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# COMPACT TRI-BAND RECTANGULAR MEANDER ANTENNA WITH ASYMMETRICAL L-SHAPED STRIPS FOR WLAN/WIMAX APPLICATIONS

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**Abstract**—A novel meander antenna with tri-band operation is presented for WLAN and WiMAX applications. The proposed antenna consists of a rectangular meander with two asymmetrical L-shaped strips. The rectangular meander is used for the lower band operation at 2.5 GHz. The left L-shaped strip is employed to generate the higher resonant mode at about 5.5 GHz, while the right L-shaped strip is employed to create a new resonant mode at 3.5 GHz and enhance the bandwidth of the middle band operation. Prototype of the proposed antenna has been constructed and experimentally studied. The measured 10 dB return loss bandwidths at the resonant frequency of 2.5, 3.5, and 5.5 GHz can be up to 520 MHz (2.18–2.70 GHz), 800 MHz (3.34–4.14 GHz) and 830 MHz (5.07–5.90 GHz), respectively. The antenna is simple in configuration and has a compact dimension of $37 \times 42 \times 1\,\mathrm{mm}^3$.

## 1. INTRODUCTION

With the rapid development of WLAN/WiMAX systems, the multiband broadband antenna has attracted much interest. To meet the WLAN standards in the 2.4 GHz (2.4–2.484 GHz)/5.2 GHz (5.15–5.35 GHz)/5.8 GHz (5.725–5.825 GHz) operating bands and the WiMAX standards in the 2.5 GHz (2.4–2.6 GHz)/3.5 GHz (3.4–3.6 GHz)/5.5 GHz (5.25–5.85 GHz) bands, multiband antennas with compact size, low cost, and easy fabrication are required. Various types of multiband antenna designs have been reported [1–11]. Some of them only can fulfill the requirement of the WLAN or WiMAX band, such as the monopole antennas [1–3] and the slot antennas [4–6]. Some efficient

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methods have been discussed to enhance the impedance matching and increase the operating band of the antenna, such as etching two pairs of T-shaped slots on the ground plane [7], employing two T-shaped strips in the two circular slots [8], inserting two pairs of strips into a rectangular slot [9], and adding two pairs of planar inverted L strips to the slotted ground [10]. Though those antennas can be applied to both WLAN and WiMAX systems, they are complex in structures. The antenna proposed in [11] has a simple structure, but it has a large overall size which limits its application to the portable device. Though antennas proposed in [12, 13] have small size, the bandwidths of those antennas are narrow.

In this paper, a novel tri-band antenna for WLAN and WiMAX applications is proposed. Unlike those antennas mentioned above, the proposed antenna has a very simple structure. By introducing two asymmetrical L-shaped strips, tri-band characteristic is created to meet the bandwidth requirements for WLAN and WiMAX applications. Details of the antenna design and analysis are presented, with the simulated and measured results.

## 2. ANTENNA DESIGN

As shown in Figure 1, the proposed antenna is printed on a 1-mm-thick Teflon substrate, which has a relative permittivity of 2.65 and a

