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# A COMPACT CPW-FED MONOPOLE ANTENNA WITH A U-SHAPED STRIP AND A PAIR OF L-SLITS GROUND FOR WLAN AND WIMAX APPLICATIONS

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**Abstract**—A compact tri-band planar monopole antenna suitable for 2.4/5.2/5.8 GHz WLAN and 3.5 GHz WiMAX is presented. The antenna employs a U-shaped parasitic strip and a defect ground-plane structure. By inserting a U-shaped strip as a parasitic strip into a normal monopole which operates at lower band of the WLAN, one more resonance at the higher WLAN band comes out. A defect ground-plane composed of two symmetrical L-shaped slits leads to another resonance operating at WiMAX band. The proposed antenna has a compact size of $22 \times 41 \times 0.8\,\text{mm}^3$ and offers good radiation and reflection characteristics in the above frequency bands. The measured VSWR exhibits a good agreement with the simulated one. Detailed design steps, parametric studies and experimental results for the antenna are investigated in this paper.

## 1. INTRODUCTION

Two commonly used protocols for Wireless Local Area Network (WLANs) based on access points to relay data are WiFi and WiMAX, which promise higher data rates and increased reliability. Antennas of small size, low cost, multi-band are good candidates for such multiple

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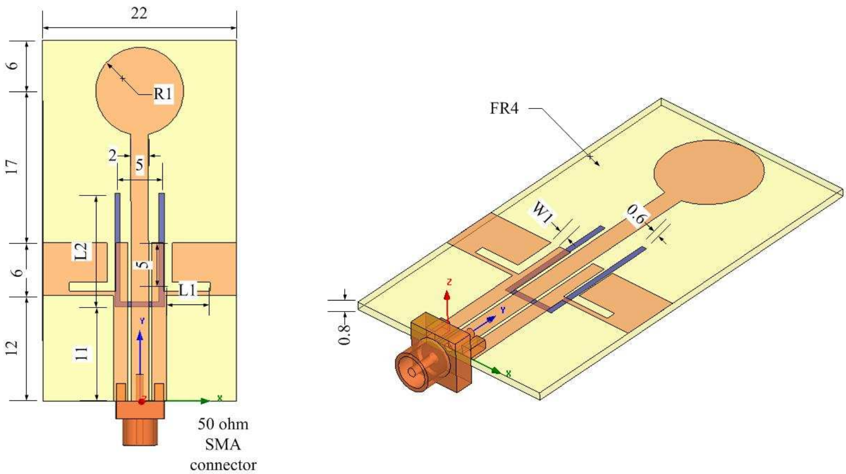
wireless communication protocol systems. Also, antennas for multi-band usage attract public attention. Many related antenna designs have been demonstrated recently. Although these antennas have achieved dual or tri-band operations, there are also some limits to obtaining some characteristics, and [1-7] are all modified monopole antennas for dual or multi-band uses. In [1], by loading a stacked conducting strip to a monopole patch, the antenna achieves dual-band operations as well as omni-directional radiation in azimuth plane. Reference [2] uses a C-shaped radiating element and a shorted parasitic element to make the antenna operate at the WLAN bands. And in [3], the authors inverted an L-shaped slit and an I-shaped slit as well as a U-shaped parasitic strip to achieve multi-band characteristic. But they cannot avoid a large volume or requires a large ground-plane. Besides monopole antennas are used for WLAN application, dipole antennas are also a good choice, and [8, 9] are both dipoles that operate at WALN bands. Antenna in [8] is not a planar structure, and it is not easily integrated with microwave circuits. And in [9] the three sections impedance transform-line takes up large volume. In [10, 11], there is a limit in obtaining omni-directional radiation characteristics, especially at the higher band.

