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A Simple Dual-Wideband Magneto-Electric Dipole Directional Antenna

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Abstract—A simple dual-wideband magneto-electric (ME) dipole directional antenna is proposed in this paper. The antenna is composed of a ground plane, four Γ-shaped parasitic strips and an ME dipole fed by a Γ-shaped feed strip. Simulated results show that the ME dipole can only work in the higher frequency band from 1.7 to 2.7 GHz. By adding four Γ-shaped parasitic strips at each corner of the ground plane, the lower frequency band ($0.788 \sim 1.17$ GHz) impedance matching is improved. The antenna is prototyped and measured. Measured results show that the antenna obtains -10 dB impedance bandwidths of 39% ($0.788 \sim 1.17$ GHz) and 51.7% ($1.62 \sim 2.75$ GHz) for the lower and higher bands. The achieved gains are 5.5 ± 0.5 dBi in the lower frequency band and 7 ± 1 dBi in the higher frequency band. The proposed antenna has good impedance and directional radiation characteristics in the whole frequency band. It can be widely used for 2G, 3G, LTE, WLAN, etc. communication systems.

1. INTRODUCTION

The development of various wireless communication systems increases the demands for wideband antennas. As an essential part of wireless communication systems, antenna should provide a reliable wireless link, have low cost and low profile. The bandwidth of these antennas should be also wide enough to cover the 2G, 3G and LTE mobile communication frequency bands. Hence these antennas should operate in $0.806 \sim 0.96$ GHz and $1.71 \sim 2.69$ GHz bands, and display omnidirectional or directional radiation performance for practical application consideration. Recently, various wide bandwidth omnidirectional antennas have been proposed in [1–5]. The literatures about dual-wideband directional antennas are relatively few. Directional antenna can increase spatial reuse ratio and reduce energy consumption for wireless networks.

Different kinds of dual-band directional antennas are proposed in [7–10]. The antenna proposed in [7] consists of a pair of printed dipoles for the lower frequency band and two pairs of dipoles for the higher frequency band. Luk and Wong proposed ME dipole antennas in [6] firstly, and then ME dipole antennas attract much attention from several research institutions and scholars. Different types of ME dipole antennas were proposed in [6–15]. As discussed in [6–15], ME antennas have outstanding radiation and impedance bandwidth performance. A dual-band directional antenna is presented in [8], and the antenna consists of an irregular shorted patch and three planar dipoles. A V-slot is loaded on the planar dipole acting as a capacitive loading in the lower frequency band ($0.780 \sim 1.1$ GHz), enhancing the band impedance matching. Two additional smaller planar dipoles are placed and connected to the irregular short patch for achieving another wideband performance in the higher frequency band ($1.58 \sim 2.62$ GHz). A dual-wideband double-layer ME dipole antenna with a modified horned reflector was proposed in [9]. A double-layer folded electric dipole structure with a certain inclination is utilized to provide wideband nature by changing the current distribution. A feeding structure with a U-shaped and tapered line is designed to reduce the size and enhance the impedance matching performance. The

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radiation performance is improved by using a modified horn-shaped reflector. The antenna can achieve bandwidths of 24.4% (0.79 ∼ 1.01 GHz) for the lower frequency band and 67.3% (1.38 ∼ 2.78 GHz) for the higher band. Though the dual-wideband characteristics have been realized in the above references, some defects, such as the main beam splitting at higher frequencies, always exist in the dual-band ME dipole directional antennas.

In this paper, we propose a dual-wideband ME dipole directional antenna. The ME dipole is composed of two isosceles trapezoid patches, two rectangle short patches and a Γ-shaped feed strip. Four Γ-shaped parasitic strips are added at the corner of the ground plane as capacitive and inductive loads to extend the lowest frequencies of the operating band. The antenna covers the lower frequency band from 0.778 GHz to 1.108 GHz (33.7%) and higher frequency band from 1.567 GHz to 2.8 GHz (56.5%) for VSWR ≤ 2. The achieved gains of the antenna are greater than 5 dBi for the lower frequency band and 7.4 dBi for the higher frequency band, respectively. To verify the design principles, the antenna is fabricated and measured in this paper. The simulated and measured reflection coefficients and radiation results show good agreement, and the radiation patterns are stable in the higher frequency band.

