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A Single-Feed Circularly Polarized Magnetoelectric Dipole Antenna for Wideband Wireless Applications

Chao-Qiang Feng*, Fu-Shun Zhang, Han-Jing Zhang, and Jun-Xiu Su

Abstract—A wideband circularly polarized magnetoelectric dipole antenna fed by a Γ-shaped structure is investigated. In the design, a pair of vertical plates connected to ground work as a magnetic dipole, while a pair of rotationally symmetric horizontal plates with strips bent downward work as an electric dipole. And four metallic plates are vertically added on edges of the ground, forming a cavity reflector with four gaps to improve the axial ratio (AR) bandwidth. Measurements show that the antenna has a wide impedance bandwidth of 102% from 1.35 GHz to 4.2 GHz for voltage standing wave ratio (VSWR) ≤ 2 and a 3-dB AR bandwidth of 79.7% from 1.6 GHz to 3.72 GHz, over which the antenna gain varies from 5.4 dBic to 10.6 dBic. Furthermore, the antenna exhibits right-hand circular polarization and has good unidirectional radiation characteristic. The proposed antenna can be applied to wideband wireless applications.

1. INTRODUCTION

Since the magnetoelectric (ME) dipole antenna was first proposed by Luk and Wong [1], various wideband ME dipole antennas have been investigated to meet requirements of modern wireless communication systems. The ME dipole antennas presented in [2–5] all achieve wide impedance bandwidth over 44% (VSWR ≤ 2). Unfortunately, these antennas can only be applied to linearly polarized applications.

In recent years, circularly polarized (CP) radiation has the advantages of multipath interference suppression and polarization mismatch reduction. ME dipole antennas with circular polarization characteristic have attracted extensive attention. Meanwhile, for high-speed transmission in wireless communications, CP antennas with wide axial ratio (AR) bandwidth are increasingly required. In [6], a crossed dipole loaded with an ME dipole is proposed, which achieves a 3-dB AR bandwidth of 27%. By adjusting shapes and dimension of a linearly polarized ME dipole antenna [7], a wideband CP antenna is obtained, which has a 3-dB AR bandwidth of 47.7%. An ME dipole antenna fed by an L-shaped probe is designed in [8]. This antenna employs four parasitic patches perpendicular to the probe to obtain a wide AR bandwidth of 56.2%. Moreover, an ME dipole antenna with a 3-dB AR bandwidth of 71.5% is designed in [9]. However, its size is extremely large. Although the antenna proposed in [10] has dual-band and dual-sense CP characteristic, its AR bandwidth is narrow in both bands, only 29% and 13%, respectively.

In this paper, a wideband single-feed circularly polarized magnetoelectric dipole antenna fed by a Γ-shaped structure is investigated, and its overall dimension is $0.81\lambda_0 \times 0.7\lambda_0 \times 0.16\lambda_0$ (λ_0 is the free-space wavelength at 1.61 GHz). The proposed antenna consists of a pair of grounded vertical plates working as a magnetic dipole and a pair of rotationally symmetric horizontal plates working as an electric dipole. The antenna can achieve right-hand circular polarization on the broadside. Additionally, at the end of

