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A WIDEBAND MAGNETO-ELECTRIC DIPOLE ANTENNA USING CPW STRUCTURE

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Abstract—A new wideband magneto-electric dipole antenna using coplanar waveguide (CPW) structure is proposed in this paper. The proposed antenna consists of a pair of horizontal triangular patches and two vertically oriented L-shaped strips. By introducing triangular patches working as an electric dipole, the antenna can operate in a wide band. With the use of L-shaped strips equivalent to a magnetic dipole, the antenna is low in profile. A microstrip feed line is located between the two L-shaped strips to form a coplanar waveguide structure and excite the antenna. By carefully adjusting the gap between the feed line and the strips, the impedance bandwidth can be improved largely. A parametric study is performed to provide information for designing and optimizing such an antenna. A prototype is fabricated and measured. The simulated and measured results show that the impedance bandwidth for SWR less than 2 of the proposed antenna is 58.7% (1.95–3.57 GHz). Due to the complementary nature of the antenna, the proposed antenna has a unidirectional radiation pattern with low-polarization and low back-lobe radiation over the whole operating band. Furthermore, the gain of the antenna is stable across the entire bandwidth.

1. INTRODUCTION

With the rapid development of wireless communication, there is an increasing demand for wideband antennas. Many wideband antennas have been presented in the literatures [1–6]. However, most of them are bi-directional radiation types. For this, several methods have been proposed to achieve a wideband antenna with unidirectional characteristics. The simple method is to introduce a cavity-backed

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structure located below a dipole antenna. A composite cavity was placed below the elliptical bowtie dipole to realize the unidirectional radiation in [7]. By locating a cylindrical cavity on the crossed bowtie dipoles, unidirectional radiation patterns have been achieved with the impedance bandwidth of 50% [8]. Another common method is to employ a plane reflector or a metallic cavity box located the slot antenna. A slot antenna was located above a plane reflector for one quarter of a wavelength [9]. In [10, 11], different cavities and apertures were studied for stable unidirectional radiation and wide impedance matching. Notwithstanding, these methods have the disadvantages of bulky structures and large variations in beam width over the operating band.

Due to its various advantages including the low profile, light weight and easy fabrication, patch antenna has also been widely studied and used to achieve unidirectional radiation pattern [12, 13]. However, the patch antenna is narrow in bandwidth. To improve the bandwidth of the patch antenna, two rectangular patches and U-shaped elements were added as the parasitic resonators in [14]. With the use of a pair of parasitic L-wires placed above the triangular patches, a wide impedance bandwidth and directional radiation patterns have been achieved [15]. Nevertheless, this antenna is complex in structure.

In this paper, a new wideband magneto-electric dipole antenna is proposed. A pair of horizontal triangular patches are employed as an electric dipole for their wideband properties. Two vertically oriented L-shaped strips are used as a magnetic dipole and reduce the profile of the antenna. A microstrip feed line is placed between the two L-shaped strips to form a CPW structure, which can excite the electric dipole and magnetic dipole simultaneously and improve the impedance bandwidth. Due to the combination of a magnetic dipole and an electric dipole, good electrical characteristics such as unidirectional radiation pattern, low cross polarization, and stable gain can be achieved. Details of the antenna design and experimental results are presented and analyzed.

2. ANTENNA DESIGN

The configuration of the proposed antenna and its detailed dimensions are shown in Figure 1. The antenna consists of a pair of triangular patches, two L-shaped strips, a microstrip feed line and a ground plane. The pair of triangular patches which operate as an electric dipole are printed on a 1-mm-thick horizontal FR4 substrate with the dielectric constant (ε_r) of 4.4 and the loss tangent ($\tan\delta$) of 0.02. Each patch separated by a small gap has a length of $0.245\lambda_0$ where λ_0 is the

