

CPW-Fed Compact Multiband Monopole Antenna for WLAN/WiMAX/X-Band Application

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Abstract—A CPW-fed compact multiband planar printed monopole antenna for WLAN/WiMAX/X-Band applications is presented in this paper. The structure size of antenna is $0.144\lambda_0 \times 0.176\lambda_0 \times 0.008\lambda_0$. The proposed antenna is composed of three monopole radiators, a microstrip feed line, and the ground with chamfer. With these structures employed, the antenna can generate four different resonances to cover the desired bands while maintaining low profile. The antenna simulation results show four distinct bands from 2.24 to 2.85 GHz, from 3.29 to 4.12 GHz, from 5.13 to 6.24 GHz, and from 6.58 to 8.57 GHz, which cover the entire WLAN bands (2.4–2.484, 5.15–5.35, and 5.725–5.825 GHz), WiMAX bands (2.5–2.69, 3.4–3.69, and 5.25–5.85 GHz), and X-band satellite communication systems (7.25–7.75 and 7.9–8.4 GHz). For verification of simulation results, a prototype of quad-band antenna is designed, fabricated, and tested. The simulated and measured return losses, radiation patterns, and gains are presented. The proposed antenna possesses compact size, simple structure, high gain, and omnidirectional radiation pattern, which make it a suitable candidate used in small/portable WLAN/WiMAX/X-Band devices.

1. INTRODUCTION

With the development of multiple wireless communications standards, group of engineers focus their interests on how to design multiband antennas that can be integrated as many standards such as WLAN, WiMAX, and satellite communication as possible into a single wireless terminal device. In order to meet these requirements, various types of promising multiband antenna designs were studied in [1–18]. Planar printed monopole antennas with various structures in [1–3] have become popular candidates in multi-frequency applications for its advantages of low-cost, low-profile, and easy fabrication, whereas the antenna size is relatively large which is not suitable to be installed in mobile wireless terminals. In [4, 5], the antenna only supports dual bands. Triple-band antennas covering the WLAN (2.4/5.2/5.8 GHz) and WiMAX (3.5/5.5 GHz) bands were presented in [6–12]. Although these antennas support triple bands, they cannot fully cover the required bands, which is a common problem of these antennas. In [13], the antenna covers the entire WLAN/WiMAX band, but its low-frequency gain is low and does not support applications in other bands. Although the design of [14–18] supports up to four operating bands, the antenna structure is either complicated, so it is difficult to manufacture, or takes up unnecessary space, resulting in a large size. And these antennas cannot completely cover the required frequency bands.

In this paper, a compact quad-band printed monopole antenna is proposed for WLAN/WiMAX/X-band applications. The total size of the proposed monopole antenna is $18 \times 22 \times 1 \text{ mm}^3$. The proposed planar monopole antenna also provides nearly omnidirectional radiation patterns in H -plane with maximum peak antenna gains of 2.87/3.48/1.82/3.34 dBi across 2.4/3.5/5.8/8 GHz bands, respectively.

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2. ANTENNA DESIGN

2.1. Structure and Dimensions

The geometry of the proposed antenna is shown in Figure 1. The antenna is printed on an FR4 substrate with thickness of 1 mm and relative permittivity of 4.4. It consists of an L-shaped patch on the right side, an I-shaped patch in the middle, a curved inverted U-shaped patch on the left side of the front side of the substrate, and two symmetrical irregular rectangular grounds on both sides of the microstrip feed line. Cutting on the basis of the traditional rectangular ground can improve the antenna's impedance bandwidth effectively. It is better in the high frequency part. The detailed dimensions of the proposed antenna are optimized by using the commercial software HFSS and shown in Table 1.