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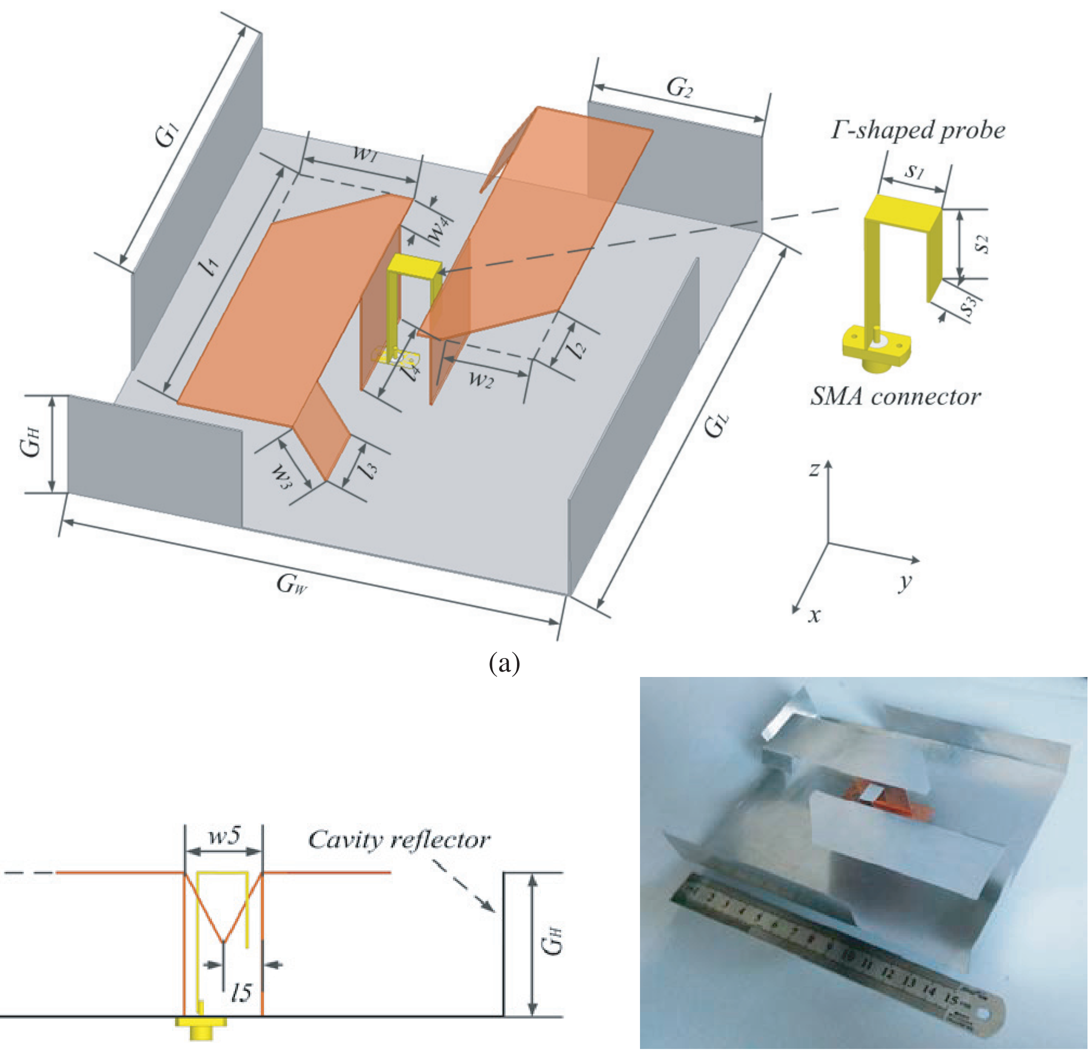
the horizontal plates, strips bent downward are introduced, enhancing the 3-dB AR bandwidth. Four metallic plates are vertically added on edges of the ground, forming a cavity reflector with four gaps. As a result, the AR bandwidth can be improved extremely. The proposed ME dipole antenna is fabricated with metallic plates and has the advantages of easy manufacture and low cost. Experimentally, the proposed antenna exhibits good unidirectional radiation characteristic and delivers a wide impedance bandwidth of 102% and a 3-dB AR bandwidth of 79.7%. Compared with the previous works in [6–10], this antenna has a wider bandwidth and more compact configuration.

