Single-Feed Wideband Circularly Polarized Antenna With Novel Parasitic Elements

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***Abstract*—A novel wideband crossed dipole loaded with four parasitic elements is investigated in this letter. The printed crossed dipole is incorporated with a pair of vacant quarter rings to feed the antenna. The antenna is backed by a metallic plate to provide an unidirectional radiation pattern with a wide axial-ratio (AR) bandwidth. To verify the proposed design, a prototype is fabricated and measured. The final design with an overall size of 0.46 λ_0 × 0.46 λ_0 × 0.23 λ_0 (λ_0 is the free-space wavelength of circularly polarized center frequency) yields a 10-dB impedance bandwidth of approximately 62.7% and a 3-dB AR bandwidth of approximately 47.2%. In addition, the proposed antenna has a stable broadside gain of 7.9 ±0.5 dBi within passband.**

Keywords—Single-feed; circularly polarized; wideband; parasitic element.

I. Introduction

Circularly polarized (CP) antennas have attracted significant attention due to their numerous advantages over traditional LP antennas. For example, CP radiation can improve multipath interference suppression and reduce polarization mismatch. These features make CP antennas widely used in various wireless communication systems, such as global navigation satellite systems (GNSS), satellite communications, mobile communications, radio frequency identification systems (RFID), and wireless local area networks.

With the trend of high-speed transmission in wireless communication, the demand for CP antennas with wide impedance bandwidth and wide axial-ratio bandwidth is urgent. Single-feed CP crossed dipoles have attracted extensively attention because of the merits of simple structure, wide band, and easy manufacture. Therefore, great efforts have been dedicated to broaden the axial ratio (AR) bandwidth of this type of antenna. The AR bandwidth can be enhanced by using external components, such as parasitic elements [1] [2], unequal power network [3], two capacitive bent slots [4] or a magneto-electric [5]. The second approach is to change the shape of the dipole, such as bowtie [6] [7], rectangular [8] [9], elliptical-shaped [10]. Changing the shape of ground plane and metal cavity can be as an alternative way. Additional minimum AR points can be generated when a crossed dipole is backed by a dual-cavity [11], or four rotated metallic plates [12].

A simple and effective method of using four rotated novel parasitic elements is proposed in this letter. The main principle is to generate two adjacent CP bands. The lower band is excited by the original crossed dipole, while the higher is generated by parasitic elements. The optimized antenna, with an overall dimension of 0.46 λ_0 × 0.46 λ_0 × 0.23 λ_0, is fabricated and measured. The measured reflection coefficient bandwidth for $|S_{11}| \leq$ -10 dB is 62.7% and AR bandwidth for AR ≤ 3dB is 47.2%. Additionally, the antenna has good broadside radiation patterns and yields an average broadside gain of approximately 7.9 ±0.5dBi which is stable over the CP operating bandwidth.

II. Antenna Design

A. Antenna Configuration

The configuration of the proposed crossed dipole antenna is shown in Fig.1 (a), which consists of two crossed strip dipoles arranged orthogonally, four irregular parasitic elements and a metallic plate. The dipole arms are printed on two sides of a 0.8mm thick substrate (εr = 2.65 and tan δ = 0.002) and excited directly by a 50 Ω coaxial cable. The inner conductor of the coaxial cable is soldered to the top dipole arm, while the outer conductor is soldered to the bottom arm and the ground plane. Besides, the arms are connected by a pair of vacant quarter phase delay rings with length of approximately $\lambda_g/4$ (λ_g is the guide wavelength at the center frequency) and therefore 90° phase difference between the two arms is realized to generate CP radiation. Fig.1 (b) shows the side view of the proposed antenna and Fig.1 (c) shows the details. The four rotated corner cut square parasitic elements with a narrow slot are arranged on the top side of the substrate. The metallic plate is placed behind the radiator at a distance of H. The antenna has been simulated and optimized by the Ansoft high-frequency structure simulation. Detailed design parameters of the optimized antenna are as follows: Lm = 140 mm, H = 35 mm, l = 100 mm, W1 = 33 mm, W2 = 19.5 mm, Wd = 6 mm, Ld = 34 mm, d= 2 mm, Rd = 5.7 mm, Wr = 0.3 mm.