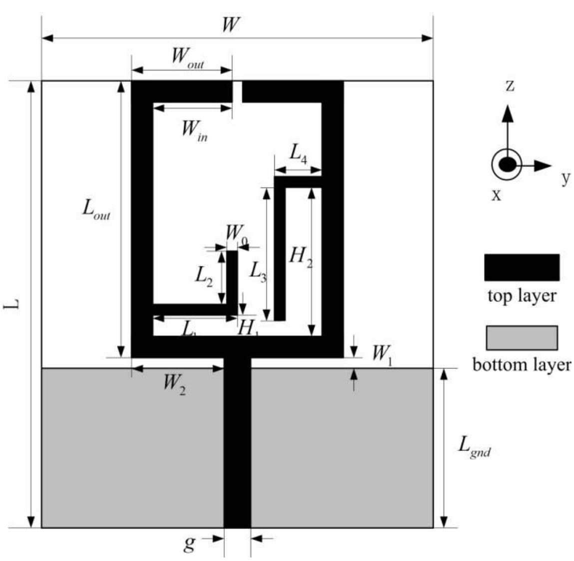



**Figure 1.** Configuration of the proposed antenna.

loss tangent of 0.001. The proposed antenna consists of a rectangular meander and two L-shaped strips which are placed asymmetrically with the microstrip feed line. The rectangular meander with a width of 1 mm, is used for the band 2.5 GHz operation. With the use of the left L-shaped strip, the proposed antenna can operate at 5.5 GHz. By adding the right L-shaped strip, the middle resonant mode at about 3.5 GHz can be generated. Additionally, a 50 Ω microstrip transmission line with a width of 2.5 mm is used for feeding the antenna. The optimized design parameters and values are summarized as follows: $W = 37$ mm, $L = 42$ mm, $W_{in} = 17.5$ mm, $L_1 = 8$ mm, $L_2 = 5$ mm, $W_0 = 1$ mm, $W_1 = 1$ mm, $W_2 = 17.25$ mm, $H_1 = 2$ mm, $H_2 = 14$ mm, $L_3 = 12.5$ mm, $L_4 = 4.5$ mm, $L_{out} = 26$ mm, $W_{out} = 19.5$ mm, $L_{gnd} = 15$ mm, $g = 2.5$ mm.

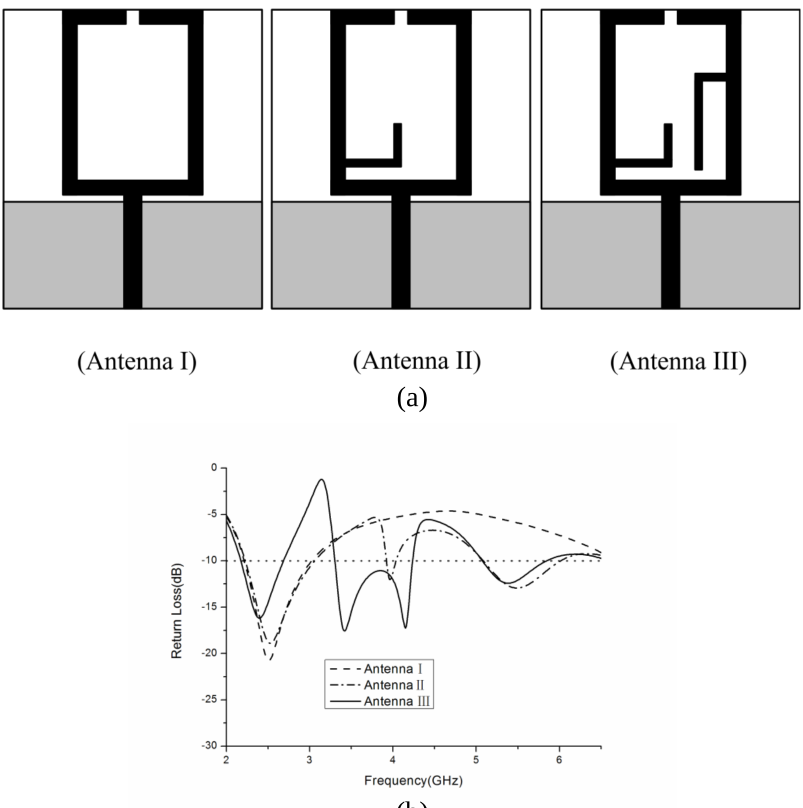



**Figure 2.** (a) Design evolution of the proposed antenna. (b) The corresponding simulated return loss curves.

## 3. PARAMETRIC STUDY

The study is based on the basic antenna structure (Antenna I) shown in Figure 2(a), which is a simple rectangular meander antenna without the two asymmetrical strips. Figure 2 shows the design evolution of the proposed antenna and its corresponding simulated return loss curves. It can be found from Figure 2(b), by adding the left L-shaped strip (Antenna II), the resonant mode centered at 5.5 GHz can be excited, but there is a bad impedance matching at 4 GHz. To improve the impedance matching and enhance the bandwidth of the middle resonant mode, another L-shaped strip (Antenna III) is employed. Finally, the proposed antenna can meet the requirements of the WLAN/WiMAX applications, as shown in Figure 2(b). The effects of the key structure parameters on the antenna performance are analyzed and presented.