2. ANTENNA DESIGN AND CONFIGURATION

The geometry of the proposed antenna is shown in Figure 1. The antenna is designed with center resonant frequencies at $f_L = 0.88$ GHz ($\lambda_L = 340$ mm) and at $f_H = 2.2$ GHz ($\lambda_H = 136$ mm), respectively. Figure 1(a) shows that the antenna is composed of a square ground plane, four Γ-shaped parasitic strips and an ME dipole fed by a Γ-shaped feed strip. The ME dipole is fixed at the center of the ground plane. The dimension of the ground plane is $180 \times 180\,\text{mm}^2$ ($0.53\lambda_L \times 0.53\lambda_L\,\text{mm}^2$). The ME dipole consists of two Γ-shaped patches with a height of 42 mm ($0.3\lambda_H$). The distance between them is about 19 mm. A Γ-shaped feed strip is used for exciting the ME dipole at the center of the ground plane, and the gap between the strip and the ME dipole is 2.3 mm, as shown in Figure 1(c). We design a special structure at the end of the strip to weld easily to inner conductor of the coaxial line. This structure does not change the impedance matching in the operating frequency band. Four Γ-shaped parasitic strips are applied at each corner of the ground plane as shown in Figure 1(a), and

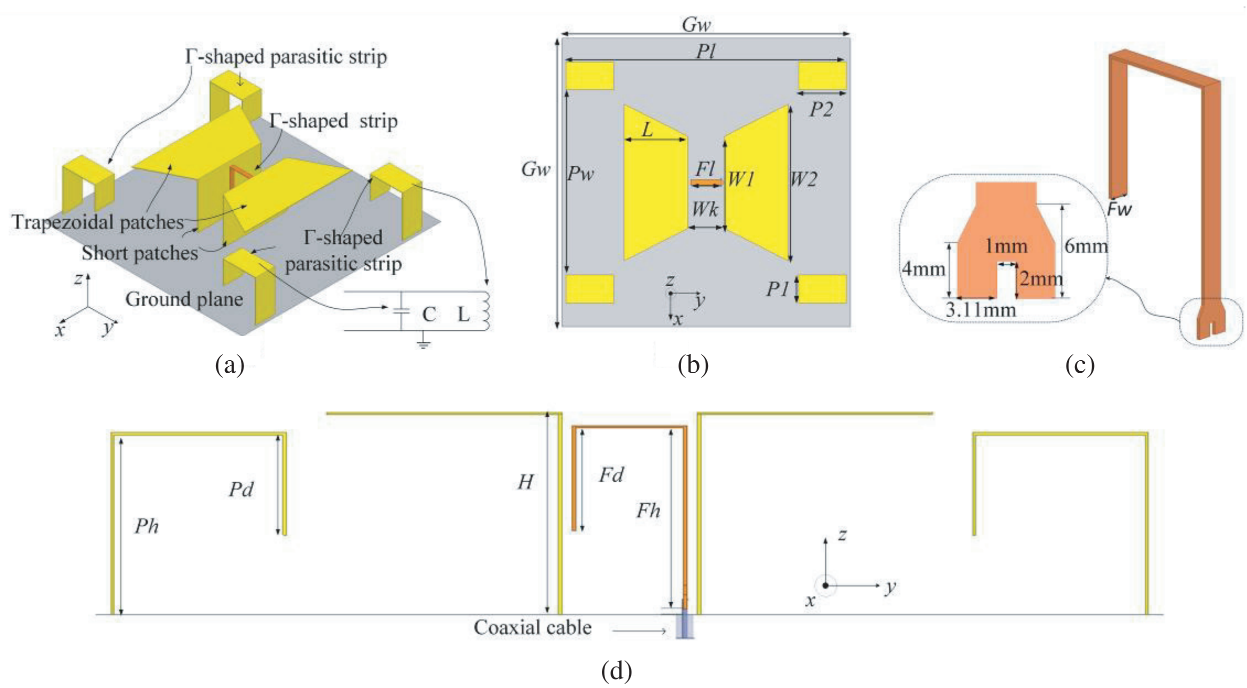


Figure 1. Geometry of the proposed antenna. (a) 3D view of the antenna, (b) top view of the antenna, (c) 3D view of the feed strip and (d) side view of the antenna.