B. Antenna Mechanism

Three reference antennas are investigated to show how a wide AR bandwidth can be achieved by using such structure. Fig.2 shows configurations of the reference antennas, including Antenna A which only has rectangular crossed dipoles, Antenna B which loaded with four square parasitic elements, and Antenna C, the proposed design, which is different from

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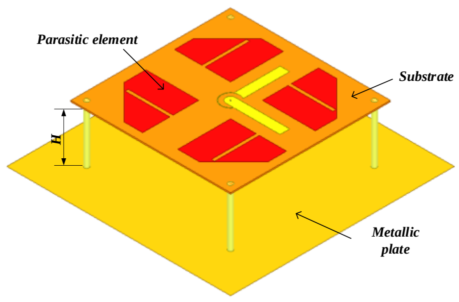
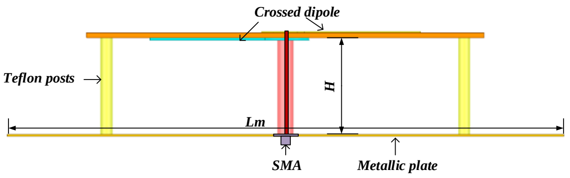
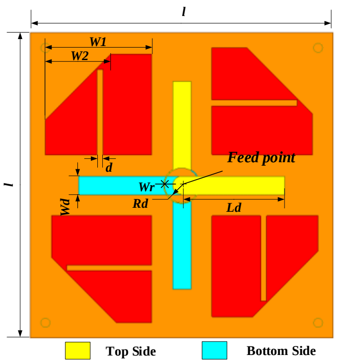


(a)

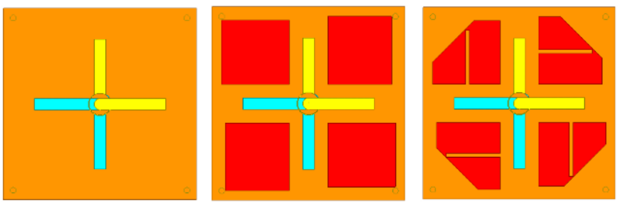


(b)



(c)

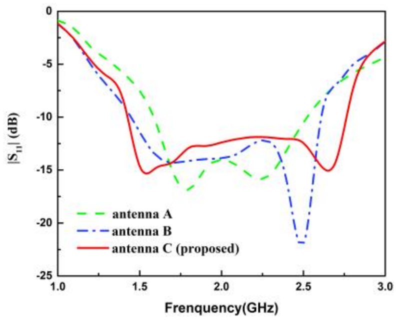
Fig. 1. Configuration of the proposed CP crossed dipole antenna. (a) perspective view. (b) side view. (c) top view.



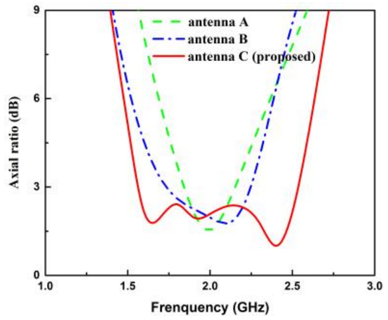
(a) (b) (c)

Fig. 2. Configuration of the reference antennas. (a) Antenna A. (b) Antenna B. (c) Antenna C.

Antenna B by cutting a corner and a narrow slot on the square parasitic elements. Fig.3 shows reflection coefficients, ARs of the reference antennas. Same dimensions are used for each antenna for ease of comparison. With reference to Fig.3 (a), the reflection coefficient varies obviously for each configuration. With the transformation of antenna structure, impedance bandwidth is improved considerably. Correspondingly, the AR bandwidth broadens gradually. Especially a significant change have happened from antenna B to antenna C, providing a broad AR bandwidth of 47 %.



(a)



(b)

Fig.3. Simulated reflection coefficients, ARs of the reference antennas and proposed design. (a) Reflection coefficients. (b) ARs.

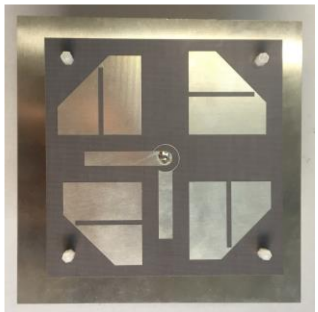


Fig. 4. Prototype of the proposed antenna.

III. Simulated and Measured Results

A prototype of the proposed antenna is fabricated and tested for demonstration. Fig.4 shows the photograph of the prototype, in which four Teflon posts are used to assemble and fix the substrate and the metal reflector.