### 3.1. Length of the Left L-shaped Strip ($L_1 + L_2$)

The effect of the left L-shaped strip on the performance of the proposed antenna is analyzed in this section. The length ($L_1 + L_2$) of the left L-shaped strip is given by

$$(L_1 + L_2) \approx \frac{\lambda_1}{4} \tag{1}$$

where $\lambda_1$ is the free space wavelength at 5.5 GHz. To prove the rationality of the expression, the return loss characteristic of the antenna for various length ($L_1 + L_2$) of the left L-shaped strip are

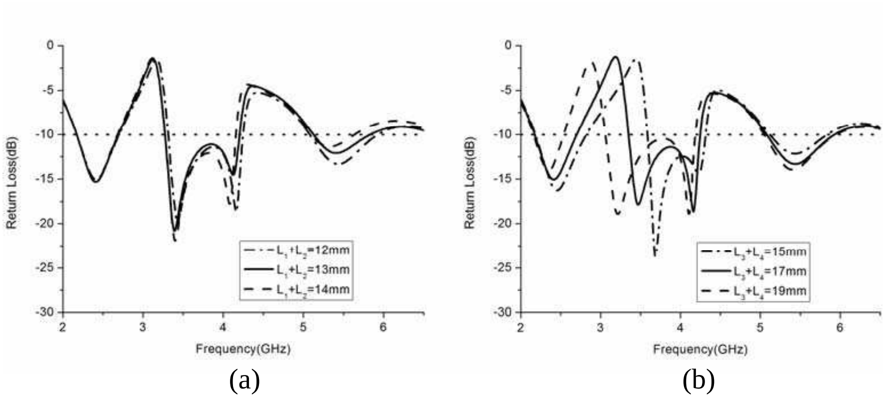



**Figure 3.** (a) Simulated return loss for different values of $L_1 + L_2$. (b) Simulated return loss for different values of $L_3 + L_4$.

demonstrated in Figure 3(a). It is observed that the higher resonant frequency can be adjusted by the length of the left L-shaped strip. As the length $(L_1 + L_2)$ increases from 12 mm to 14 mm, the resonant frequency of the higher band decreases dramatically, while the resonant frequency of the lower band changes slightly. It is also found when the length of the left L-shaped strip is set to 13 mm $(0.25\lambda_1)$, the antenna can generate the higher resonant mode. Therefore, it can be concluded that the main function of the left strip is to generate the higher operating band.

### 3.2. Length of the Right Inverted L-shaped Strip $(L_3 + L_4)$

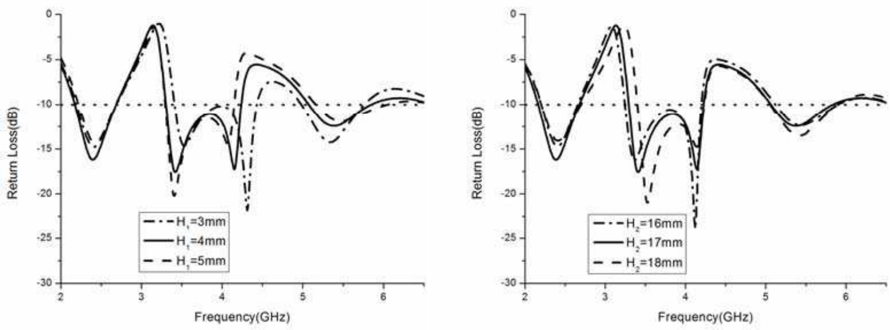
In this section, the effect of the right L-shaped strip on the performance of the proposed antenna is studied. The length $(L_3 + L_4)$ of the left L-shaped strip is given by