In this paper, we demonstrate a modified monopole antenna. By inserting a pair of symmetrical L-shaped slits into the ground and a U-shaped parasitic strip on the other side of the substrate, the proposed antenna easily operates at three bands. The long strip with a circular patch controls the lower band of the proposed antenna. The slits on the ground directly affect the middle band, and the U-shaped parasitic strip generates the high band of the antenna. By putting the monopole between the two arms of the letter "U", symmetrical radiation patterns can be kept. Because of the inherent radiating characteristics of the monopole antenna, the proposed antenna got omni-directional radiation patterns in azimuth plane of the three service bands.

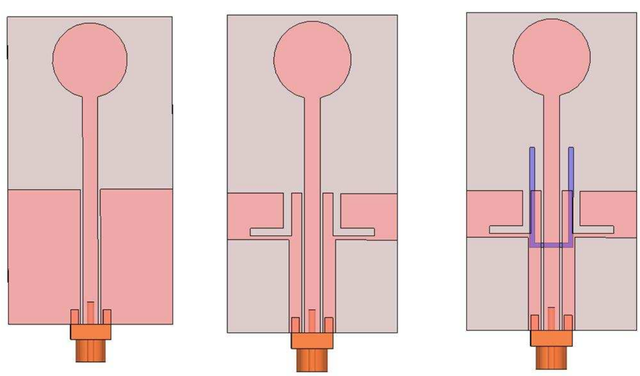
## 2. ANTENNA DESIGN

The geometry of the antenna is illustrated in Fig. 1. The antenna is printed on an FR4 substrate with the size of $22\,\mathrm{mm} \times 41\,\mathrm{mm}$, thickness of 0.8 mm and relative permittivity of 4.6. As shown in Fig. 1(a), there are three structures which comprise the front structure of the antenna: a CPW (coupled planar waveguide) transmission-line, defect ground-plane and the monopole. The width of the CPW transmission-line is 2 mm, with a gap 0.5 mm to match a 50 ohm SMA connector. By inserting a pair of symmetrical L-shaped slits with its width of 1 mm, total length (vertical part added to horizontal part) of $5\,\mathrm{mm} + 4.8\,\mathrm{mm}$




(a) (b)

**Figure 1.** Geometry of the proposed monopole antenna; (all dimensions units are mm). (a) Top view. (b) 3D view.



(a) (b) (c)

**Figure 2.** (a) Initial CPW fed monopole antenna, (b) antenna with defect ground-plane, (c) antenna with defect ground-plane and a U-shaped parasitic strip.

($L_1$) in the ground-plane, a middle frequency for WiMAX band can be easily excited. The length of the monopole is adjusted according to the lowest resonance frequency, and the current path on it is approximately $\lambda_0/4$ (30.62 mm at 2.45 GHz). Here we use a circular patch with radius

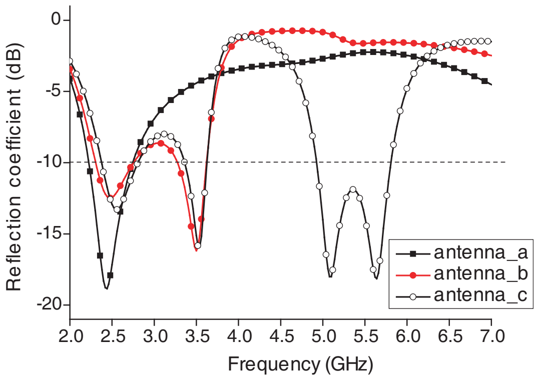



**Figure 3.** Simulated $S_{11}$ for the antenna $a$, $b$ and $c$.

$R_1$ to join the termination of the monopole, so it slightly reduces the antenna height (about 28 mm from bottom of the slits to the top of the circular patch). On the bottom side of substrate, there is a U-shaped parasitic strip with its width 0.6 mm. By adjusting the position and length of its arms, higher WLAN band can be easily covered into our service bands.

The process of designing the proposed antenna is shown in Fig. 2. From the initial commonly used CPW fed monopole antenna to our final design, we complete it by three steps, and they are antennas a, b and c. Simulated $S_{11}$ of these three antennas are clearly illustrated in Fig. 3, from which we see that every time we improve our design, one more resonance frequency comes out at the same time. And the newly added structure hardly affects resonance frequencies that we have got before. In other words, we can adjust one of the three resonances independently by varying corresponding structures and convenience of the debugging work for obtaining the antenna.