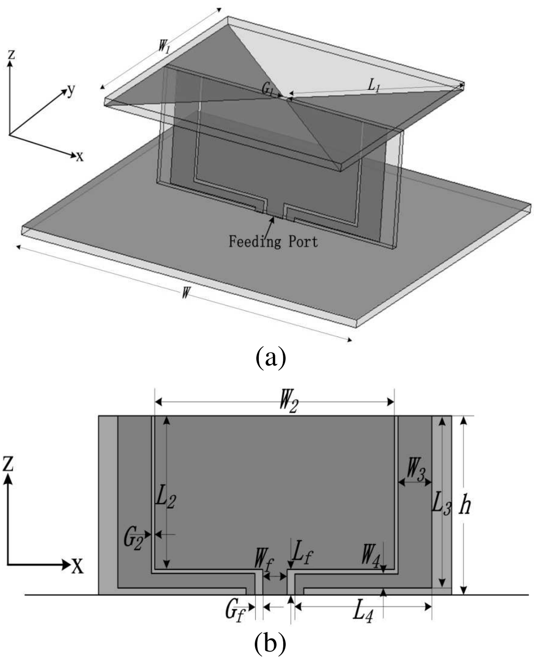


Figure 1. Antenna configuration and detailed dimensions. (a) 3d view; (b) side view.

free space wavelength at the center frequency. These two horizontal triangular patches are attached at the top of the two L-shaped strips act like a magnetic dipole. Each vertically oriented L-shaped strip is printed on the vertical substrate and shorted to the ground plane. The overall length of a shorted L-shaped strip is about $0.258\lambda_0$ close to that of the horizontal triangular patch. Due to the introduction of the L-shaped strips, the antenna only has a height of $0.13\lambda_0$. To excite the electric dipole and magnetic dipole simultaneously, a microstrip feed line is located between the two L-shaped strips. This feed structure has the advantage of forming the CPW structure, which can improve the impedance bandwidth of the proposed antenna. With the aid of simulation by electromagnetic simulation software Ansoft HFSS, all geometrical parameters of the proposed magneto-electric dipole antenna are optimized. The optimum design parameters are shown in Table 1.

To demonstrate the mechanism of the proposed antenna, the current distributions of the proposed antenna at different times are presented in Figure 2. As depicted in Figure 2(a), the current is mainly

Table 1. Optimal geometrical parameters of the proposed antenna.

Parameters	W	W_1	L_1	G_1	W_2
Unit (mm)	51	36	24.7	1	24.8
Parameters	L_2	G_2	W_3	L_3	W_4
Unit (mm)	12.9	0.1	3.5	14.3	1.3
Parameters	L_4	W_f	L_f	G_f	h
Unit (mm)	14.25	2.5	0.5	1.6	14.5

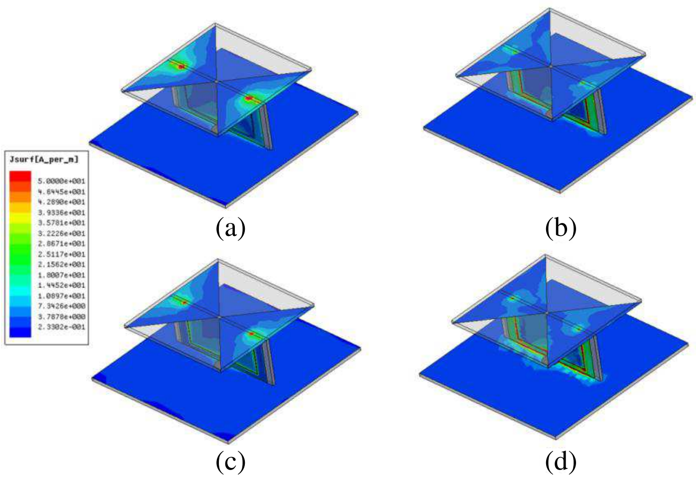


Figure 2. Current distributions of the proposed antenna at different times. (a) $t = 0$; (b) $t = T/4$; (c) $t = T/2$; (d) $t = 3T/4$.

concentrated at the horizontal triangular patches at time $t = 0$, and the vertical current is minimized. So the electric dipole is strongly excited at time $t = 0$. As shown in Figure 2(b), the current is strong along the vertical L-shaped strips and minimized on the horizontal patches at time $t = T/4$, which demonstrates the magnetic dipole is excited at time $t = T/4$. It is also observed from Figures 2(c) and 2(d) that the electric dipole is excited again at time $t = T/2$, and the magnetic dipole is excited at time $t = 3T/4$. Therefore, it can be concluded that the electric dipole and the magnetic dipole are excited.