$$(L_3 + L_4) \approx \frac{\lambda_2}{4} \tag{2}$$

where $\lambda_2$ is the free space wavelength at 3.5 GHz. To corroborate the rationality of the expression, the return loss characteristic of the antenna for various length $(L_3 + L_4)$ of the right L-shaped strip are illustrated in Figure 3(b). It can be seen that the middle resonant mode can be adjusted by the length of the right L-shaped strip. As the length of the right strip increases from 15 mm to 19 mm, the resonant frequency of the middle band decreases dramatically, while the resonant frequencies of the lower band and the upper band change slightly. It is also found when the length of the left L-shaped strip is set to 17 mm $(0.19\lambda_2)$, the antenna can excite the resonant mode at 3.5 GHz. Thus, the right L-shaped strip is used to adjust the middle resonant mode.

### 3.3. Positions of the Two Strips $H_1$, $H_2$

To further investigate the effect of the asymmetrical L-shaped strips on the characteristic of the proposed antenna, the positions of the L-shaped strips have been discussed in this part. Figure 4(a) shows the return loss of the proposed antenna for various $H_1$. When $H_1$ is increased from 3 mm to 5 mm, the resonant frequency of the higher band increases. The return loss of the antenna for various $H_2$ is given in Figure 4(b). As $H_2$ increases from 16 mm to 18 mm, the higher and the lower resonant modes of the antenna changes slightly, while the resonant frequency of the middle band increases dramatically. Therefore, the positions of the L-shaped strips have a stronger effect on the performance of the proposed antenna. By properly tuning the




(a) (b)

**Figure 4.** (a) Simulated return loss for different values of $H_1$. (b) Simulated return loss for different values of $H_2$.

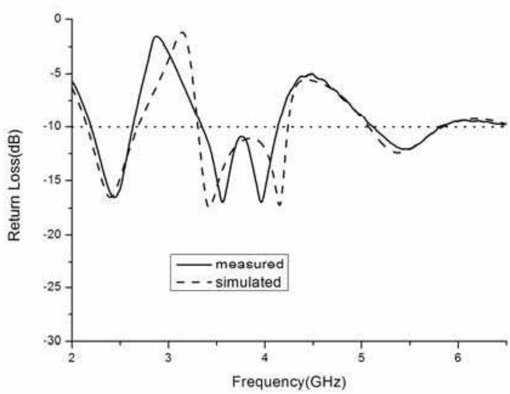



**Figure 5.** The measured and simulated return losses of the antenna.

position of the left and right L-shaped strips, the triple operating bands can be achieved.

## 4. EXPERIMENTAL RESULTS AND DISCUSSION

According to the parametric study above, the proposed tri-band rectangular meander antenna is fabricated. The return loss of the fabricated antenna is measured using WILTRON 37269A vector network analyzer. Figure 5 shows the measured and simulated return loss of the proposed antenna. The measured 10 dB return loss bandwidths are 520 MHz (2.18–2.70 GHz), 800 MHz (3.34–