2. ANTENNA DESIGN AND CHARACTERISTICS

The detailed geometry of the proposed ME dipole antenna is illustrated in Figure 1. This antenna consists of a Γ-shaped feed structure, a pair of vertical plates, a pair of rotationally symmetric horizontal plates, and a cavity reflector. As shown in Figure 1(a), the vertical plates are connected at the center of the ground, which can be equivalent to a magnetic dipole, while the horizontal plates work as an electric dipole. For improving the AR bandwidth, edges of the horizontal plates are chamfered,



(a) (b) (c)

Figure 1. Geometry and fabricated prototype of the proposed antenna. (a) 3D view. (b) Side view. (c) Photograph of the fabricated antenna.

and an extra strip bent downward at the end of each horizontal plate is introduced. Additionally, four metallic plates are vertically added on edges of the ground, forming a cavity reflector with four gaps. As a result, not only the AR bandwidth can be expanded extremely, but also a lower backward radiation can be obtained. Furthermore, with the Γ-shaped feed structure, the proposed antenna obtains a wide impedance bandwidth. In order to connect the Γ-shaped feed structure to the SMA connector, a hole with radius of 2 mm is punched on the ground. Figure 1(b) shows the side view of the prototype. Meanwhile, Figure 1(c) depicts a photograph of the fabricated antenna, which has an external dimension of 150 mm × 130 mm × 30 mm. The detailed dimensions of the proposed antenna are as follows: $G_L = 150$ mm, $G_W = 130$ mm, $G_H = 30$ mm, $G_1 = 100$ mm, $G_2 = 45$ mm, $l_1 = 94$ mm, $w_1 = 30$ mm, $l_2 = 20$ mm, $w_2 = 23.7$ mm, $l_3 = 19$ mm, $w_3 = 17.4$ mm, $l_4 = 30$ mm, $w_4 = 10$ mm, $l_5 = 8.8$ mm, $w_5 = 17.6$ mm, $s_1 = 11.5$ mm, $s_2 = 16$ mm, $s_3 = 7$ mm.

For better understanding the design procedure of the proposed antenna, three antenna structures are modeled and simulated by using ANSYS HFSS, as shown in Figure 2. First, we investigate an ME dipole without strips bent downward and cavity, namely Ant 1. Edges of the horizontal plates in Ant 1 are chamfered. Next, in Ant 2, strip bent downward at the end of each horizontal plate is introduced. Finally, on the basis of Ant 2, four metallic plates are vertically added on edges of the ground, forming a cavity reflector with four gaps. Performances in terms of simulated VSWR and AR characteristics are depicted in Figure 3. It can be seen that with the Γ-shaped feed structure, all these antennas can achieve an impedance bandwidth of more than 90%. However, there is a significant difference in the AR bandwidth. For Ant 1, edges of the horizontal plates are chamfered, making the currents flow more along the longer edge. Therefore, a circular polarization radiation is achieved. Nevertheless, the AR bandwidth is very narrow. In Ant 2, the strips bent downward have the same effect as chamfered edges stated above. Moreover, the strips extend the current path, shift the minimum AR point to lower frequency, and improve AR bandwidth at high frequency simultaneously. In Ant 3,

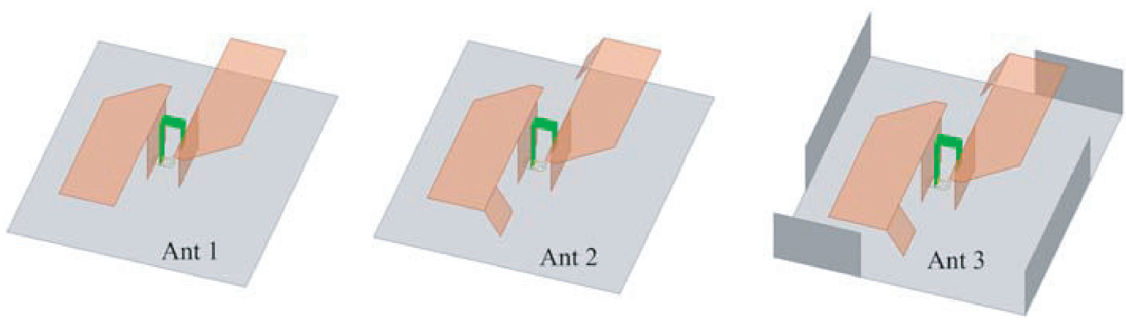


Figure 2. Configurations of the prototypes of Ant 1 to Ant 3.