3. PARAMETRIC STUDY

To analyze the effects of the key structure parameters on the antenna performance, a parametric study has been performed with HFSS. When one parameter is studied, the others are kept constant. The parametric study provides a useful information for designing and optimizing such an antenna.

3.1. Parameters for the Triangular Patch: L_1, W_1

In this section, the functions of the triangular patch are studied in Figure 3. Figure 3(a) shows the simulated reflection coefficient of the proposed antenna for various L_1. As L_1 increases from 24.7 mm to 30.7 mm, it is observed that the lower resonant frequency shifts down dramatically, while the higher resonant frequency changes slightly. Additionally, a larger L_1 worsens the impedance matching in the whole operating band. Thus, $L_1 = 24.7$ mm was chosen as the length of the horizontal triangular dipole for good impedance matching. From the results given in Figure 3(b), it can be seen that the width of the triangular patch has a significant effect on the antenna performance. The increasing of W_1 from 30 mm to 36 mm causes a lower resonant frequency in the higher band and good impedance matching in the lower band. Therefore, W_1 was selected to be 36 mm for wide impedance bandwidth.

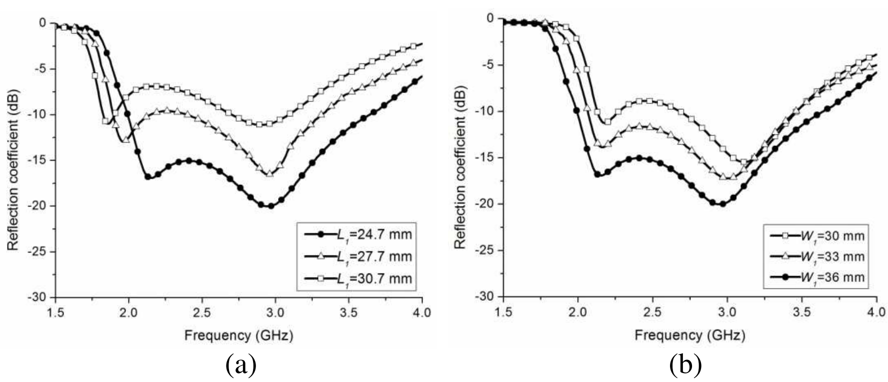
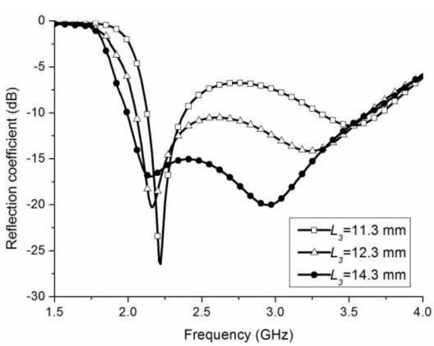


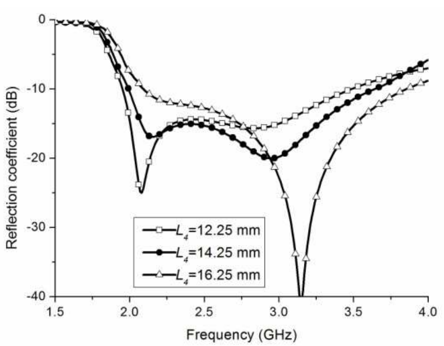
Figure 3. Effect of the triangular patch on the antenna performance. (a) Length of the patch (L_1). (b) Width of the patch (W_1).

3.2. Parameters for the L-shaped Strip: L_3, L_4

To illustrate the effect of the L-shaped strip on the performance of the antenna, Figure 4(a) shows the reflection coefficient of the proposed antenna for various L_3. From the graph, it is clearly visible that the bandwidth is very sensitive to the length of the vertical portion of the L-shaped strip. When L_3 increases from 11.3 mm to 14.3 mm, both the lower and higher resonant frequencies decreases. In addition, wider impedance bandwidth can be achieved when L_3 increases. Thus, L_3 can be set to be 14.3 mm for wide operating band. Figure 4(b) gives the simulated reflection coefficient versus L_4. It can be found that, a larger L_4 produces better impedance matching at the lower resonant frequency. However, over increasing the length of the horizontal portion of the L-shaped strip will cause poorer impedance matching at the higher resonant frequency. Therefore, $L_4 = 14.25$ mm was selected for good matching in the whole operating band and a low profile structure.



