

# A Compact Triple-band Monopole Antenna for WLAN/WIMAX Application

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**Abstract**—A compact triple-band monopole antenna is proposed to cover the frequency band for WLAN/WIMAX application in this paper. The triple-band monopole antenna proposed in this letter has the advantage of compact size and relatively wide bandwidth. The proposed antenna consists of a modified E-shaped radiation patch and slotted ground plane. It has a compact size of only  $15 \times 30 \times 1.2 \text{ mm}^3$ . The compactness of the triple-band antenna is achieved by adding slots on the ground plane. The triple-band antenna has three operation bands, ranging from 2.4 GHz to 2.493 GHz, 3.01 GHz to 3.84 GHz and 4.89 GHz to 6 GHz, which can apply for 2.4/5.2/5.8 GHz WLAN bands (2.4-2.484 GHz, 5.15-5.35 GHz, and 5.725-5.825 GHz) and 3.5/5.5 GHz WIMAX (3.3-3.79 GHz and 5.25-5.85 GHz) band. The operating mechanism and the effect for parameters on the antenna performance are studied. Experimental results show that the antenna gives omnidirectional radiation patterns and good antenna gains in the operating bands.

## I. INTRODUCTION

Wireless communication systems have experienced enormous growth over the last decade. Wireless local area network (WLAN) and the Worldwide Interoperability for Microwave Access (WiMAX) technology have extensively been used in commercial, medical, and industrial applications. The WLAN has a lower frequency band 2.4–2.484 GHz for the 802.11b/g standards, and two higher frequency bands 5.15–5.35 GHz and 5.725–5.825 GHz for the 802.11a standard. The WiMAX has a lower frequency band 3.3–3.79 GHz and a higher frequency band 5.25–5.85 GHz for the 802.16 standard. The multiband antenna must have simple structure, small size, light weight, low cost, and easily integrated with RF circuits. So far, numerous antennas have been proposed to reduce size, enhance bandwidth for WLAN application [1–14]. Different shapes of monopole antenna used to apply for WLAN application, such as G-shaped, F-shaped, 9-shaped, T-shaped and L-shaped [10]–[13]. However, the sizes of most antennas are large. For WLAN and WiMAX application, the smaller size of antenna for 2.4/3.5/5.2/5.8 GHz wireless applications is  $22 \times 29 \text{ mm}^2$  [14], which is still larger than our proposed antenna of only  $15 \times 30 \text{ mm}^2$ .

In this paper, a compact dual-band monopole antenna is proposed to cover the frequency band for 2.4/3.5/5.2/5.8 GHz for WLAN and WiMAX application. The designed antenna has wider bandwidth for WiMAX application compared to antenna [6]. In the mean time, it has a compact size

of  $15 \times 30 \times 2 \text{ mm}^3$ , which is smaller than the antenna [14]. The triple-band antenna has three operation bands, ranging from 2.40 GHz to 2.493 GHz, 3.01 GHz to 3.84 GHz and 4.89 GHz to 6 GHz which can apply for 2.4/5.2/5.8 GHz WLAN bands (2.4-2.484 GHz, 5.15-5.35 GHz, and 5.725-5.825 GHz) and 3.5/5.5 GHz WIMAX (3.3-3.79 GHz and 5.25-5.85 GHz) band. The operating mechanism and the effect for parameters on the antenna performance are studied. The triple-band antenna is fabricated and experimental results are presented. Experimental results show that the antenna gives omnidirectional radiation patterns and good antenna gains over the operating bands. The design of antenna and operating mechanism are shown in Section II. Experimental results are shown in Section III. The conclusion is in Section IV.

