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COMPACT WIDE-SLOT TRI-BAND ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—In this paper, a wide-slot triple band antenna fed by a coplanar waveguide (CPW) for WLAN/WiMAX applications is proposed. The antenna mainly comprises a ground with a wide square slot in the center, a rectangular feeding strip and two pairs of planar inverted L strips (PIL) connecting with the slotted ground. By introducing the two pairs of PIL's, three resonant frequencies, 2.4/5.5 GHz for WLAN, and 3.5 GHz for WiMAX, are excited. Prototypes of the antenna are fabricated and tested. The simulated and measured results show that the proposed antenna has three good impedance bandwidths (S_{11} better than -10 dB) of 300 MHz (about 12.6% centered at 2.39 GHz), 280 MHz (about 8% centered at 3.49 GHz) and 790 MHz (about 14.5% centered at 5.43 GHz), which make it easily cover the required bandwidths for WLAN band (2.4–2.48 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz) and WiMAX (3.4-3.6 GHz) applications. Moreover, the obtained radiation patterns demonstrate that the proposed antenna has figure-eight patterns in E-plane, and is omni-directional in H-plane. The gains of the antenna at operation bands are stable.

1. INTRODUCTION

Recently, the ability to integrate more than one communication standard into a single system has become an increasing demand for a modern portable wireless communication device. Due to the limited space, it often requires the antenna can work at several frequencies simultaneously [1]. Therefore, there are various multi-band antennas that have been developed over the years, which can be utilized to

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achieve multi-band operations, such as PIFA [2], monopole antenna [3], patch antenna [4], slot antenna, and others [5–7], while wide-slot antennas are attractive because they usually have wide impedance bandwidths In addition, they are completely uniplanar and can easily be integrated with active devices or MMICs [8] In the available literatures, slot antennas which base on the slot configurations and the tunable antenna fabrications have been developed to obtain wide impedance bandwidth and small size, but they have complex designed structure [9–17].

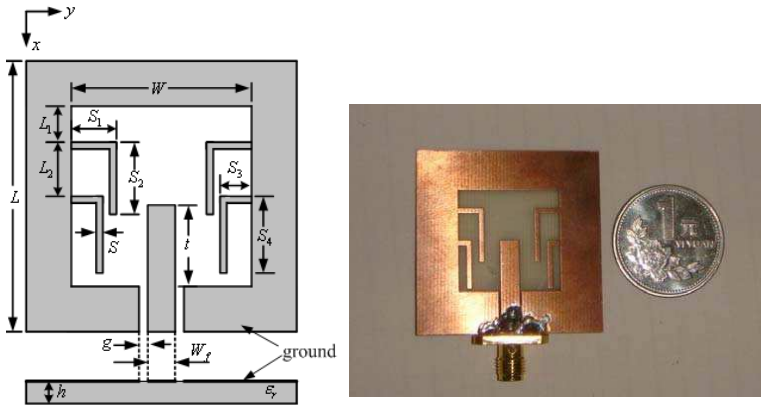
In this paper, a wide-slot triple band antenna for WLAN/WiMAX applications is proposed, which is fed by a coplanar waveguide (CPW). The antenna mainly comprises a ground with a wide square slot in the center, a rectangular feeding strip and two pairs of planar inverted L strips (PIL) connecting with the slotted ground. The three operation bandwidths of the proposed antenna are 300 MHz, 280 MHz and 790 MHz, respectively, which satisfy the required bandwidth of the 2.4/5.2/5.8 GHz wireless local area networks (WLAN) and 3.5/5.5 GHz worldwide interoperability for microwave access (WiMAX) with S_{11} better than -10 dB.

2. ANTENNA DESIGN

The geometry and photograph of the proposed antenna are presented in Figure 1. The optimal geometrical parameters of the proposed antenna are obtained by using Ansoft simulation software high-frequency structure simulator 11. The antenna is etched on a $40 \times 40\,\text{mm}^2$ FR-4 substrate with dielectric constant of 4.4 and thickness of 0.8 mm. Generally, the antenna structure is based on a wide-square-slotted ground, two pairs of PIL's in the square slot with the shorter end connecting with the ground, and the CPW feeding strip, as can be observed in Figure 1. The PIL's are applied to achieve the three band performances with sufficient -10 dB impedance bandwidths. Generally speaking, the size of the square slot is determinant for the 5.5 GHz operation band. The upper and lower pairs of strips are introduced to fine adjust the 2.4 GHz WLAN band and 3.5 GHz WiMAX band, separately. All the detailed parameters of the proposed antenna are summarized in Table 1.