(a)



(b)

Figure 4. Effect of the L-shaped strip on the antenna performance. (a) Length of the vertical portion (L_3). (b) Length of the horizontal portion (L_4).

3.3. Parameters for the CPW Structure G_2

In order to demonstrate the function of the CPW structure, the simulated reflection coefficient of the proposed antenna for various gap width G_2 is given in Figure 5. As depicted in the graph, the impedance matching is largely influenced by G_2. A smaller gap G_2 gives better matching in the higher band. In other words, due to the coupling between the microstrip feed line and the two vertically oriented L-

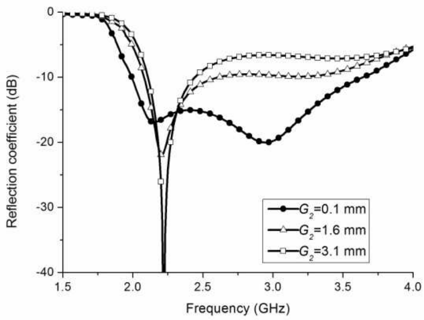


Figure 5. Effect of the CPW structure on the antenna performance.

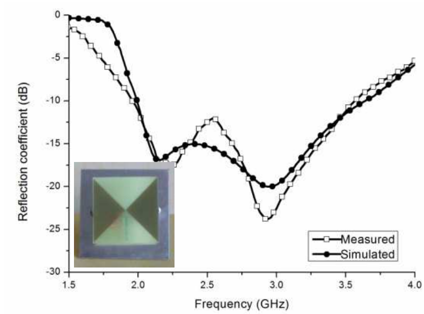


Figure 6. Measured and simulated reflection coefficient of the antenna.

shaped strips, a new resonant frequency can be excited in the higher band. Thus, a small gap $G_2 = 0.1\,\text{mm}$ was chosen for wide impedance bandwidth.

4. EXPERIMENTAL RESULTS AND DISCUSSION

A prototype of the proposed antenna is fabricated according to the optimum dimensions shown in Table 1. The antenna is measured with WILTRON 37269A vector network analyzer and a fully automated anechoic chamber. Figure 6 shows the measured and simulated reflection coefficient of the proposed antenna. Good agreement between the measured and simulated results is obtained. The measured impedance bandwidth of the proposed antenna is 58.7% from 1.95 to 3.57 GHz. Figure 7 gives the measured and simulated gain of the

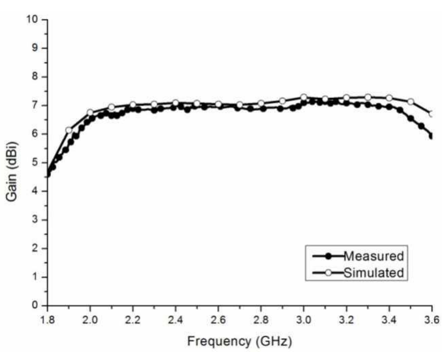


Figure 7. Measured and simulated gain of the proposed antenna.