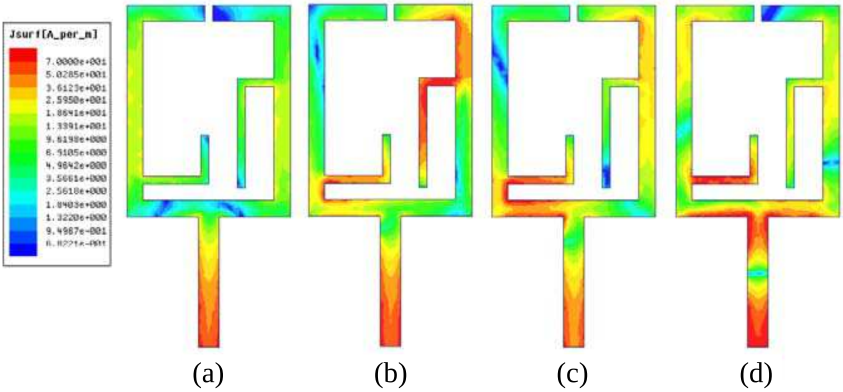



**Figure 6.** Simulated current distributions at (a) 2.5 GHz, (b) 3.5 GHz, (c) 4 GHz, and (d) 5.5 GHz.

4.14 GHz) and 830 MHz (5.07–5.90 GHz), which can cover the required bandwidths for WLAN and WiMAX applications. Good agreement between the measured and simulated results is achieved. The difference between the two results may be caused by the SMA connector or the radiation from the cable of the measurement device.

To further demonstrate the mechanism of the proposed antenna, the simulated current distributions on the proposed antenna at the frequencies of 2.5 GHz, 3.5 GHz, 4 GHz, and 5.5 GHz are presented in Figure 6. It can be seen that the current distributions are different in the different resonant frequencies. As shown in Figure 6(a) the current flows around the rectangular meander so that the lower resonant mode at about 2.5 GHz can be excited. In Figure 6(b), the current flows mainly focused on the right L-shaped. Therefore, the 3.5 GHz resonant modeis excited by the right strips. From the results shown in Figure 6(c), it can be seen that the left L-shaped strip has some effect on the middle bands. As observed in Figure 6(d), the current flows mainly along the left L-shaped strip, therefore the higher resonant mode at about 5.5 GHz can be achieved.

The simulated and measured radiation patterns at 2.5, 3.5, and 5.5 GHz are demonstrated in Figure 7. The antenna gives a nearly omni-directional radiation pattern in the $x$-$y$ plane ($H$-plane) and a dipole-like radiation pattern in the $x$-$z$ plane ($E$-plane). Figure 8 shows the simulated and measured peak gains in the whole operating bands. It can be clearly seen that appreciable gains are obtained over the operating bands.

