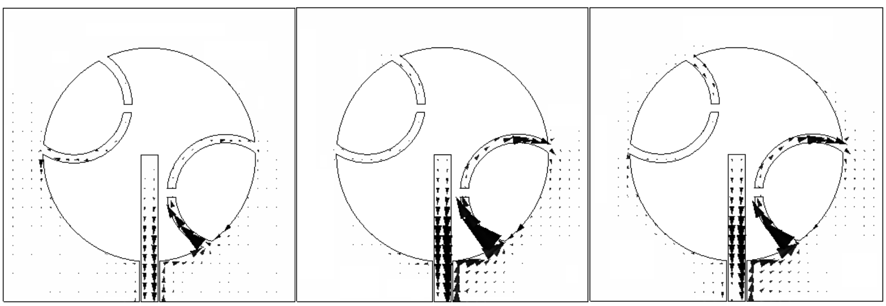


Figure 4. Axial ratio spectrums (a) 1.57 GHz, (b) 2.46 GHz.



(a) (b) (c)

Figure 5. Simulated vector current distributions at 1.57 GHz, (a) 45 degree, (b) 90 degree, (c) 135 degree.



(a) (b) (c)

Figure 6. Simulated vector current distributions at 2.46 GHz, (a) 0 degree, (b) 45 degree, (c) 90 degree.

The frequency ratio is 1.56 (1.57 GHz/2.46 GHz).

Both Fig. 5 and Fig. 6 exhibit the vector current distributions of the proposed antenna. They provide a physical insight on the CP of the antenna. The enhanced feed lines are excited with concentrating current distributions to induce the two opened-ground rings. Figs. 5(a) to (c) show that both opened-ground rings are induced, and the right opened-ground ring dominates the CP due to close the enhanced feed lines. The left-hand circularly polarized (LHCP) is observed at 45°, 90° and 135° phases, which satisfies the quadrature requirement for circular polarization [8]. Thus the 1.57 GHz band generates LHCP radiations mainly in the $+z$ directions. Figs. 6(a) to (c) present that the right opened-ground rings are induced with RHCP at 0°, 45° and 90° phases,