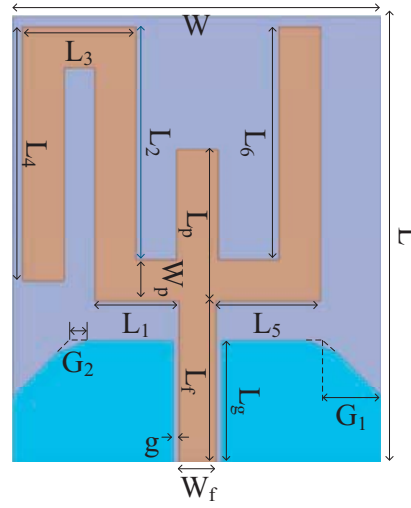


Figure 1. Schematic configuration of the proposed antenna.

Table 1. Dimensions of the proposed antenna.

Parameters	L	L_f	L_g	L_p	L_1	L_2	L_3	L_4
Value/mm	22 ($0.176\lambda_0$)	8 ($0.064\lambda_0$)	6 ($0.048\lambda_0$)	7.5 ($0.06\lambda_0$)	4.1 ($0.033\lambda_0$)	11.5 ($0.092\lambda_0$)	5.5 ($0.044\lambda_0$)	12.5 ($0.1\lambda_0$)
Parameters	W	W_f	g	W_p	L_5	L_6	G_1	G_2
Value/mm	18 ($0.144\lambda_0$)	1.8 ($0.014\lambda_0$)	0.3 ($0.002\lambda_0$)	2 ($0.016\lambda_0$)	5.1 ($0.041\lambda_0$)	11.5 ($0.092\lambda_0$)	2.8 ($0.022\lambda_0$)	2.2 ($0.018\lambda_0$)

λ_0 is the wavelength of 2.4 GHz.

2.2. Design Evolution

The antenna design evolution process to achieve the quad-band operation for WLAN/WiMAX/X-band applications is shown in Figure 2(a). Antenna 1 is the original CPW-fed monopole, which is composed of a CPW-fed structure and a rectangular monopole. A wideband antenna can be easily obtained by adjusting the impedance bandwidth of a monopole antenna. In order to obtain a multi-band antenna, the antenna is cut to obtain a monopole antenna with three radiating branches, as shown in Figure 2(a) Antenna 2. The reason for cutting into this shape is to reduce the effect on the original frequency band of the antenna, and we cut vertically in the middle of the antenna, so that the impact of the cutting portion on the current is minimal. In order to get the lowest frequency mode of operation, a curved L-shaped