the matching of the lower frequency band is enhanced. The parameters of the antenna are studied by ANSYS High Frequency Structure Simulation 15 (ANSYS HFSS 15). Detailed parameter values are listed as follows (unit: mm): $Gw = 180$, $Pl = 174$, $Pw = 116$, $Pd = 20.9$, $Ph = 37.3$, $P_1 = 17.4$, $P_2 = 29.1$, $W_1 = 57.6$, $W_2 = 77.6$, $Wk = 23.3$, $Fh = 37.8$, $Fd = 21.5$, $Fl = 18.7$, $Fw = 3.2$, $H = 42$.

3. RESULTS AND DISCUSSION

The ME diploe antenna presented in [11–15] can only work in a single band without a relatively lower frequency band. In this paper, the ME antenna still radiates some energy if we do not consider the impedance matching characteristic in the lower frequency band. The radiation patterns of the ME antenna in the lower frequency band are shown in Figure 2. It can be seen that the ME antenna has strong backward radiation patterns from 0.8 GHz to 0.89 GHz and front radiation patterns from 0.89 GHz to 1.04 GHz, respectively.

Here, we will make a detailed explanation about why the antenna radiates to the backward direction. The ME dipole can be regarded as a combination of two short patches and trapezoidal patches, as shown in Figure 1 (a). The distance between the short patches and edge of the floor is about $0.25\lambda_L$. The ground plane demonstrates inductive feature when the frequency band is larger than f_L and capacitive feature when the frequency band is less than f_L. According to Yagi antenna theory, if the ground plane displays capacitive feature, it will have director function. Conversely, if the ground plane displays inductive feature, it will have reflector function. Hence, the ME antenna radiates to the backward direction in the lower frequency band and to the front direction in the upper frequency band, as shown in Figure 2.

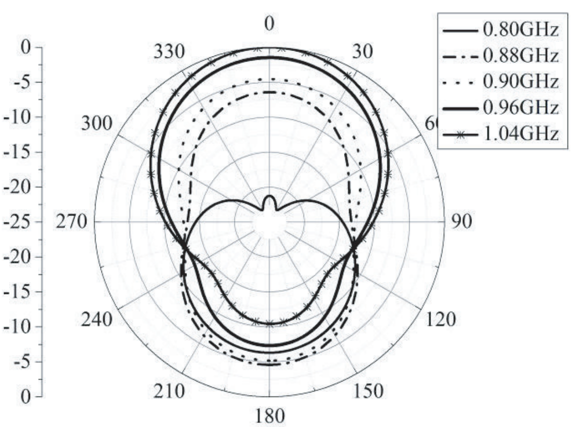


Figure 2. The *xoz*-plane radiation patterns of low frequency band without parasitic strips.

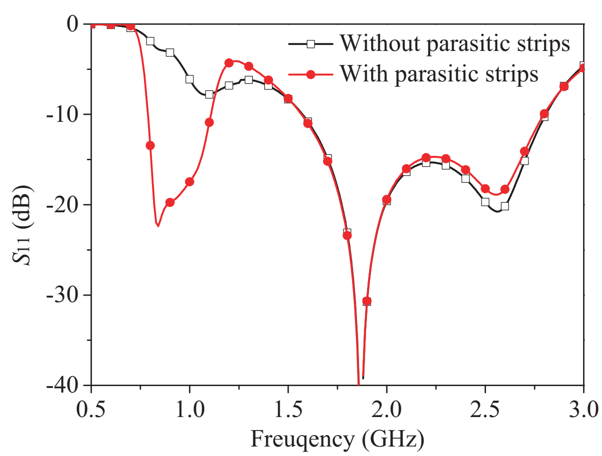


Figure 3. Simulated S_{11} for without/with parasitic strips.