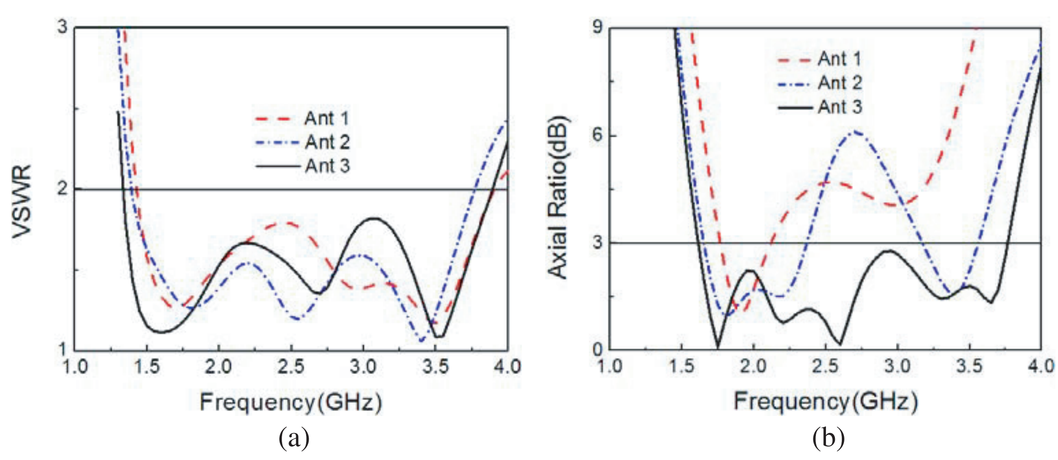


Figure 3. The simulated results of Ant 1 to Ant 3. (a) VSWR. (b) AR.

four metallic plates are introduced. Owing to the strengthened coupling between four metallic plates and the horizontal plates, two additional minimum AR points are generated, substantially broadening the 3-dB AR bandwidth. After optimization, a 3-dB AR bandwidth of 80% (1.61 GHz–3.76 GHz) is obtained.

In order to further explain the CP mechanism, the surface current distributions of the electric dipole at 1.8 GHz and 3.5 GHz for different time phases of 0°, 90°, 180°, and 270° are examined and depicted in Figure 4, respectively.