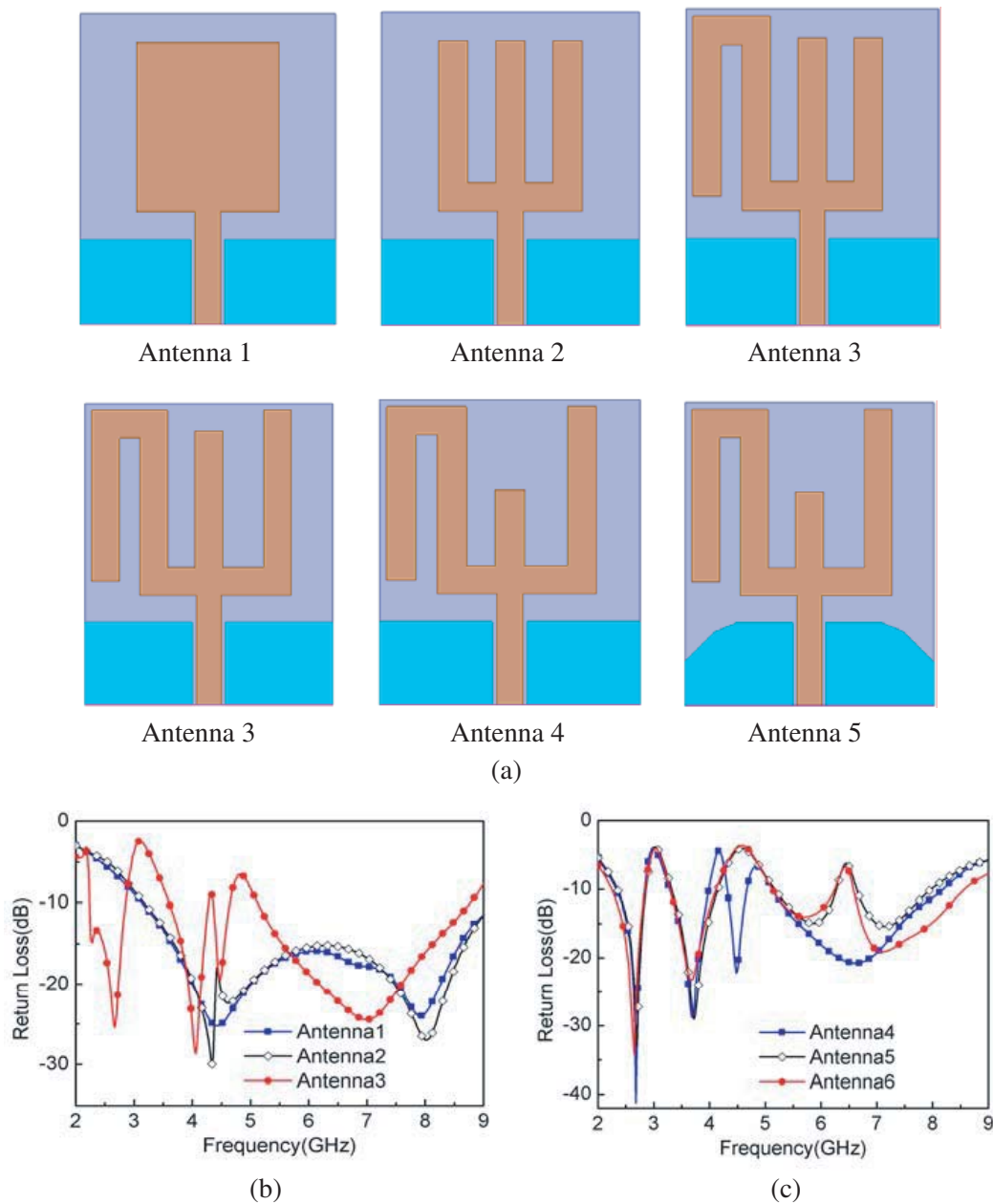


Figure 2. (a) The evolution of the proposed antenna, (b) and (c) simulated return loss.

radiant section is added to the left of the patch, as shown in Figure 2(a) Antenna 3. It can be seen from Figure 2(b) that the radiation branches added to the left side of the patch stimulate the 2.4 GHz working mode. Meanwhile, the 3.5 GHz working band is deviated due to the coupling between branches. At this point, we adjust the 3.5 GHz radiation mode by moving the right branch as shown in Figure 2(a) Antenna 4. It can be seen from Figure 2(c) that a quad-band antenna is implemented, but it cannot completely cover the required frequency band. We adjust the middle branch as shown in Figure 2(a) Antenna 5 so that the antenna reaches the required frequency band. It can be seen from Figure 2(c) that Antenna 5 cannot completely cover the highest frequency bandwidth of the antenna. Then, we can adjust the high frequency impedance matching by cutting the ground. Finally, an antenna that meets the requirements is obtained. The impact of the key parameters is analyzed in the next section.

2.3. Parametric Analysis

In order to understand radiation characteristics of the antenna vividly, Figure 3 shows the current distributions at frequencies of 2.4 GHz, 3.5 GHz, 5.8 GHz, and 8 GHz. The resonance frequencies of 2.4 GHz and 5.8 GHz depend on the left bent L-shaped patch, and electric currents at frequency of 2.4 GHz and 5.8 GHz mainly spread on the left bent L-shaped patch and microstrip line. At the resonance frequency of 3.5 GHz, the currents mainly distribute on the right L-shaped patch and microstrip line. The middle I-shaped patch and the ground being cut mainly affect the characteristics of resonance frequency of 8 GHz.