## II. ANTENNA DESIGN

### A. Antenna Configuration

The geometry of the proposed antenna is shown in Fig. 1 and the parameters are given in Table I. The antenna is constructed on the FR-4 substrate with dielectric constant of 4.4, loss tangent 0.02, thickness of 1.2 mm. The antenna has a compact size of  $15 \times 30 \text{ mm}^2$ . The antenna consists of a modified E-shaped radiation patch on the top side of the substrate and slots on the ground plane. The point A is used to excite the resonant modes at 5.55 GHz, and the point B and the point C on the slotted ground excite the resonant modes for 3.3 GHz and 2.45 GHz, respectively.

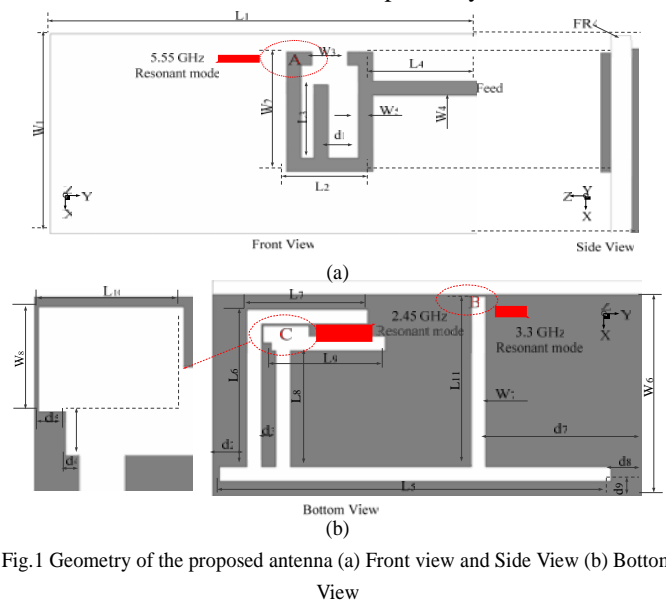


Fig.1 Geometry of the proposed antenna (a) Front view and Side View (b) Bottom View

Fig.1 Geometry of the p

TABLE I

PARAMETERS OF THE PROPOSED ANTENNA (UNITS: MM)

$W_1$	$L_1$	$W_2$	$L_2$	$W_3$	$L_3$	$d_1$
15	30	9	6	2.5	5.5	2.1
$W_4$	$L_4$	$W_5$	$d_2$	$d_3$	$d_4$	$d_5$
1.2	7.5	1	2.4	1	0.3	0.6
$d_6$	$d_7$	$d_8$	$d_9$	$W_6$	$W_7$	$W_8$
0.4	11	2.3	1.1	14	1	1.2
$L_5$	$L_6$	$L_7$	$L_8$	$L_9$	$L_{10}$	$L_{11}$
27.2	10.9	8.4	8.1	7.9	3.2	11.8

### B. Current Distribution analysis of the antenna

To further examining the mechanism of the proposed antenna, the surface current distributions on both the radiator and the ground is studied. Fig. 2 shows the current distributions for the three resonant frequencies at 5.55, 3.3, and 2.45 GHz. At 5.55 GHz, the current is mainly distributed along the point A of modified E-shaped patch, as is shown in Fig.2 (a). At 3.3 GHz, the current is mainly distributed along the point B of slot  $L_{11}$ , as is shown in Fig. 2 (b). At 2.45 GHz, the current was mainly distributed along the point A of slots  $L_9$  and  $L_{10}$ , as is shown in Fig. 2 (c).