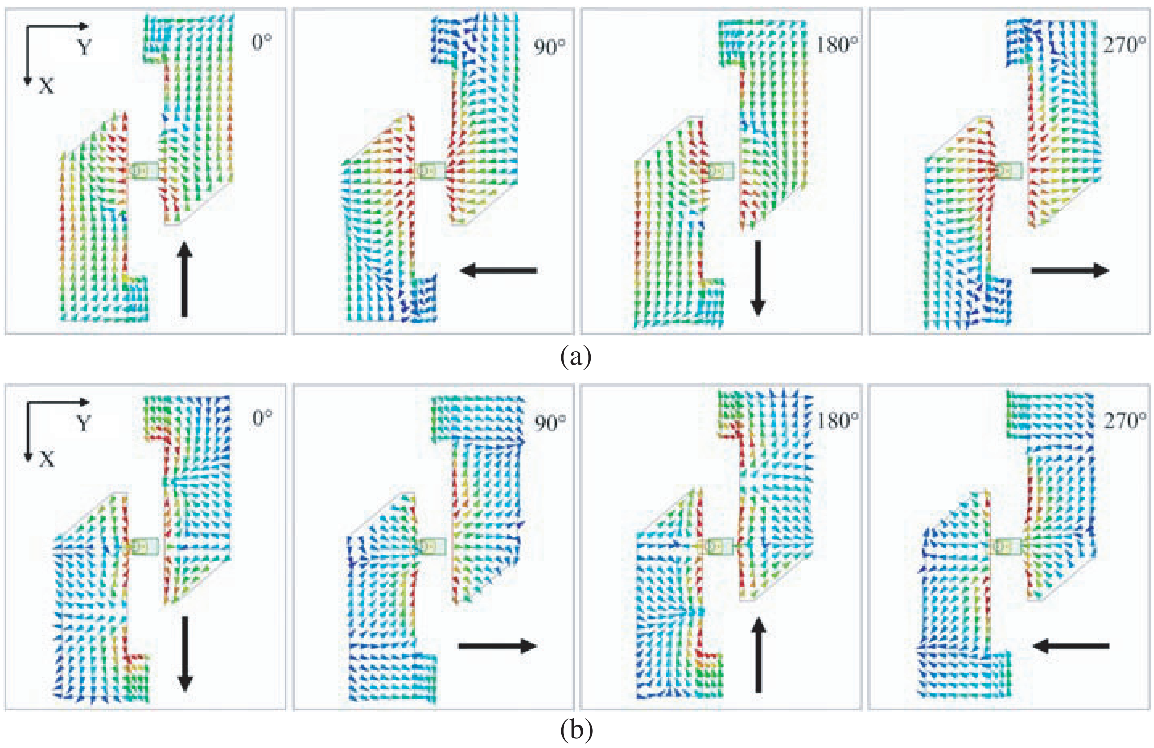
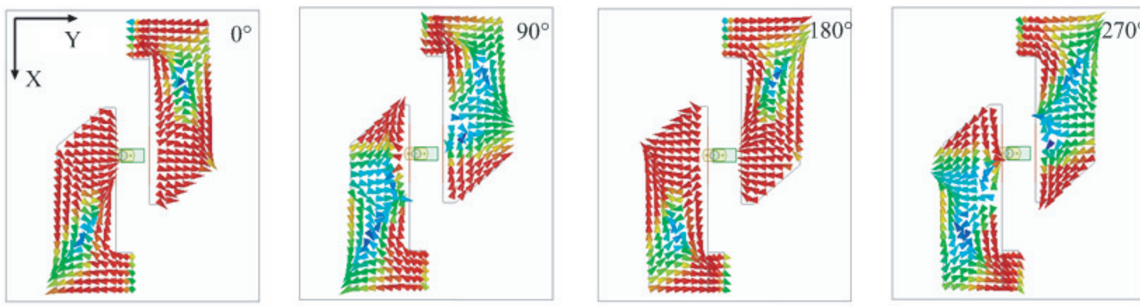


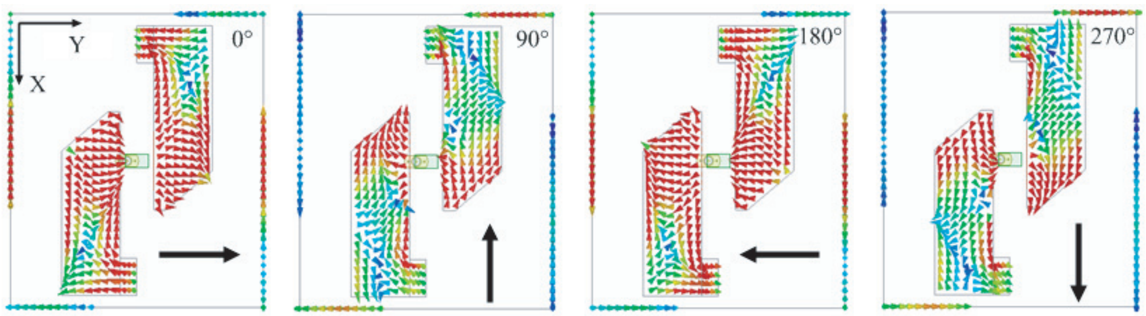
Figure 4. Simulated surface current distributions at different time phases of 0°, 90°, 180°, and 270°. (a) At 1.8 GHz. (b) At 3.5 GHz.