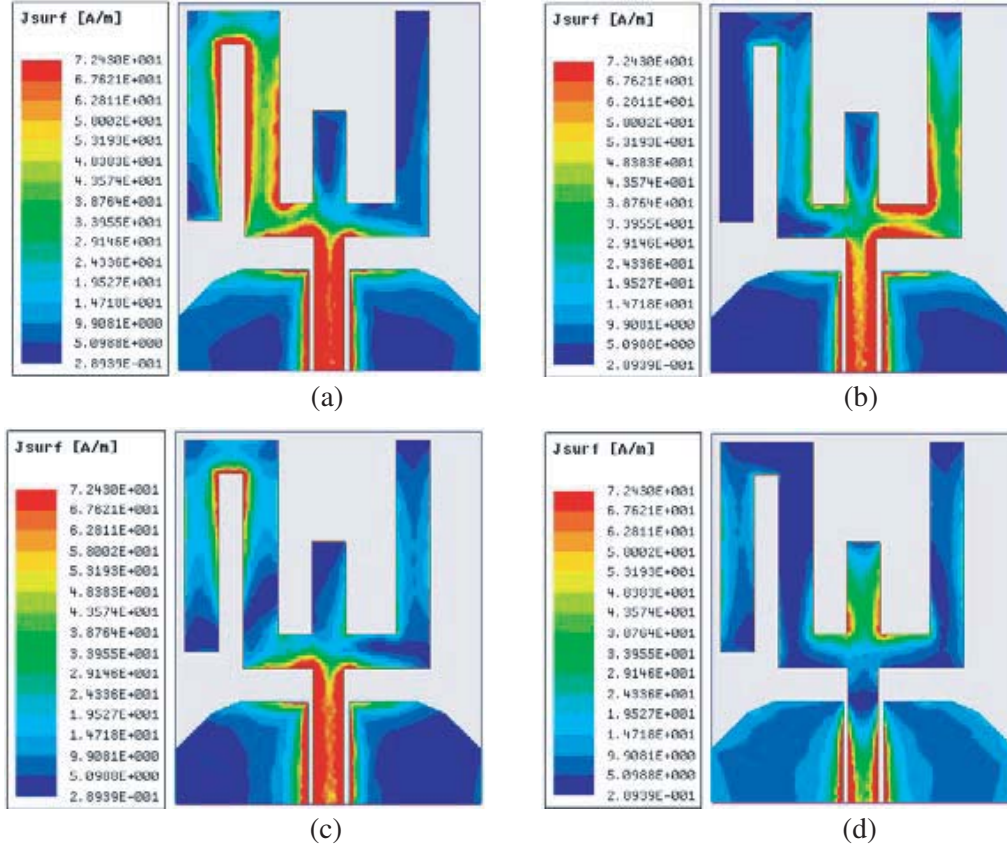


Figure 3. Simulated surface current distributions of the proposed antenna at (a) 2.4 GHz, (b) 3.5 GHz, (c) 5.8 GHz and (d) 8 GHz.

The performance of the antenna is affected by several key parameters. Therefore, effects of the key parameters are simulated and shown in Figure 4. The simulated return loss varying with the lengths L_2 , L_3 , L_4 , L_6 , L_p , and G_1 is depicted in Figures 4(a)–(f). We can see that the changes of lengths L_2 , L_3 , and L_4 almost have no influence on the resonance frequency of 3.5 GHz and 8 GHz, only affect frequencies of 2.4 GHz and 5.8 GHz. Figure 4(d) shows the simulated return loss when varying L_6 . It is revealed that the length of L_6 has little impact on the frequencies of 2.4 GHz, 5.8 GHz, and 8 GHz. Resonance frequency of 3.5 GHz shifts towards low frequency when L_6 increases. In order to cover 3.4–3.69 GHz frequency band, L_6 is chosen as 13.5 mm. The middle I-shaped patch is the main conditioning unit at 8 GHz frequency. Figure 4(e) shows the simulated return loss when varying L_p from 5 mm to 6 mm. As the value of L_p increases, resonance frequencies of 2.4 GHz, 3.5 GHz, and 5.8 GHz are almost unchanged; just the resonance frequency of 8 GHz decreases; and there is an optimum I-shaped length of $L_p = 5.5$ mm at 8 GHz. The simulated return loss varying with the length G_1 is depicted in Figure 4(f). As can be seen, the change of length G_1 almost has no influence on the resonance frequencies of 2.4 GHz, 3.5 GHz, and 5.8 GHz, and only affects resonance frequency of 8 GHz. The