In order to improve the ME dipole antenna's impedance matching and radiation performance, four Γ-shaped parasitic strips are added at each corner of the ground plane. The Γ-shaped parasitic strips are equivalent to LC parallel resonant circuits. The strips improve the impedance matching in the lower frequency band and have little influence on the reflection coefficient of higher frequency band as shown in Figure 3. The input impedance of the lower frequency band is shown in Figure 4. The four Γ-shaped parasitic stubs make the input impedance smoother in the wanted frequency band. The real part of the impedance is near 50 Ω, and the imaginary part of the impedance floats near zero in the desired frequency band. When the Γ-shaped parasitic strips are added at the ground plane, the equivalent length of the ground plane is also added. The ground plane displays inductive function in the desired lower frequency band. According to Ya-gi antenna theory, if the ground plane displays inductive feature, it will act as a director so that the antenna radiate to the front direction in the lower frequency. The *xoz*-plane radiation patterns of the antenna with four Γ-shaped parasitic strips are shown in Figure 5. Four Γ-shaped parasitic strips not only improve the impedance matching but also make the antenna

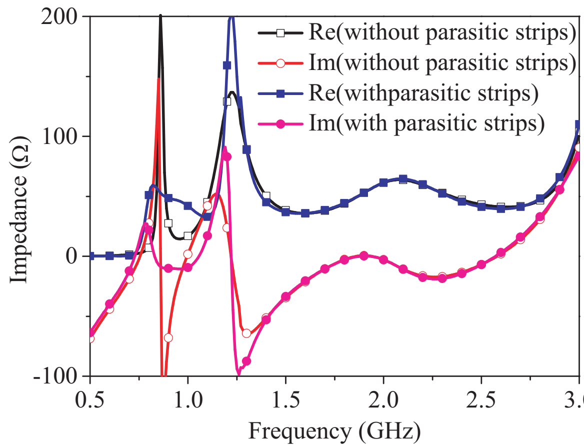


Figure 4. The input impedance in the whole frequency band.

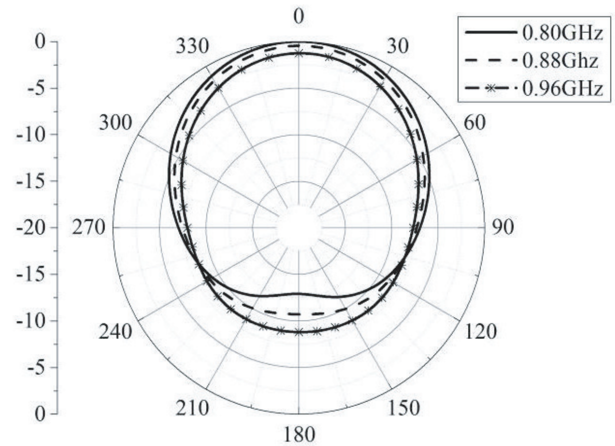
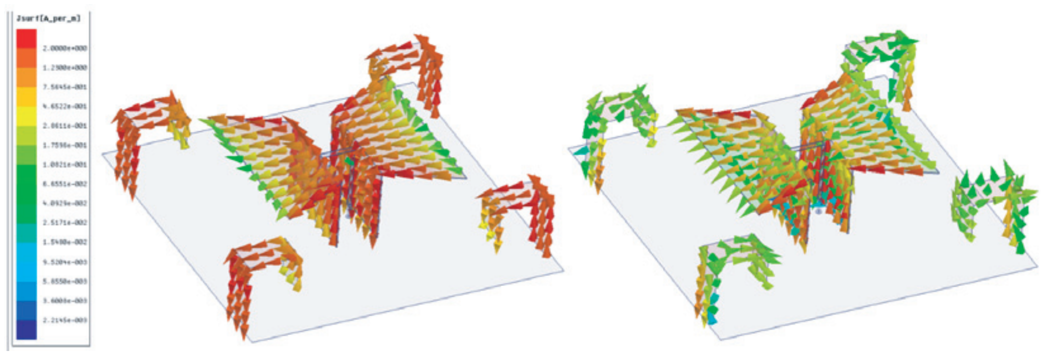


Figure 5. The *xoz*-plane radiation patterns of low frequency band with parasitic strips.