The performance of the proposed antenna is compared with those

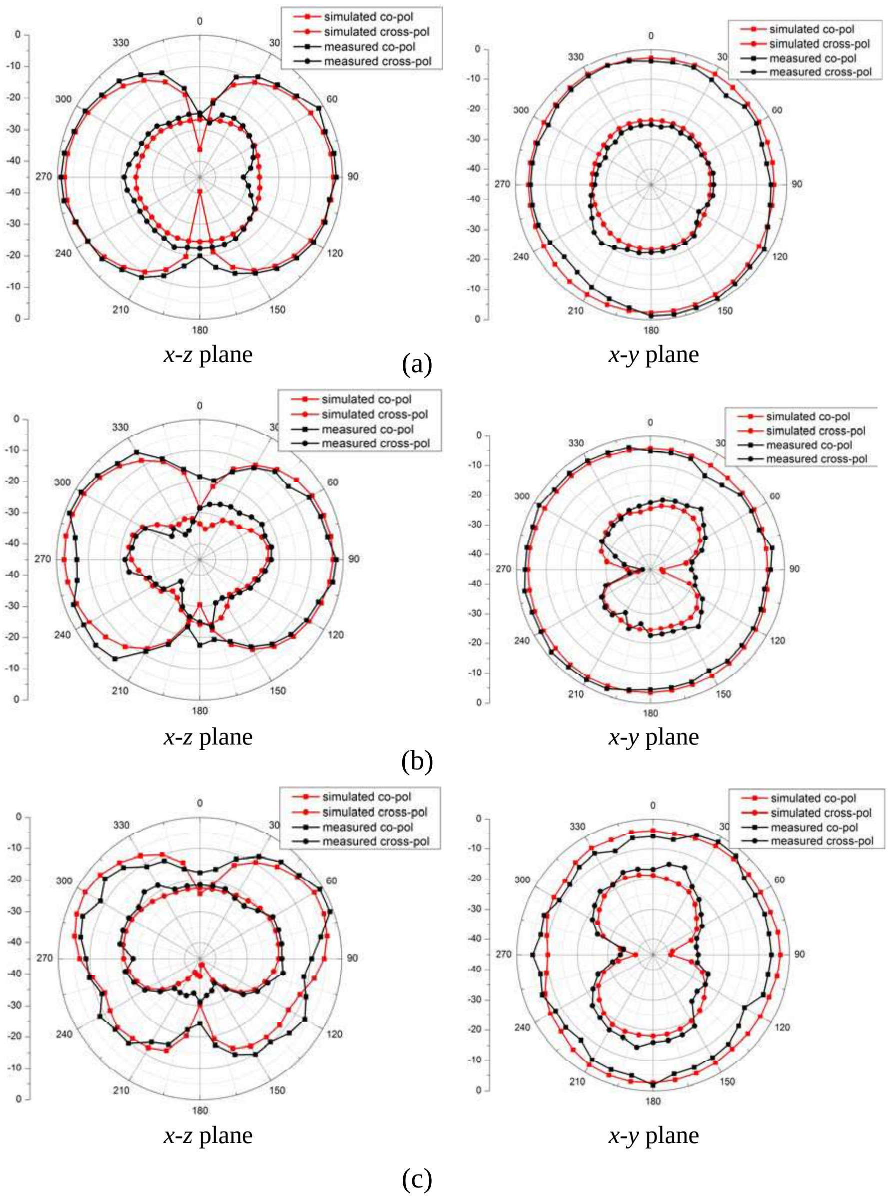



**Figure 7.** Simulated and measured radiation patterns at (a) 2.5 GHz, (b) 3.5 GHz, (c) 5.5 GHz.

of other tri-band antennas [11–13] in Table 1. The comparison includes the size, bandwidth, and gain. It indicates that the proposed antenna has a higher gain than other antenna. It can be seen that antennas

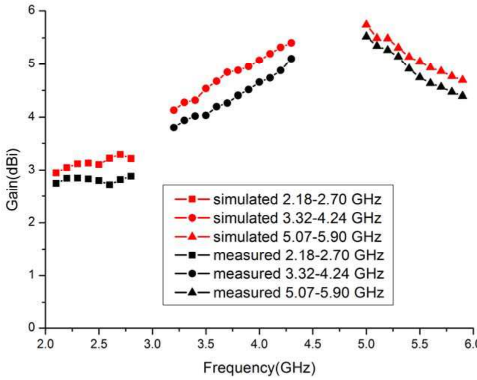



**Figure 8.** Simulated and measured gain of the proposed antenna.

**Table 1.** Comparison between the previous studies and our design.

| | | Antenna in [11] | Antenna in [12] | Antenna in [13] | Proposed antenna |
|---|---|---|---|---|---|
| BW (%) | 2.5 GHz | 30.8% | 13.6% | 4.4% | 20.8% |
| | 3.5 GHz | 23.4% | 18.2% | 7.4% | 22.8% |
| | 5.5 GHz | 25.5% | 10.7% | 10% | 15.1% |
| size | Length (mm) × Width (mm) | 44 × 48 | 35 × 30 | 30 × 25 | 37 × 42 |
| Maximum gain (dBi) | | 5.4 | 3.68 | 3.4 | 5.7 |

in [11–13] have a narrow bandwidth or a large size. As a compromise, the optimal values are chosen to achieve the small size and broad bandwidth.

## 5. CONCLUSION

A novel meander antenna for WLAN and WiMAX applications is proposed. With the use of a pair of asymmetrical L-shaped strips in the rectangular meander, the antenna can generate three separate impedance bands. The effects of the key structure parameters on the performance of the proposed antenna are studied. Good antenna performance of the operating frequencies across the three operating bands have been obtained. The measured results show that the antenna has good impedance matching and reasonable gains. The proposed antenna has the advantages of low cost, simple structure and easy design, which make it a good candidate for modern wireless communication applications.

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