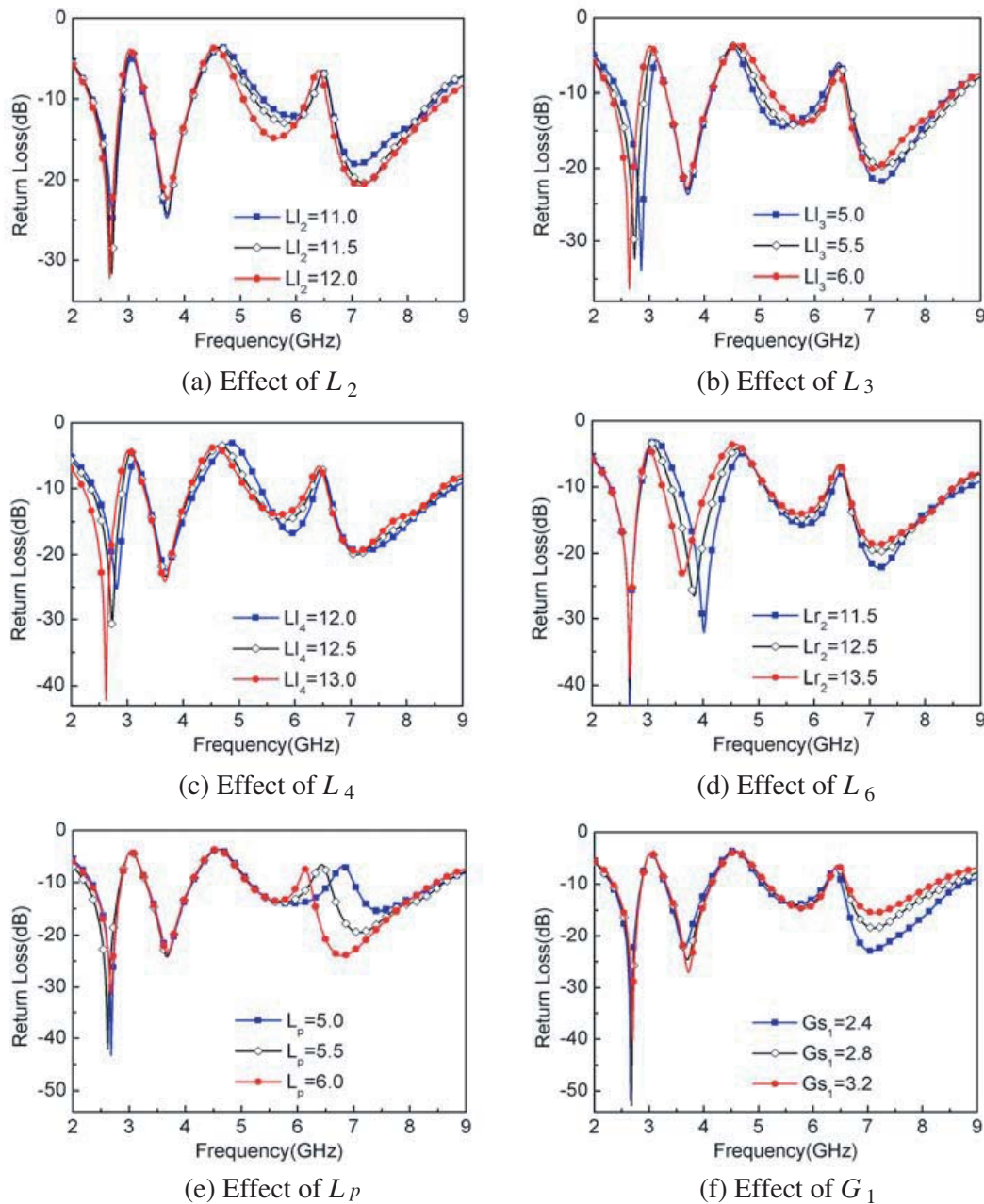


Figure 4. The simulated reflection coefficient of the proposed antenna with (a) varied L_2 , (b) varied L_3 , (c) varied L_4 , (d) varied L_6 , (e) varied L_p , (f) varied G_1 .

results discussed above indicate that the four resonant frequencies and impedance bandwidth can be controlled effectively by adjusting the dimensions of L_2 , L_3 , L_4 , L_6 , L_p , and G_1 .

3. RESULTS AND DISCUSSIONS

A prototype of the proposed quad-band antenna is fabricated and measured, and its photograph is shown in Figure 5(a). The return loss of the quad-band antenna is measured by Agilent N5247A vector network analyzer. The simulated and measured return losses against frequency of this antenna are given in Figure 5(b). The antenna simulation results show four distinct bands from 2.24 to 2.85 GHz, from 3.29

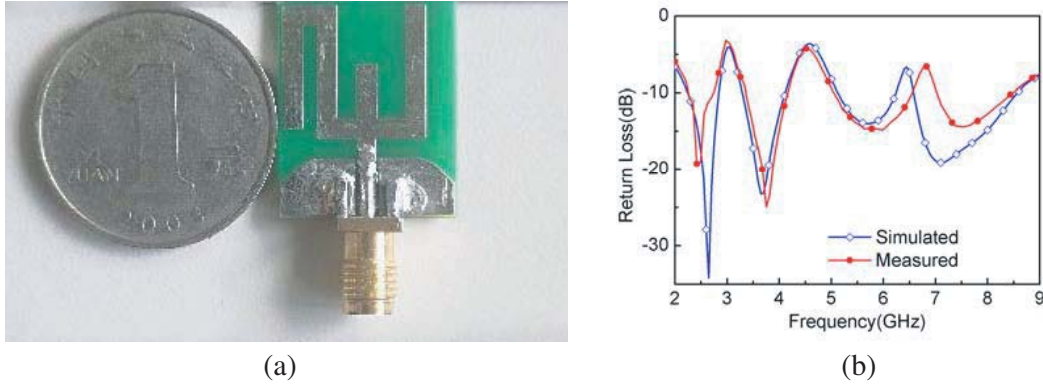


Figure 5. (a) Photograph of the fabricated antenna. (b) Simulated and measured return loss of the proposed antenna.

to 4.12 GHz, from 5.13 to 6.24 GHz, and from 6.58 to 8.57 GHz. The measured impedance bandwidths for return loss are about 480 MHz (2.26–2.74 GHz) resonated at 2.4 GHz, 800 MHz (3.36–4.16 GHz) resonated at 3.5 GHz, 1500 MHz (5.05–6.55 GHz) resonated at 5.8 GHz, and 1450 MHz (7.03–8.48 GHz) resonated at 8 GHz, which can be used for 2.4/5.2/5.8 GHz WLAN bands, 2.5/3.5/5.5 GHz WiMAX bands, and 7.5/8 GHz X-band application. It can be seen that the simulated and measured results show reasonable agreement, and the four resonant frequencies at about 2.4, 3.5, 5.8, and 8 GHz are achieved. Fabrication tolerance is the cause of the differences between measured and simulated results. In addition, we compare it with other similar works, and the results are listed in Table 2.