(a) (b)

Figure 6. Simulated current distributions of the antenna at (a) 0.88 GHz and (b) 2.2 GHz.

radiate to the front direction in the lower frequency band.

The current distributions on the antenna at 0.88 GHz and 2.2 GHz are shown in Figure 6. The current is distributed on the ME dipole and four Γ-shaped parasitic strips in the lower frequency band. The direction of induced current on the parasitic strips agrees well with the ME diploe's. So the radiations of the lower frequency band are enhanced in the front direction. However, in the higher frequency band, the current distributions mainly concentrate on the ME dipole. Thus, ME dipole is the main radiation part, and parasitic strips have little effect on antenna radiations. The working principle of the proposed antenna in the higher frequency band can be explained as ME dipole in [6].

To verify the proposed design, the prototype of the proposed antenna was fabricated and measured in this paper. A photograph of the fabricated antenna is shown in Figure 7. The antenna is simulated by ANSYS HFSS 15. The VSWR is measured by an Anritsu MS46322A vector network analyzer, and the radiation patterns are measured by a far-field antenna measurement system.

The VSWR of the proposed antenna is shown in Figure 8. The measured results are in good agreement with the simulated ones. It is easy to observe that the simulated impedance bandwidth is 33.7% from 0.788 to 1.108 GHz, while the measured impedance bandwidth is 39.5% from 0.787 to 1.175 GHz (VSWR ≤ 2) in the lower frequency band. The simulated impedance bandwidth is 56.5% from 1.567 to 2.8 GHz, while the measured impedance bandwidth is 51.7% from 1.62 to 2.75 GHz (VSWR ≤ 2) in the higher frequency band. The proposed antenna covers the 2G, 3G, LTE and WLAN bands.

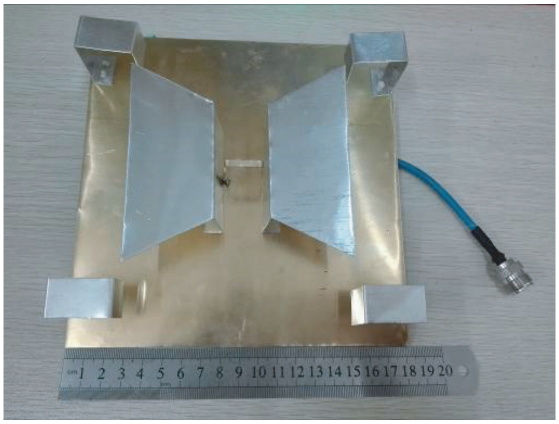


Figure 7. Photograph of the proposed antenna.

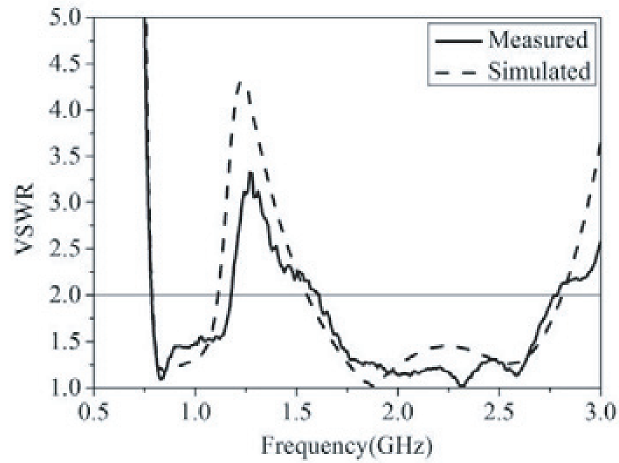


Figure 8. Simulated and measured VSWRs of the proposed antenna.

Figure 9 shows the simulated and measured gains of the proposed antenna. The measured gains vary from 5.1 dBi to 5.7 dBi for the lower frequency bands and from 6.6 dBi to 8.3 dBi for the higher frequency bands. The measured radiation efficiencies of the proposed antenna are shown in Figure 10. As depicted in the figure, the measured radiation efficiencies are above 85%, and the antenna has a peak measured radiation efficiency of 95% at 2.1 GHz.