## 3. PARAMETRIC STUDY

In the present design, as known clearly the two additional parts (defect ground and U-shaped parasitic strip) induce two more resonances. Now we study the effects of some key parameters of the two parts in each service band. The first parameter that we will discuss is the radius ($R_1$) of the circular at the end of monopole. From Fig. 4(a) we see that when $R_1$ increasing from 3 mm to 5 mm, $S_{11}$ curve in lower band moves toward lower frequency direction with higher band invariable. The next two parameters are about the dimension of the L-shaped slits of the defect ground. As we adjust the horizontal length ($L_1$)

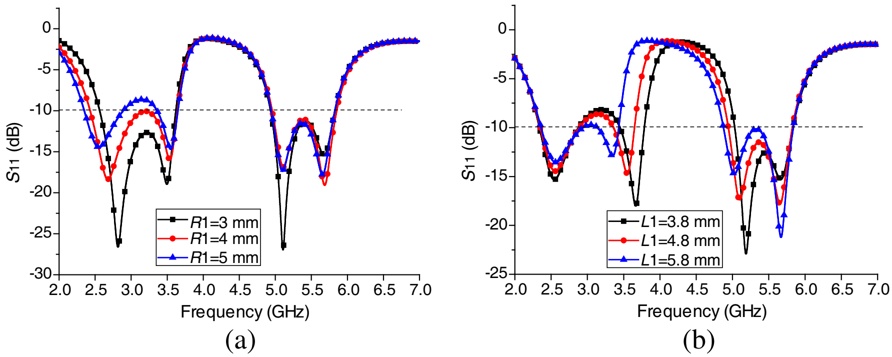



**Figure 4.** Simulated $S_{11}$ for various $R_1$ and $L_1$.

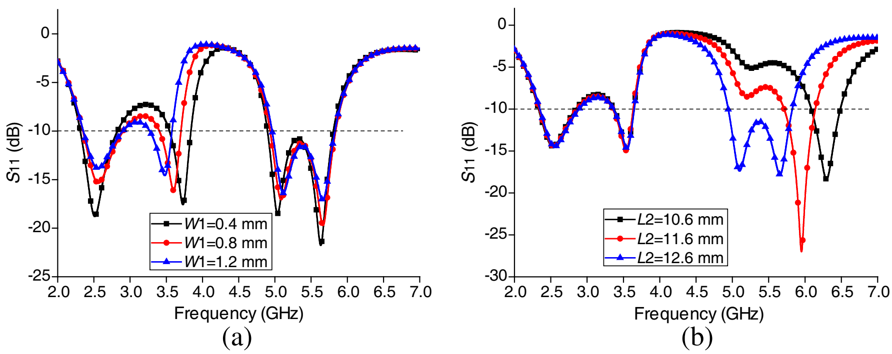



**Figure 5.** Simulated $S_{11}$ for various $W_1$ and $L_2$.

and width ($W_1$) of the slit, only the middle operating band shifts. These changes are illustrated in Fig. 4(b) and Fig. 5(a). The last important parameter is the vertical length ($L_2$) of U-shaped parasitic strip. Fig. 5(b) displays these effects. As the $L_2$ get longer, the upper service bands get lower, and we should notice in Fig. 5(b) that two lower bands are almost unchanged.