The simulated and measured far-field radiation patterns in *E*-plane and *H*-plane at 2.4, 3.5, 5.8, and 8 GHz are shown in Figure 6. Nearly omnidirectional patterns in *H*-plane are obtained over the desired operating bands. It can be seen that the radiation pattern deteriorates slightly at the higher resonant frequency, which may be because the asymmetric patch of this design. The simulated and measured gains are shown in Figure 7. The measured gains are about 2.3 dBi, 3.74 dBi, 2.54 dBi, and 3.25 dBi for the 2.4 GHz, 3.5 GHz, 5.8 GHz, and 8 GHz bands, respectively. It can be seen that the antenna exhibits stable gain in the working bands, which makes it suitable for practical applications.

Table 2. Comparison with other works.

Multiband antennas	Dimensions (mm ³)	Frequency bands (GHz)			Antenna purpose	Gain (dBi)	
		WLAN	WiMAX	Other		WLAN WiMAX	Other
[2]	50 × 50 × 1.6	5.2/5.8	3.5	/	triple band	2.6, 3.6, 4.3	/
[5]	96 × 73 × 14	2.4/5.2/5.8	2.5/3.5/5.5	/	dual band	9.2, 7.0, 10.1	/
[8]	19 × 25 × 1.6	2.4/5.8	2.5/3.5/5.5	/	triple band	1.5, 1.7, 3.05	/
[12]	34.8 × 26 × 1.6	2.4/5.2/5.8	2.5/5.5	/	triple band	2.4, 1.5, 4.1	/
[13]	34 × 18 × 1.6	2.4/5.2/5.8	2.5/3.5/5.5	/	triple band	0.2, 1.4, 4.5	/
[15]	33 × 36 × 0.5	2.4/5.2	3.5	1.71 ~ 1.89	quad band	0, 3.5, 5	0
[16]	29 × 27 × 1.6	2.4/5.2	5.5	1.55 ~ 1.96	quad band	2.1, 2.7, 1.8	2.4
[18]	50 × 32 × 0.8	2.4/5.2/5.8	2.5/3.5/5.5	1.53 ~ 1.59	quad band	3.1, 5, 4.2	3
Proposed antenna	18 × 22 × 1	2.4/5.2/5.8	2.5/3.5/5.5	6.58 ~ 8.57	quad band	2.87, 3.48, 1.82	3.34