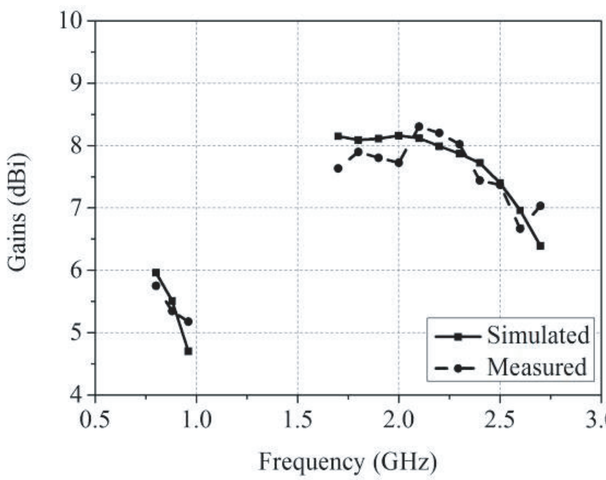


Figure 9. Simulated and measured gains of the proposed antenna.

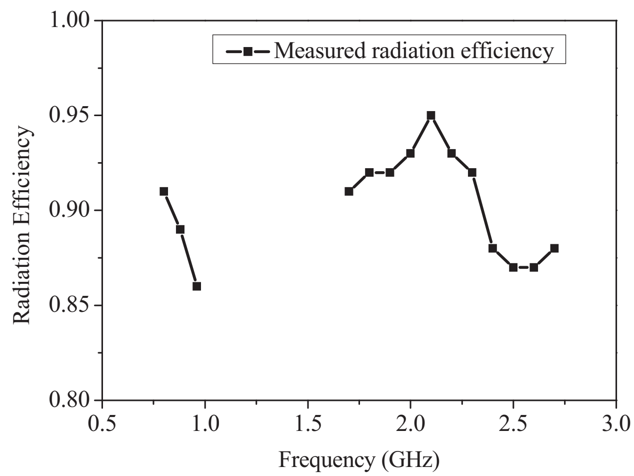


Figure 10. Measured radiation efficiency of the proposed antenna.

The simulated and measured radiation patterns at frequencies of 0.806 GHz, 0.96 GHz, 1.71 GHz, 2.2 GHz and 2.7 GHz are shown in Figure 11. The simulated and measured results are in good agreement and demonstrate good directional characteristic over the operating frequency bands. The measured 3-dB beam widths of the E-plane (yoz-plane) are 65 $\sim$ 80° for 0.806 $\sim$ 0.96 GHz and 50° $\sim$ 70° for 1.71 $\sim$ 2.69 GHz, respectively. The measured beam widths of the H-plane (xoz-plane) are 65° $\sim$ 80° for 0.806 $\sim$ 0.96 GHz and 50° $\sim$ 70° for 1.71 $\sim$ 2.69 GHz, respectively. The cross-polarization ratios in E-plane and H-plane are greater than 20 dB in $\theta = \pm 60°$ region. Simulated and measured front-to-back ratios are larger than 10 dB in the lower frequency band and larger than 18 dB in the higher frequency band.