Table 1. Parameters of the proposed antenna (units: mm).

L	W	L_1	L_2	S_1	S_2	S_3	S_4	S	t	g	W_f	h
40	22	4	7	5.5	11.5	2.8	10.3	1	11	0.5	4	0.8



(a) (b)

Figure 1. Geometry and photograph of the proposed antenna.

In order to investigate the effects of the strips in the slot, we simulated four prototypes with all the other parameters unchanged but the t and existence of strips. The one without any strip is called the reference antenna, as shown in Figure 2(a); The one with the upper pair of inverted L strips called antenna 1 as we can see in Figure 2(b) and the one with two pairs of inverted L strips is antenna 2, shown in Figure 2(c). Figure 3 demonstrates how the existence of strips impacts the S_{11} of the proposed antenna. From Figure 3, we can see that the reference antenna with $W = 22$ mm and $t = 7$ mm demonstrates a broadband design with the bandwidth of 34.8% at the centre frequency of 5.2 GHz. When adding a pair of metal strips and choosing the length of t appropriately, Antenna 1 excites one more operation band at the centre frequency of 2.25 GHz than the reference antenna. The bandwidths are 12.9% and 19.6%, respectively. Antenna 2 is formed by adding another pair of strips to antenna 1, which has tri-band characteristic with the bandwidths of 6.7%, 8.6% and 13.8%. Adjusting the value of S_2, S_4 and t, antenna 3 is obtained, which exhibits the S_{11} better than -10 dB over the bandwidths of the three operation bands of 300 MHz, 280 MHz and 790 MHz. Antenna 3 covers the required bandwidths of the 2.4/5.2/5.8 GHz wireless local area networks (WLAN) and 3.5/5.5 GHz worldwide interoperability for microwave access (WiMAX). Table 2 shows the detailed dimensions as well as performances of these four antennas.

Table 2. Dimensions and performances of the four antennas.

	S_2 (mm)	S_4 (mm)	t (mm)	f_{C1} (GHz)	BW_1 %	f_{C2} (GHz)	BW_2 %	f_{C3} (GHz)	BW_3 %
Ref	-	-	7	-	-	-	-	5.2	34.8
Ant 1	13	-	9	2.44	12.9	-	-	5.4	19.6
Ant 2	13	10.3	11	2.25	6.7	3.45	8.6	5.42	13.8
Ant 3	11.5	10.3	11	2.39	12.6	3.49	8	5.43	14.5

f_{C1}, f_{C2} and f_{C3} are the center frequency of the three operation band, respectively.

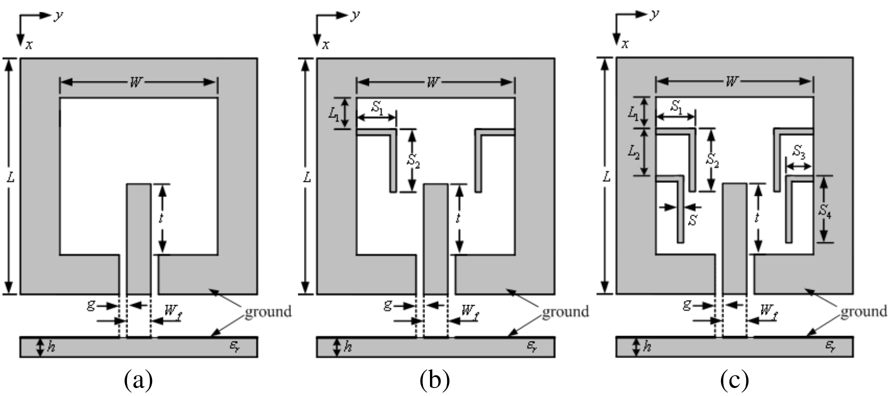


Figure 2. Geometries of (a) reference antenna, (b) antenna 1, (c) antenna 2.