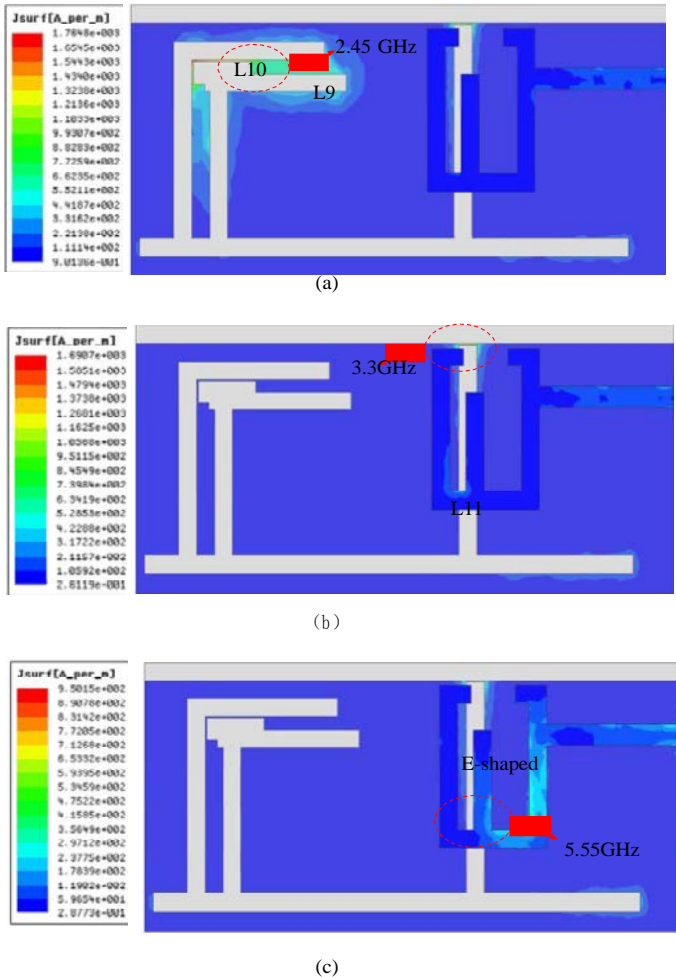


Fig.2 Simulated current distribution at (a) 2.45 GHz (b) 3.3 GHz (c) 5.55 GHz.

### C. Simulated and measured Reflection Coefficient

The compact triple-band monopole antenna for WLAN / WiMAX application is simulated by High-Frequency System Simulation software. The prototype of the proposed antenna is fabricated and measured. Fig. 3 is the prototype of the antenna. The simulated and measured  $S_{11}$  for the antenna is shown in Fig. 4. The  $S_{11}$  of the compact antenna is measured by using an Advantest R3770 network analyzer. It is observed that the proposed triple-band antenna has three operation bands, ranging from 2.4 GHz to 2.493 GHz, 3.01 GHz to 3.84 GHz and 4.89 GHz to 6 GHz. The discrepancy between the measured and simulated results is due to fabrication and measurement deviation.

### D. Parametric Analysis

The parameter effects on the impedance are shown in Fig.5 (a)-(c). First, for modified E-shaped patch, the influence of  $L_3$  is shown in Fig. 5 (a).  $L_3$  for E-shaped patch only affects the higher frequency at 5.55 GHz. The resonant mode moves towards lower frequency with the increasing of  $L_3$ . Second, for the slots, Fig. 5 (b) presents the effect for the slot  $L_9$ . The lower frequency at 2.45 GHz moves down with  $L_9$  increasing, but the resonant modes at higher frequency don't change. Third, the influence for the slot  $L_{11}$  is also observed in Fig. 5 (c). With  $L_{11}$  decreasing, the band of the higher frequency 3.3 GHz and 5.55 GHz go narrower. It is observed that the resonant mode at 2.45 GHz is affected by slot  $L_9$ , the resonant mode at 3.3 GHz is affected by slots  $L_5$  and  $L_{11}$ , and the resonant mode at 5.55 GHz is affected by the branch  $L_3$  of the modified E-shaped patch and slots  $L_5$ ,  $L_9$ , and  $L_{11}$ .