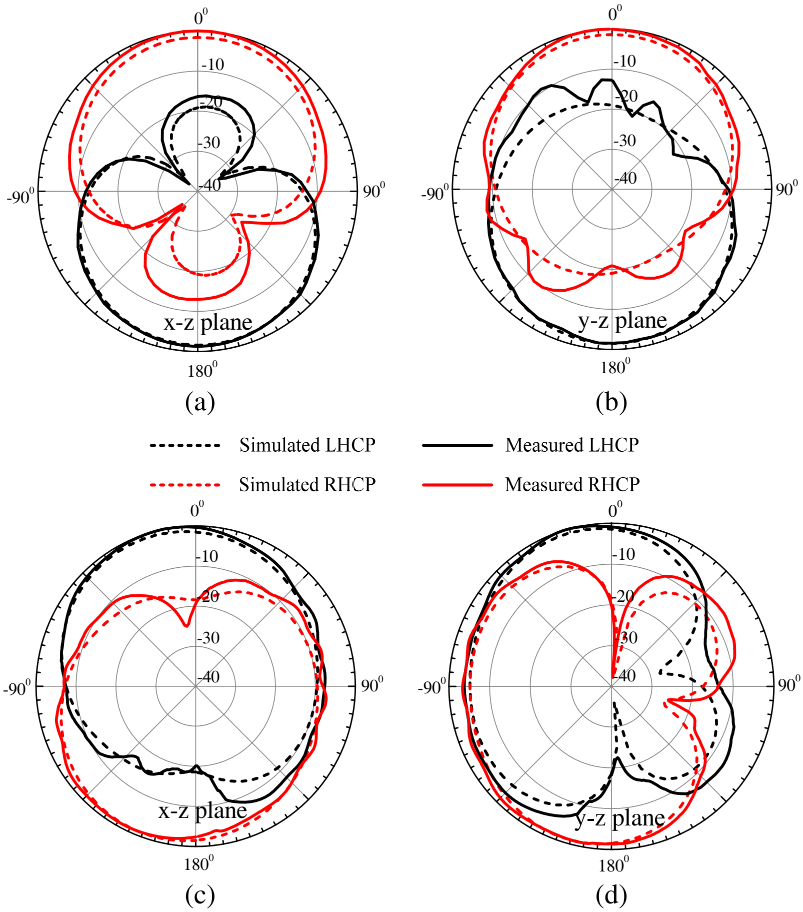


Figure 7. Radiation patterns: (a) x-z plane, (b) y-z plane at 1.57 GHz, (c) x-z plane, (d) y-z plane at 2.46 GHz.

also satisfy the quadrature requirement for circular polarization, the 2.46 GHz band provide RHCP radiations in the $+z$ directions.

In field analyses, Figs. 7(a) to (d) show the measured and simulated two-cut (x-z plane and y-z plane) radiation patterns at 1.57 GHz and 2.46 GHz, respectively. Both the measured and simulated radiation patterns are in good agreement. Since the planar antenna is a bidirectional radiator, thus both sides of the antenna are opposite polarizations. Noted that the maximum fields tilt with $-15°$ to the $+z$ directions at 2.46 GHz band. Because the slot structure operated in

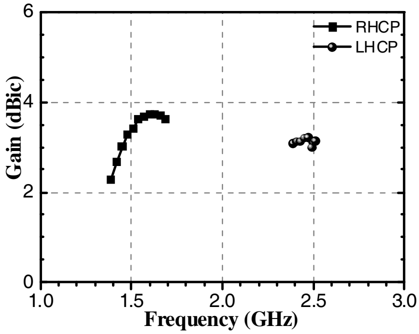


Figure 8. Measured antenna gains.

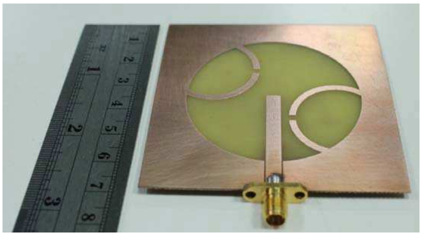


Figure 9. Photograph of proposed antenna.

the 2.46 GHz band mainly, and the asymmetrical opened-ground rings within the slot affects the radiation patterns. In Fig. 8, the measured antenna gains deliver 2.2 $\sim$ 3.72 dBic for 1.57 GHz band, and have approximately 3.21 dBic for 2.46 GHz band. The photograph of the proposed antenna is presented in Fig. 9.

4. CONCLUSION

A novel dual-band circularly polarized CPW-fed circular slot antenna with two open-ground rings is designed and measured. The measured impedance and axial ratio bandwidths are 24.68% and 8.32% for the 1.57 GHz band, and 13.38% and 8.13% for the 2.46 GHz band. The smaller FR of 1.56 and the compact size of $70 \times 70\,\text{mm}^2$ are obtained. The directional patterns with 3.72 dBic and 3.21 dBic peak power gains are obtained for 1.57 GHz and 2.46 GHz bands. The CP radiation patterns deliver RHCP and LHCP in the $+z$ direction for 1.57 GHz and 2.46 GHz bands. For applications, the frequency responses of the proposed antenna are covered in the operation bands of GPS and WLAN systems.

The novelty of this paper is that it is a simple method for accurate designing the dual-band CP CPW-fed circular slot antenna in which the frequency responses of dual-band are decided by the feed strip and slot dimensions, and the CP characteristics are adjusted by the two opened-ground rings. The first band is tuned by the feed strip and the second band is determined by the diameter of the circular slot. The two open-ground rings induce the performance of CP and wide AR bandwidth. GPS and WLAN functionalities are achieved.

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