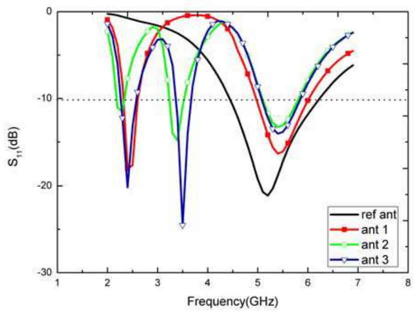


Figure 3. S_{11} of the reference antenna and antenna 1, antenna 2 and antenna 3.

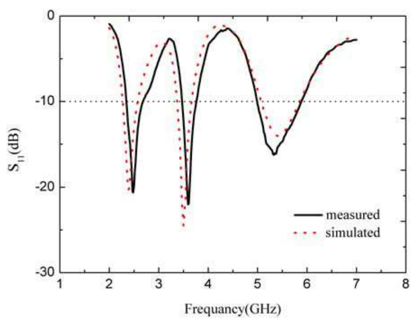


Figure 4. Simulated and measured S_{11} of proposed antenna.

3. RESULTS AND DISCUSSION

To verify the proposed antenna, an experimental prototype, shown in Figure 1(b), is fabricated and measured. The S-parameter is measured using a WILTRON37269A Vector Network Analyzer. The measured and simulated S_{11} against frequency for the presented antenna are plotted in Figure 4. As observed, the measured result agrees well with the simulated one. Figure 5 presents the Smith Chart of proposed antenna.

A study on the effect of the parameters S_2 and S_4 on the impedance matching for the proposed antenna is conducted. Figure 6 shows the simulated S_{11} with the variation in S_2. In this case, S_4 is fixed to be 10.3 mm, and small effects on the antenna's 3.5 GHz and 5.5 GHz operation bands are seen. Conversely, the 2.4 GHz band is strongly affected by the variations in S_2 and is shifted to higher frequencies with a decrease in S_2. Fixing S_2 to be 11.5 mm, effects of the variation in S_4, the vertical length of the lower pair of strips, are analyzed in Figure 7, and large effects on the 3.5 GHz band are shown. The 3.5 GHz band is shifted to lower frequency with the increase of S_4, while the 2.4 GHz and 5.5 GHz bands are rarely affected. Obviously the results indicate that the 2.4 GHz resonant band is mainly dependent on the upper pair of strips and the lower strips are the major factor of the 3.5 GHz band.

Figure 8 shows simulated S_{11} of proposed antenna as the function of frequency with the variation in L. As can be seen, the 2.4 GHz band is missed and the 5.5 GHz band is shifted to lower frequency with L decreased, while the 3.5 GHz band is missed and the 5.5 GHz band is shifted to higher frequency when L increased.

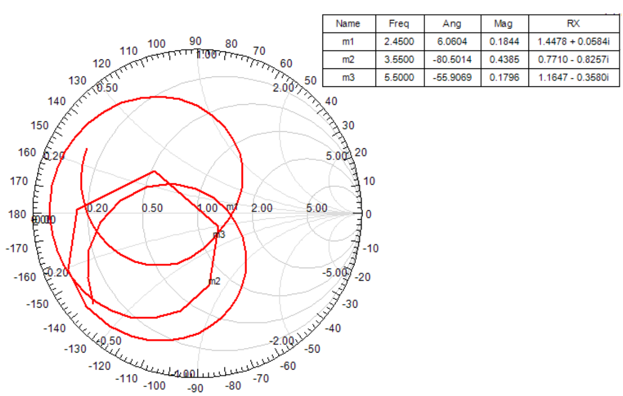


Figure 5. Simth chart of proposed antenna.

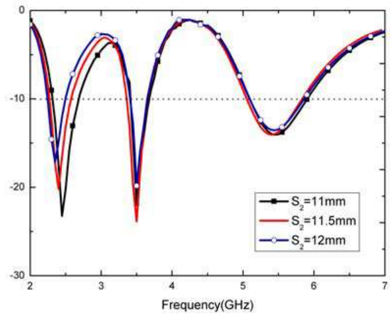


Figure 6. Simulated S_{11} of proposed antenna as the function of frequency with the variation in S_2.