It can be seen from Figure 4(a) that when the phase is equal to 0°/90°/180°/270°, surface currents flow along the direction of −180°/−90°/0°/90° with reference to $+X$-axis. In other words, as the phase varies, surface currents on the electric dipole rotate in counterclockwise direction. Consequently, a right-hand circular polarization in $+Z$ direction is generated at 1.8 GHz. With reference to Figure 4(b), when the phase is equal to 0°, although there are surface currents in opposite direction on the electric dipole, the predominant surface currents are in $+X$ direction. Similarly, when the phase is equal to 180°, the predominant surface currents are in $-X$ direction. Hence, a right-hand circular polarization in $+Z$ direction can also be generated at 3.5 GHz.

Besides, in order to explain how the AR bandwidth is enhanced, surface current distributions of Ant 2 and Ant 3 at 2.6 GHz for different time phases of 0°, 90°, 180°, and 270° are examined and shown in Figure 5. As shown in Figure 5(a), there is a weak CP field at 2.6 GHz for Ant 2. After four metallic plates are introduced, strengthened coupling exists between four metallic plates and the horizontal plates, and the surface current distributions are changed. It can be seen from Figure 5(b) that the currents at the end of electric dipoles are weakened, especially when phases are equal to 90° and 270°. The currents disturbing the CP field decrease, making the CP field generated better at 2.6 GHz. Therefore, the AR bandwidth is enhanced.

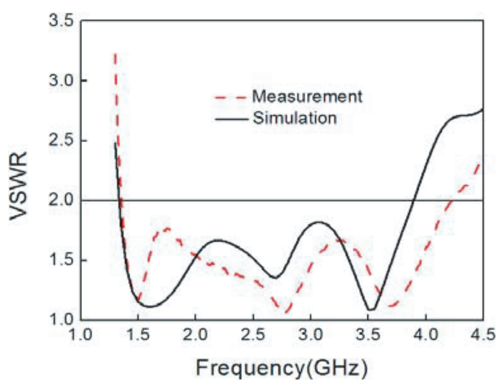


(a)

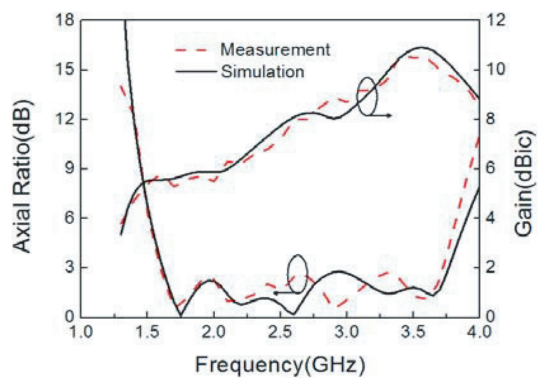


(b)

Figure 5. Simulated surface current distributions of Ant 2 and Ant 3 at different time phases of 0°, 90°, 180°, and 270°. (a) Ant 2. (b) Ant 3.



(a)



(b)

Figure 6. Measured and simulated VSWR, AR and gain of the proposed antenna. (a) VSWR. (b) AR and gain.

3. EXPERIMENTAL RESULTS AND COMPARISON

For verification, the proposed antenna is fabricated and measured. Figure 6 depicts simulated and measured results for the fabricated antenna. It can be observed that there is reasonable agreement between measured and simulated results. With reference to Figure 6(a), simulated and measured impedance bandwidths for VSWR ≤ 2 are 97% (1.34–3.86 GHz) and 102% (1.35–4.2 GHz), respectively. Figure 6(b) shows that the simulated 3-dB AR bandwidth is 80% (1.61–3.76 GHz), and the measured 3-dB AR bandwidth is 79.7% (1.6–3.72 GHz). Meanwhile, broadside gain results are also illustrated in Figure 6(b). The measured broadside gain varies from 5.4 dBic to 10.6 dBic over the AR bandwidth. It is noted that there is a slight difference between simulation and measurement, perhaps due to the error of fabrication and imperfection of the test environment.