## 4. EXPERIMENTAL RESULTS

A prototype of the demonstrated antenna is fabricated, as shown in Fig. 6. The antenna was simulated using Ansoft High-frequency structure simulator (HFSS) software, and the reflection coefficients ($S_{11}$) of the antenna are measured by a calibrated vector network analyzer. Fig. 7 shows the simulated and experimental results of the VSWR for the proposed monopole antenna designed in Fig. 1. The

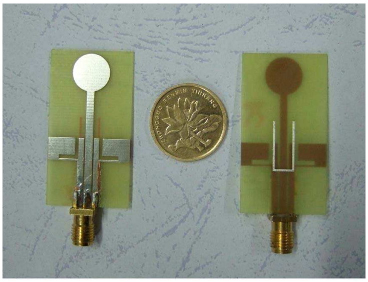


**Figure 6.** Photograph of the proposed antenna.

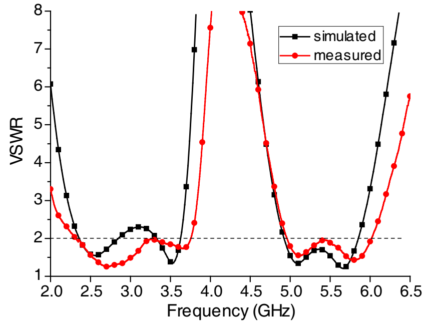
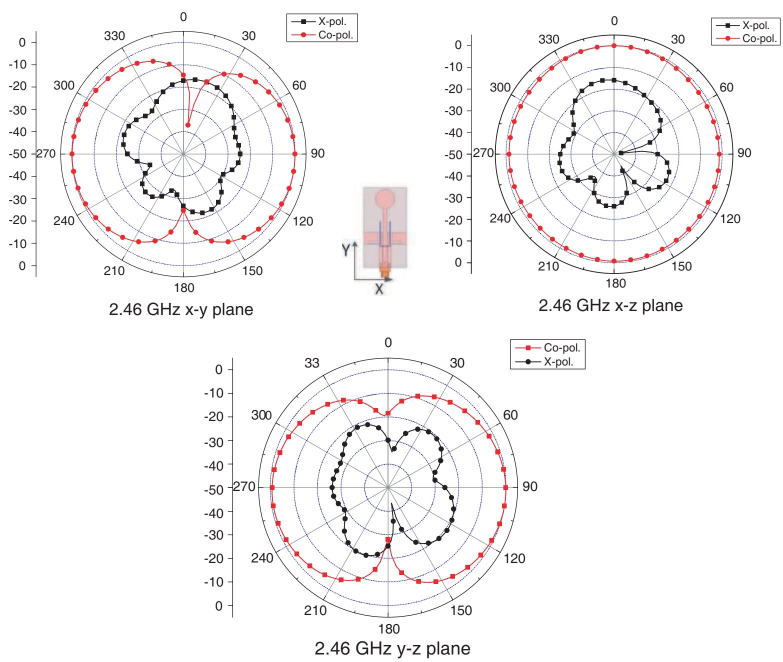



**Figure 7.** Simulated and measured VSWR.

results show a satisfactory result for the proposed tri-band monopole antenna operating at the WLAN and WiMAX bands. Impedance bandwidth (VSWR $<$ 2) of the proposed antenna are 950 MHz (2.32–3.27 GHz), 480 MHz (3.27–3.75 GHz) and 1006 MHz (4.96–6.02 GHz) respectively, which are sufficient to satisfy our design goals. The difference between the measured and simulated VSWR may be caused