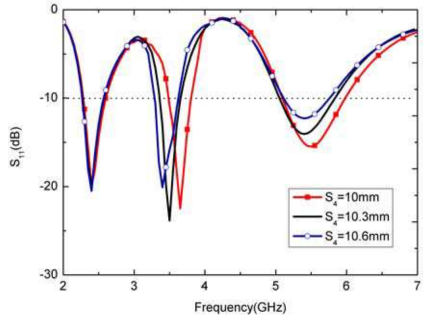


Figure 7. Simulated S_{11} of proposed antenna as the function of frequency with the variation in S_4.

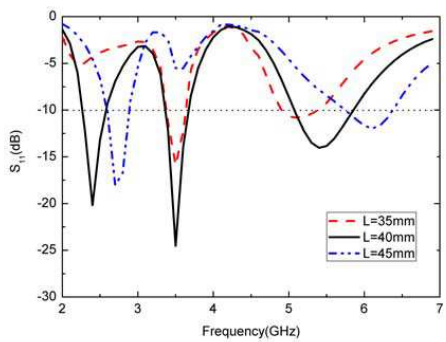
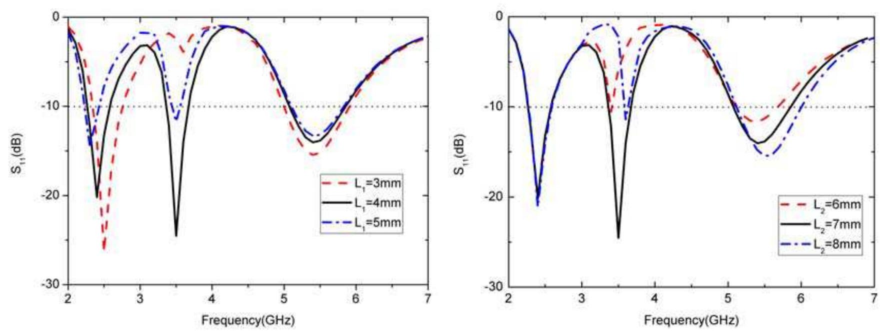


Figure 8. Simulated S_{11} of proposed antenna as the function of frequency with the variation in L.



(a) (b)

Figure 9. Simulated S_{11} of proposed antenna as the function of frequency with the variation in (a) L_1 (b) L_2.