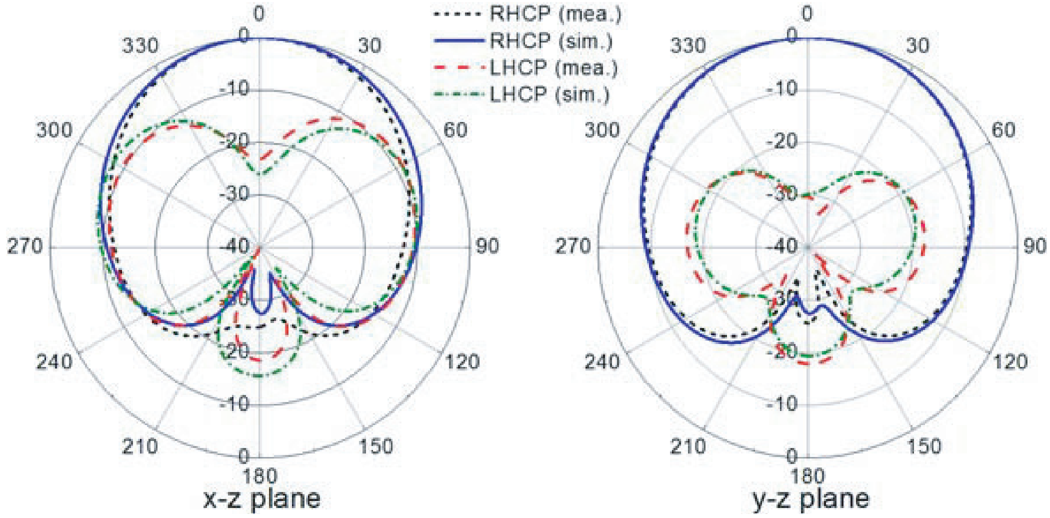


Figure 7. Measured and simulated radiation patterns of the proposed antenna at 1.8 GHz.

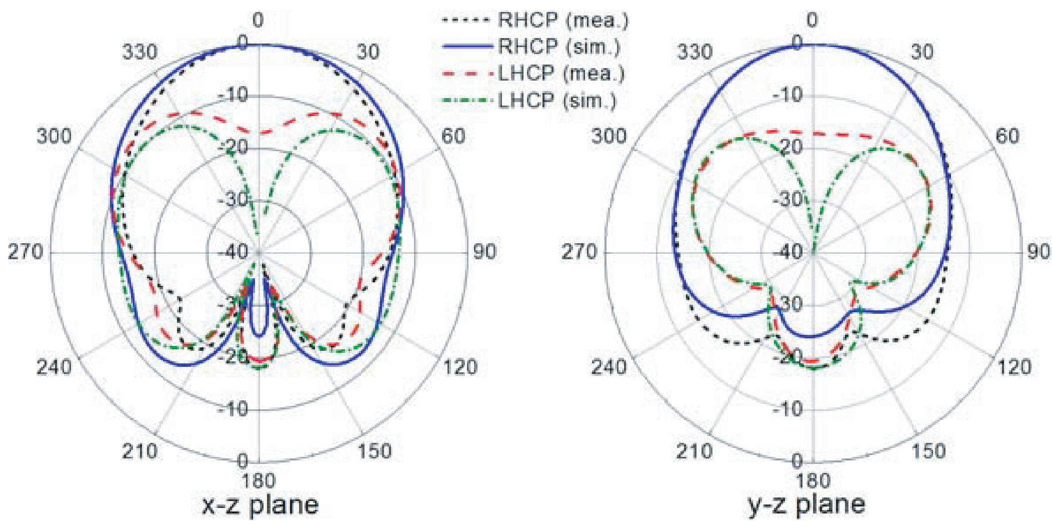


Figure 8. Measured and simulated radiation patterns of the proposed antenna at 2.6 GHz.

Table 1. Comparison between the proposed antenna and the designs reported previously.