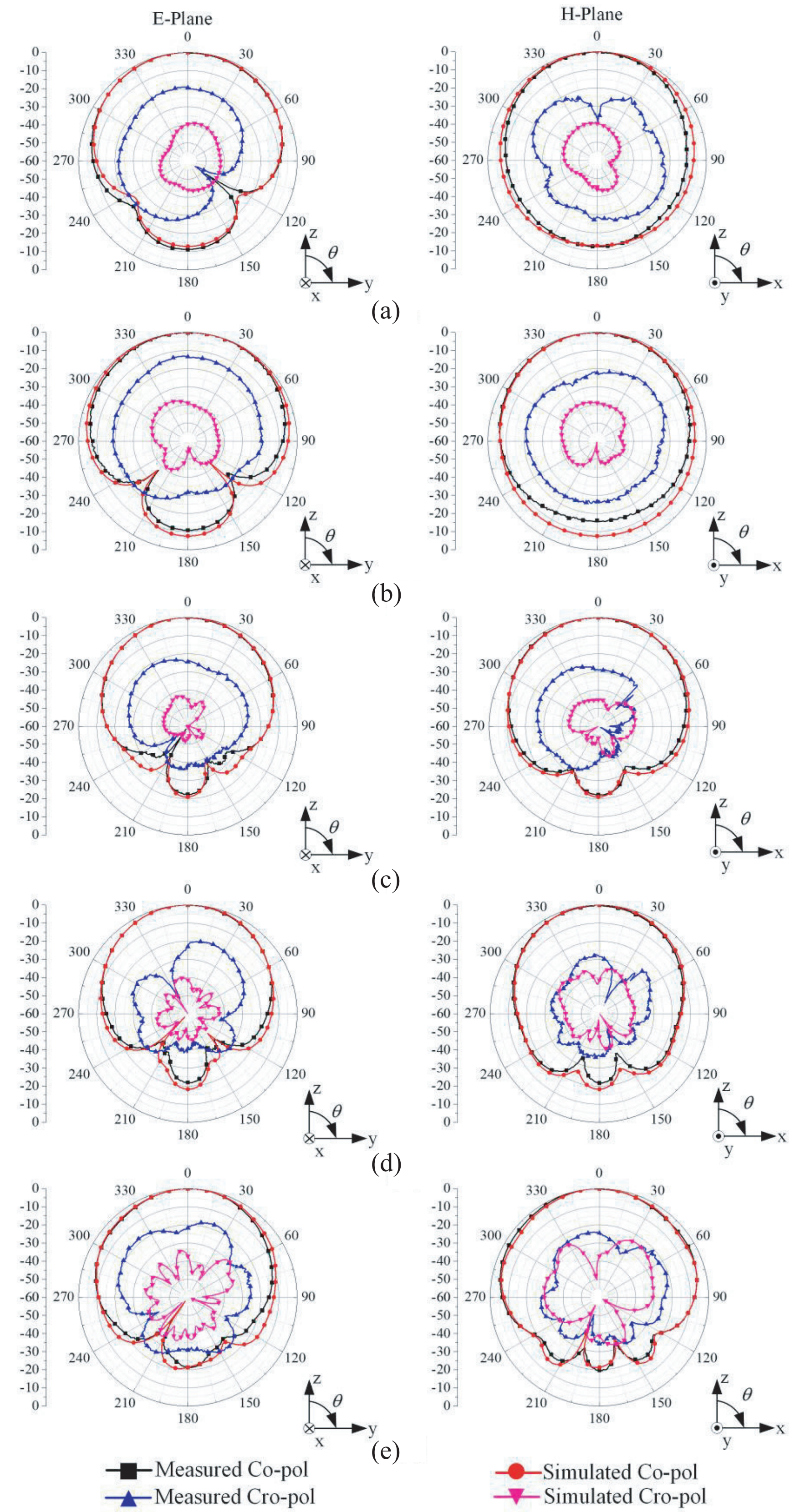


Figure 11. Simulated and measured radiation patterns at (a) 0.806 GHz, (b) 0.96 GHz (c) 1.71 GHz, (d) 2.2 GHz and (e) 2.69 GHz.

4. CONCLUSIONS

A simple dual-wideband ME dipole directional antenna is proposed in this paper. Four Γ-shaped parasitic strips are employed to extend the lower frequency band and improve the radiation performance in the corresponding frequency band. The mechanism of the Γ-shaped parasitic strips is discussed. The antenna demonstrates excellent impedance and directional radiation performance in the whole frequency band. It covers the lower frequency band from 0.806 GHz to 0.96 GHz and the higher frequency band from 1.71 GHz to 2.69 GHz with VSWR ≤ 2. The measured results are in good agreement with the simulated ones. The antenna is simple in structure and low in cost. The antenna can be widely used in 2G, 3G, LTE and WLAN wireless communication systems.

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