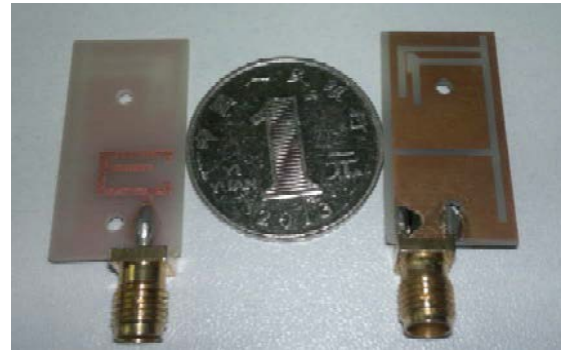
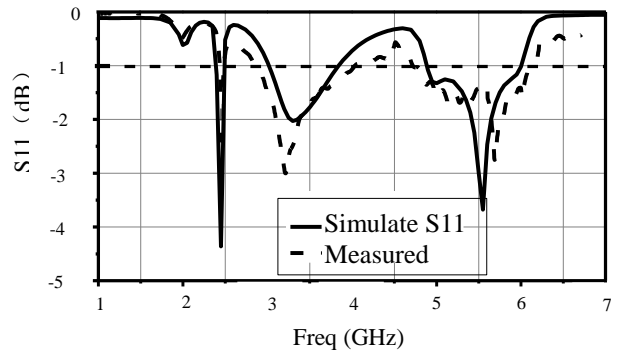


Fig.3 The fabricated antenna.

Fig.4 Simulated and measured  $S_{11}$  of the proposed antenna

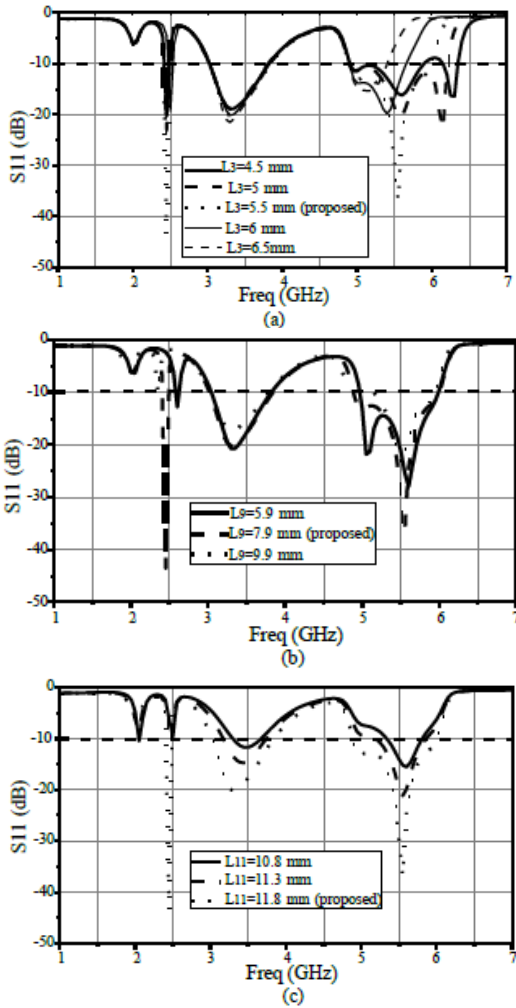


Fig.5 Parameters studies of the antenna (a)  $L_3$  (b)  $L_9$  (c)  $L_{11}$

### III. EXPERIMENTAL RESULTS

The radiation characteristics such as radiation pattern and peak gain across the three operating bands for the proposed antenna have been measured. The simulated and measured radiation patterns including the vertical ( $E_\theta$ ) and horizontal ( $E_\psi$ ) polarization in the x-z plane and y-z plane for the antenna at the three resonant modes of 2.45, 3.3, and 5.55 GHz are shown in Fig. 6 (a)–(c), respectively. First, the radiation patterns are nearly omnidirectional in the x-z plane which is similar to monopole-like radiation pattern and nearly dumbbell in the y-z plane. The radiation patterns are quite stable throughout the WLAN and WiMAX bands. Second, the average peak gain for the triple band at 2.45, 3.3, and 5.55 GHz are about -8.45, 1.83, and 1.12 dBi, and the average radiation efficiency of the compact dual-band monopole antenna is almost 85%. Considering the small size of the antenna, the efficiency and gain values are acceptable.