References	Size (λ_0^3)	Impedance bandwidth	3-dB AR bandwidth	Average Gain (dBic)
[6]	$0.56\lambda_0 \times 0.56\lambda_0 \times 0.14\lambda_0$	59.8%	26.8%	8
[7]	$0.90\lambda_0 \times 0.90\lambda_0 \times 0.23\lambda_0$	73.2%	47.7%	7.5
[8]	$1.2\lambda_0 \times 1.2\lambda_0 \times 0.2\lambda_0$	82.4%	56.2%	7.7
[9]	$1.01\lambda_0 \times 0.81\lambda_0 \times 0.17\lambda_0$	65%	71.5%	8
[10]	$0.83\lambda_0 \times 0.83\lambda_0 \times 0.25\lambda_0$	45%, 44.6%	29%, 13%	8.5
This work	$0.81\lambda_0 \times 0.7\lambda_0 \times 0.16\lambda_0$	102%	79.7%	7.7

λ_0: wavelength at the lowest frequency of CP band.

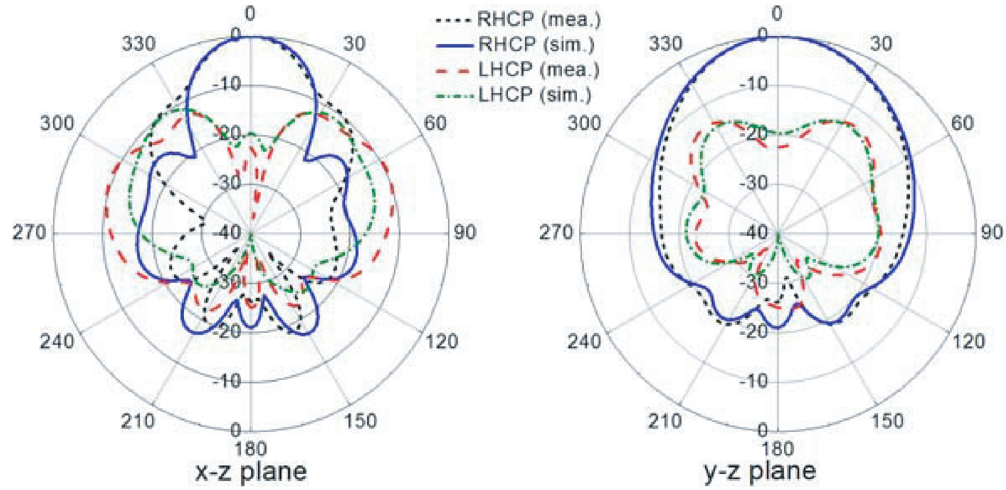


Figure 9. Measured and simulated radiation patterns of the proposed antenna at 3.5 GHz.

Simulated and measured normalized radiation patterns of the fabricated prototype in X-Z plane and Y-Z plane at frequencies of 1.8 GHz, 2.6 GHz, and 3.5 GHz are plotted in Figure 7, Figure 8 and Figure 9, respectively. The antenna generates right-hand circularly polarized fields, and measured results agree well with the simulated ones. In addition, a comparison between the proposed antenna and other ME dipole antennas reported previously in references is summarized in Table 1, which indicates that the proposed antenna has a wider impedance bandwidth and AR bandwidth. Furthermore, this antenna is more compact than antennas in references except [6].

4. CONCLUSION

In this paper, a wideband single-feed circularly polarized magnetoelectric dipole antenna is investigated. The proposed antenna, excited by a Γ-shaped feed structure, consists of a pair of grounded vertical plates working as a magnetic dipole and a pair of rotationally symmetric horizontal plates with strips bent downward working as an electric dipole. Four metallic plates are vertically added on edges of the ground, forming a cavity reflector with four gaps to improve the AR bandwidth. With an overall dimension of 150 mm × 130 mm × 30 mm, the antenna has a wide impedance bandwidth of 102% from 1.35 GHz to 4.2 GHz for VSWR ≤ 2, a 3-dB AR bandwidth of 79.7% from 1.6 GHz to 3.72 GHz over which the antenna gain varies from 5.4 dBic to 10.6 dBic. Additionally, the proposed antenna has the outstanding merits of easy manufacture, low cost and good unidirectional radiation characteristic. With these inherent characteristics, the proposed antenna is suitable for wideband wireless applications.

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