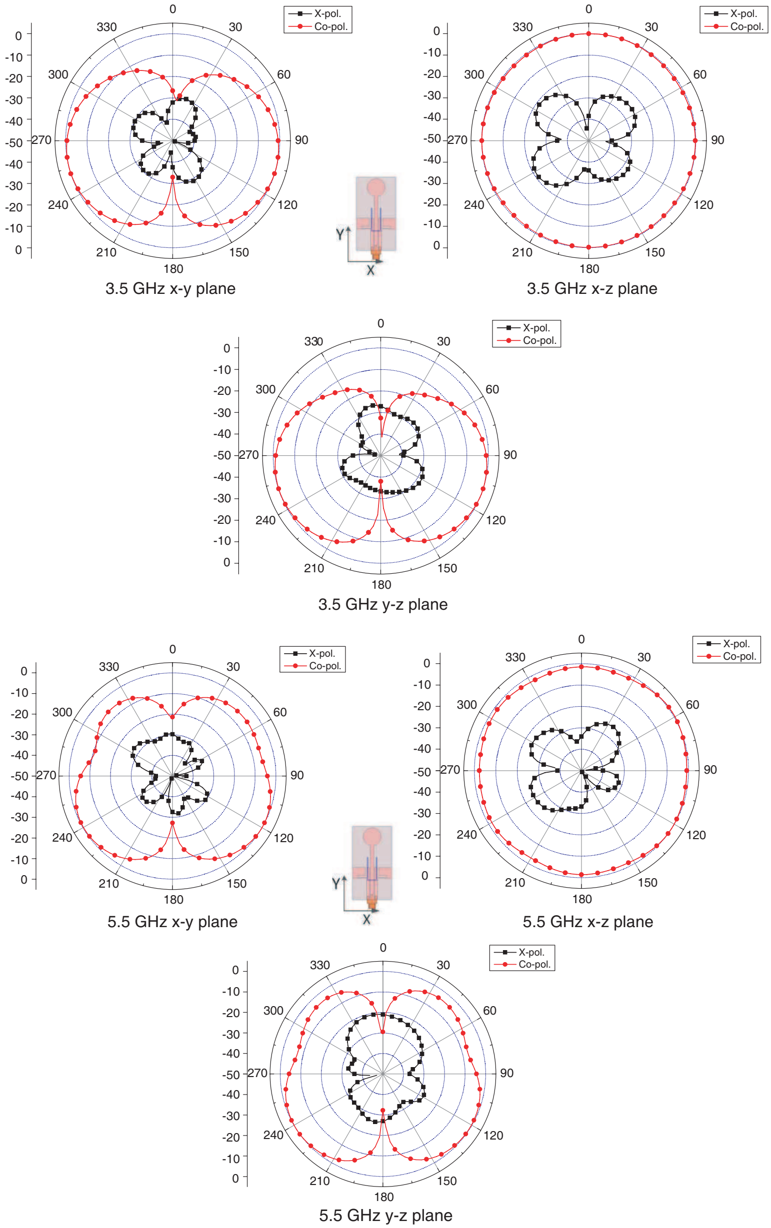



**Figure 8.** Simulated radiation patterns at 2.46 GHz, 3.5 GHz and 5.5 GHz.

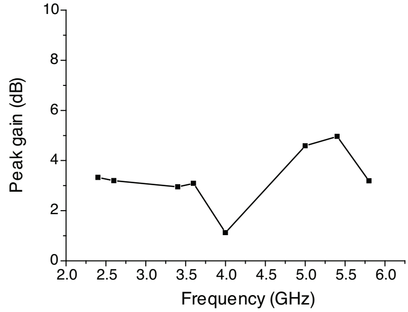



**Figure 9.** Peak gains of the proposed antenna.

by the connection of SMA to the antenna or the test environment.

The simulated radiation patterns of the proposed antenna are illustrated in Fig. 8. It can be seen that the radiation patterns in $H$-plane ($x$-$z$ plane) are approximately omni-directional at the center frequency of each service band. And radiation patterns in the two $E$-planes ($x$-$y$ and $y$-$z$ planes) are pronouncedly bidirectional. Peak gains at the three operating bands are shown in Fig. 9. At the lower bands of WLAN and WiMAX, the gain is about 3 dB, and in the middle band of the WLAN (5.15–5.35 GHz), the gain is about 4.5 dB.

## 5. CONCLUSION

A compact tri-band monopole antenna with a U-shaped parasitic strip and defect ground is proposed, fabricated and tested in this paper. The design steps of the antenna are illustrated, and each resonance frequency can be adjusted independently which makes the debug work convenient. The measured reflection coefficient curve is sufficient to encompass the WLAN and WiMAX bands. Fig. 8 shows that radiation patterns in $H$-plane ($x$-$z$ plane) are omni-directional and in other two $E$-planes ($x$-$y$ and $y$-$z$ planes), bi-directional. Peak gains are about 3 dB in each service band. The obtained results demonstrate that this design is suitable for multi-band applications.

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