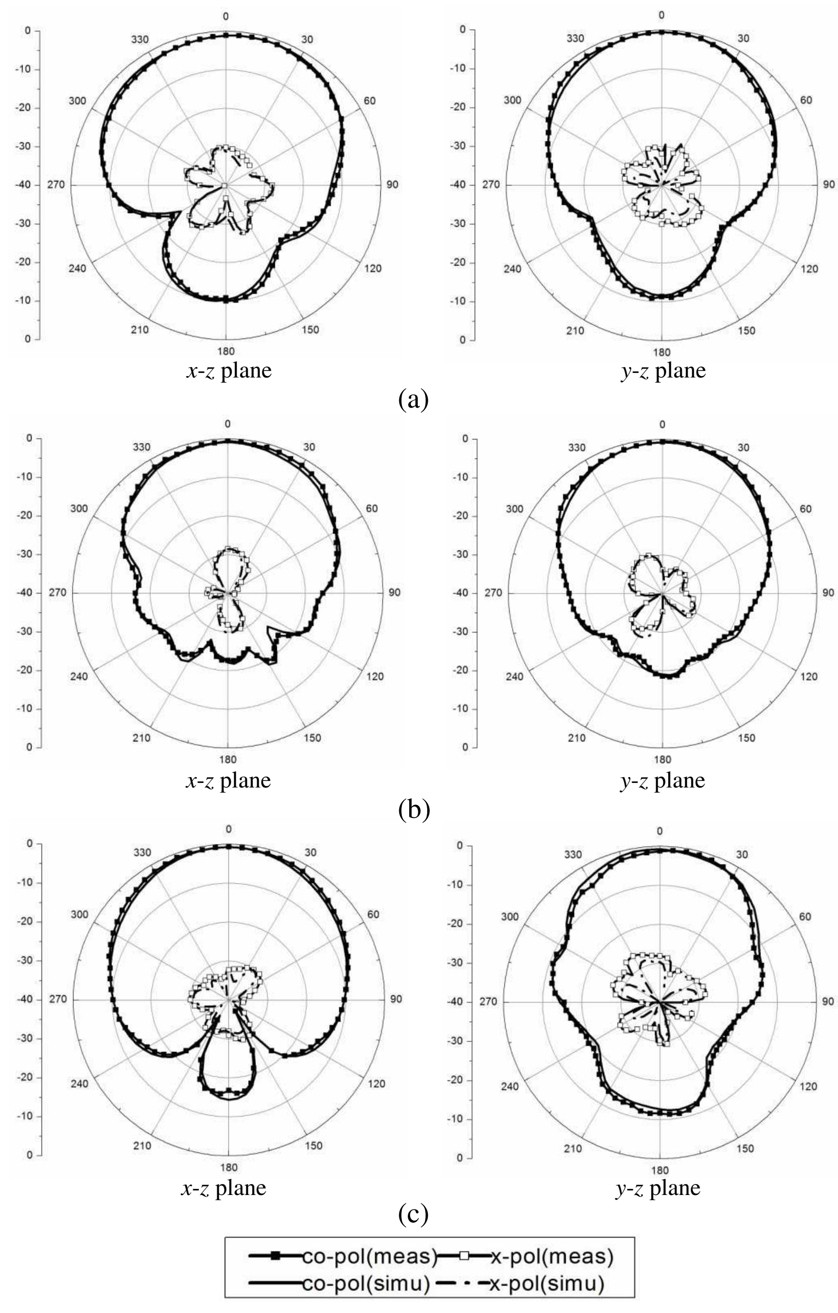


Figure 8. Measured and simulated radiation patterns at (a) 2.2 GHz, (b) 2.7 GHz, and (c) 3.1 GHz.

proposed antenna. As can be seen, stable gain is obtained over the whole operating band. A slight difference between simulated and measured results is mainly contributed from material losses.

The measured and simulated x-z plane and y-z plane radiation patterns at 2.2, 2.7, and 3.1 GHz are plotted in Figure 8. As shown in the figures, the antenna has good unidirectional radiation patterns in the E-plane and H-plane. It is caused by the combination of electric dipole and magnetic dipole, which can reinforce the radiating power in the broadside direction and suppress it in the back side. In addition, the measured cross-polarization level is below -20 dB over the whole operating band. And the broadside radiation patterns are symmetric and stable in both the E-plane and H-plane.

5. CONCLUSION

In this paper, a wideband magnetoelectric dipole antenna composed of a pair of horizontal triangular patches and two vertically oriented L-shaped strips is proposed. By using the two triangular patches as an electric dipole, the impedance bandwidth of the antenna can be improved. With the use of two L-shaped strips working as a magnetic dipole, the profile of the antenna can be reduced. The proposed antenna is excited by a coplanar waveguide structure formed by a microstrip feed line located between the two L-shaped strips. The parametric study is performed to provide information for designing and optimizing such an antenna. Moreover, the proposed antenna has the advantages of unidirectional radiation pattern, low cross polarization, and stable gain.

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