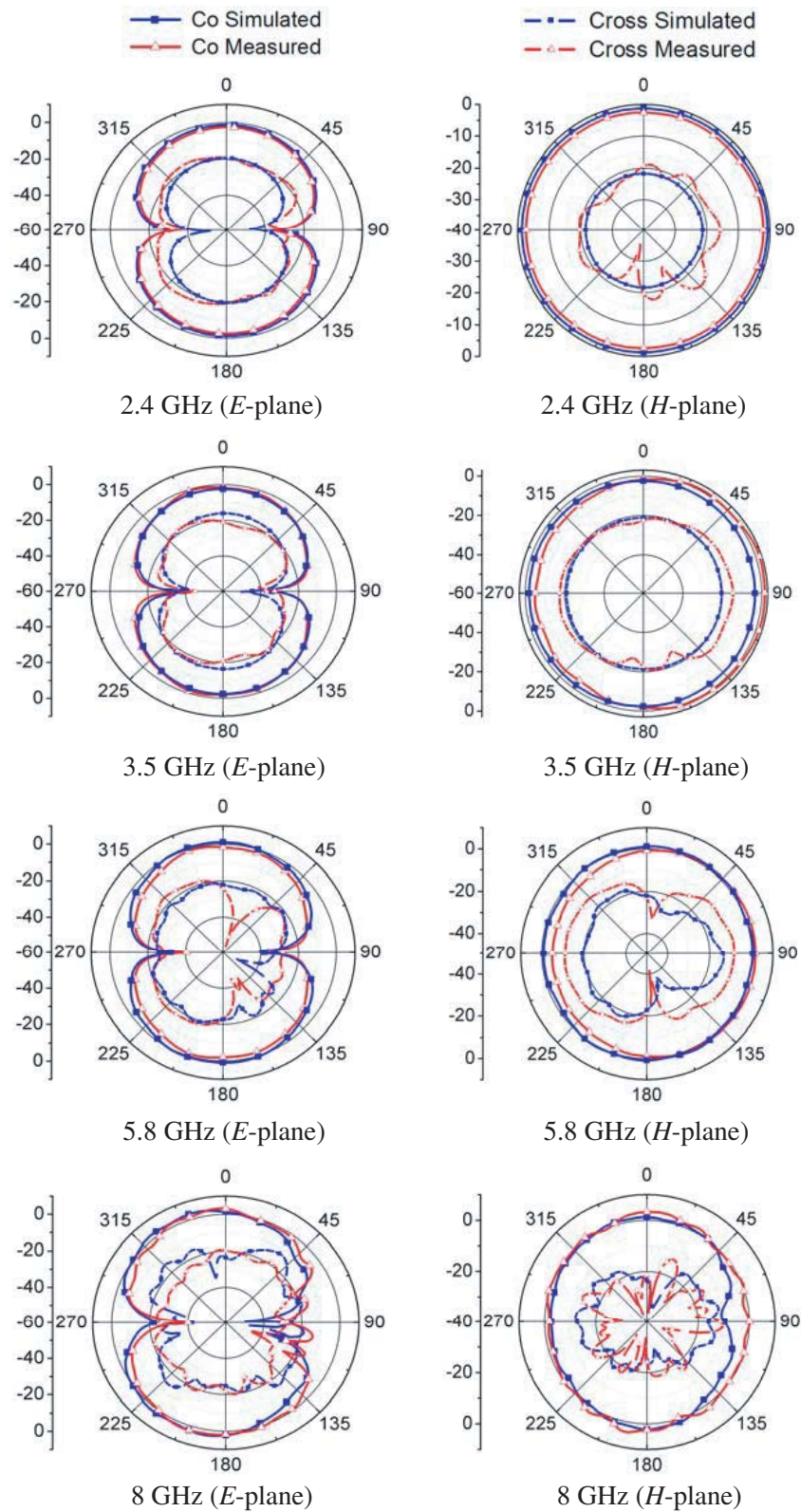


Figure 6. Simulated and measured radiation patterns of the proposed antenna at 2.4/3.5/5.8/8 GHz.

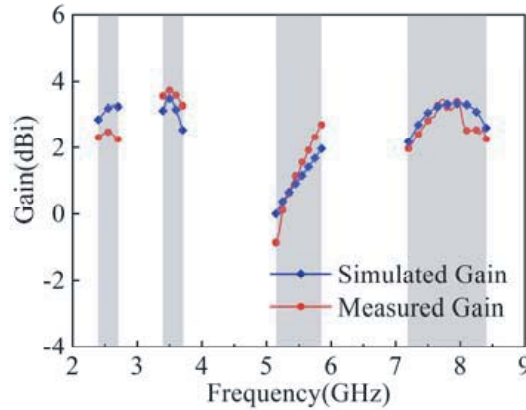


Figure 7. Simulated and measured gain of the proposed antenna.

4. CONCLUSION

In this paper, a quad-band printed monopole antenna using a multi-branch structure for WLAN/WiMAX/X-Band applications is proposed. The resonance frequencies of the WLAN/WiMAX/X-band are produced through an L-shaped patch, an I-shaped patch, and a bent inverted U-shaped patch. The key parameters of the branches in achieving resonant frequencies are discussed in detail. The effect of the length of patch on the return loss and bandwidth is investigated, and the optimal parameters are given. The measured results show that the antenna achieves desired operating bandwidths and has good omnidirectional radiation characteristics and reasonable gains at each resonant frequency. This indicates that the proposed antenna is a good candidate for wireless access points for WLAN/WiMAX/X-band applications.

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