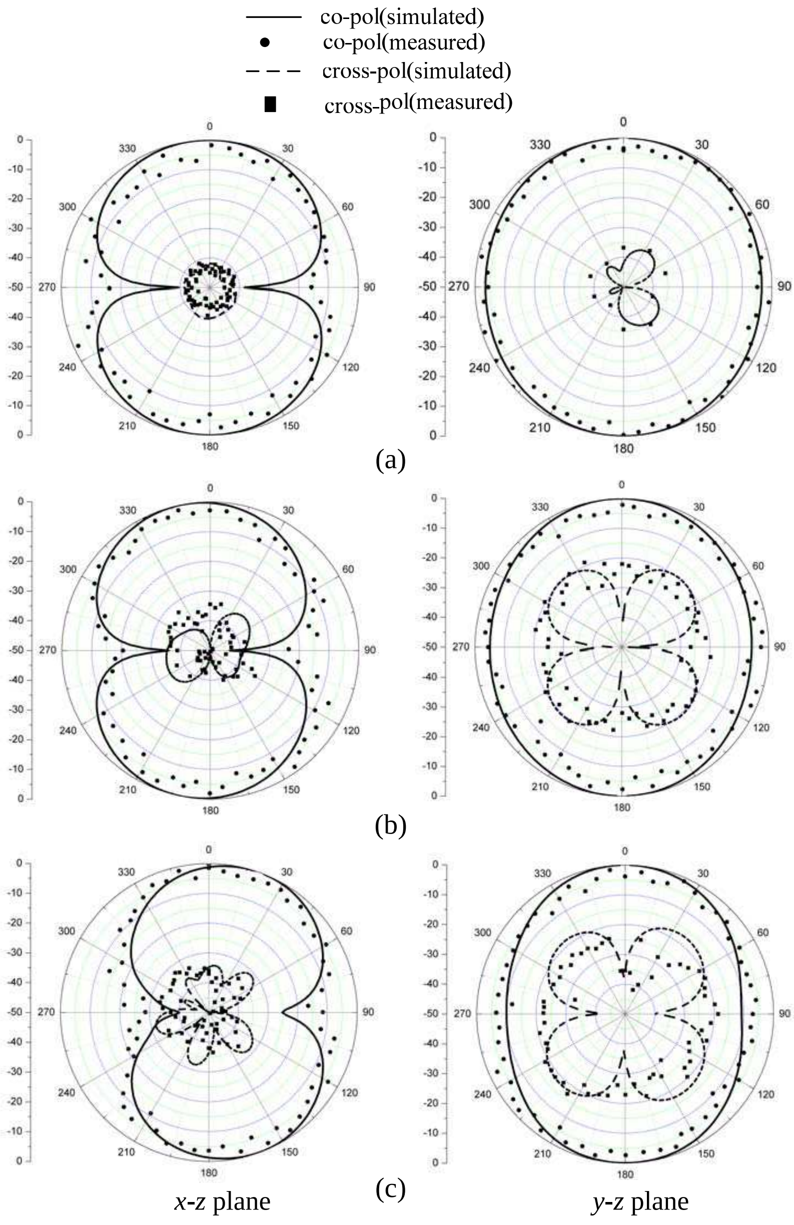


Figure 10. Simulated and measured far-field patterns of proposed antenna at (a) 2.4 GHz, (b) 3.5 GHz, (c) 5.5 GHz.

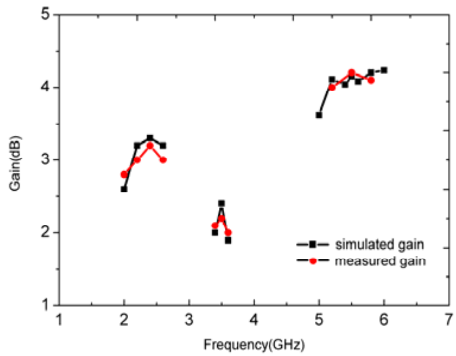


Figure 11. Simulated and measured gain of proposed antenna.

The effect of the parameters L_1 and L_2 on the impedance matching for the proposed antenna is also studied. Figure 9(a) shows simulated S_{11} of proposed antenna as the function of frequency with the variation in L_1, as can be seen from Figure 9(a), the 2.4 GHz band is shifted to higher frequencies and the 3.5 GHz is missed with a decrease in L_1. Presented in Figure 9(b) is the simulated S_{11} of proposed antenna as the function of frequency with the variation in L_2, small effects on the antenna's 2.4 GHz and 5.5 GHz operation bands are seen. Conversely, the 3.5 GHz band is strongly affected by the variations in L_2 and is shifted to lower frequencies with a decrease in L_2; also the bandwidth is strongly affected.

Figure 10 shows the simulated and measured far-field patterns of antenna 3 in both the x-z plane (E-plane) and y-z plane (H-plane) at its three resonant frequencies. All of the three resonant frequencies have figure-eight patterns in E-plane and omni-directional patterns in H-plane, and with low cross-polarization level. As shown in Figure 11, the measured gains at 2.4/3.5/5.2/5.8 GHz are 3.2 dBi, 2.2 dBi, 4 dBi and 4.1 dBi, respectively.

4. CONCLUSION

A CPW-fed square-slot antenna with two pairs of planar inverted L strips has been proposed and studied in this paper. The obtained three operation bands of the proposed antenna are ranging from 2.28–2.58 GHz, 3.38–3.66 GHz, 5.07–5.86 GHz, respectively, which are wide enough to cover the required bandwidths of the 2.4/5.2/5.8 GHz wireless local area networks (WLAN) and 3.5/5.5 GHz worldwide interoperability for microwave access (WiMAX). Additionally, the radiation patterns of the proposed antenna are figure-eight in E-plane and omni-directional in H-plane at 2.45/3.5/5.5 GHz, and with very low cross polarization level. The antenna gains at 2.4/3.5/5.2/5.8 GHz are 3.2 dBi, 2.2 dBi, 4 dBi and 4.1 dBi, respectively.

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