### IV. CONCLUSION

A compact triple-band monopole antenna for WLAN/ Wi-

MAX application is proposed, analyzed and measured. The triple-band monopole antenna proposed in this letter has the advantage of compact size  $15 \times 30 \times 1.2 \text{ mm}^3$  and relatively wide bandwidth. The compactness of the triple-band antenna is achieved by adding slots on the ground plane. The operating mechanism and the effect for parameters on the antenna performance are studied. By controlling the parameters of the antenna, the operation bands can be changed. The triple-band antenna is fabricated, and experimental results are presented. Experimental results show that the compact triple-band antenna gives omnidirectional radiation patterns and good antenna gains over the operating bands.

### ACKNOWLEDGMENT

This work is supported by the National Natural Science-Foundation of China under Grant 61071056.

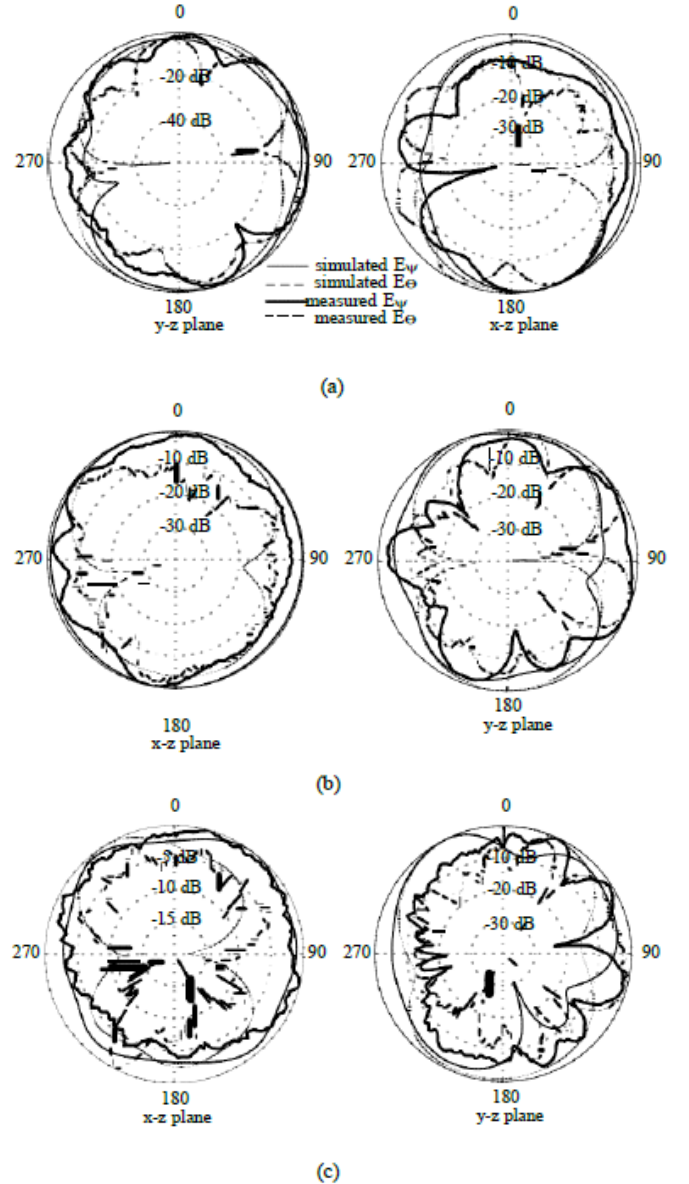


Fig.6 Simulated and measured radiation patterns of the antenna (a) 2.45 GHz (b) 3.3 GHz (c) 5.55 GHz.

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