Fig.5 shows a comparison between simulated and measured reflection coefficients which is measured by network analyzer. The simulated and measured impedance bandwidths (|S11|< -10 dB) of the prototype are 63.5% (1.43–2.76 GHz) and 62.7% (1.48–2.83 GHz), respectively. The simulated and measured 3-dB AR bandwidths (AR < 3 dB) are 47% (1.57–2.53 GHz) and 47.2% (1.62–2.62 GHz), respectively. Reasonable agreement between simulation and measurement can be observed and the small discrepancy is mainly caused by the fabrication error and experimental imperfections. Simultaneously, the proposed antenna obtained average gain of 7.9 ± 0.5dBi within the operating bandwidth as showed in Fig.6. Fig.7 shows simulated and measured radiation patterns of the prototype at frequencies

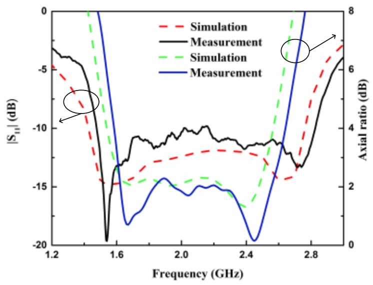


Fig. 5. Simulated and measured reflection coefficient, AR of the prototype.

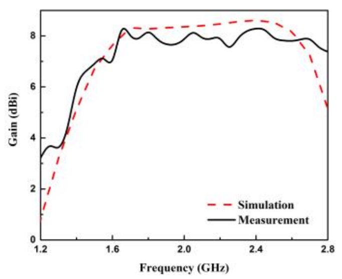


Fig. 6. Simulated and measured gain of the prototype.

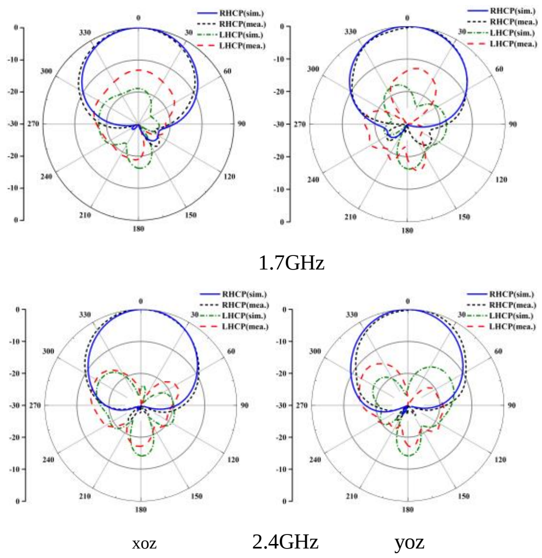


Fig. 7. Simulated and measured radiation patterns of the prototype.

of 1.7, 2.4GHz. A right-hand CP (RHCP) unidirectional wave is obtained.

A comprehensive comparison between the proposed antenna and other reported designs are summarized in Table I. As can be seen that the proposed antenna come to a tradeoff of the low profile, a broad bandwidth, and high gain simultaneously.

IV. Conclusion

In this paper, a printed crossed dipole with four novel rotated parasitic elements is proposed to broaden AR bandwidth. Since a single-feed crossed dipole itself and parasitic elements near the dipole produce two AR minimum points, a wideband CP performance can be easily obtained. The proposed antenna generates RHCP radiation in the far field. It has not only a broad 3dB AR bandwidth of 47%, but also a broad impedance bandwidth of 63.5%. In addition, a stable gain of 7.9 ±0.5dBi is reached within the operating bandwidth.

TABLE I. Performance Comparison

Ref	Size($\lambda_0{}^3$)	S11BW(%)	ARBW(%)	Average Gain(dBi)
[1]	0.97 ×0.97 ×0.22	38.2	28.6	8.34
[2]	0.58 ×0.58 ×0.26	47.73	42.8	6.6
[3]	0.40 ×0.40 ×0.17	66.2	47.8	6.0
[4]	1.05 ×1.05 ×0.19	62.6	37.0	9.0
[6]	0.48 ×0.48 ×0.25	52.1	37.4	6.9
[7]	0.88 ×0.88 ×0.23	57.0	51.0	9.6
[8]	2.06 ×2.06 ×0.13	66.9	55.1	10.4
[9]	0.45 ×0.45 ×0.24	50.2	27.0	6.2
Prop	0.46×0.46 ×0.23	63.5	47.0	8.4

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