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# PERFORMANCE ENHANCEMENT OF TRI-BAND MONOPOLE ANTENNA FOR WLAN/WIMAX APPLICATIONS

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**Abstract**—A novel tri-band monopole antenna applied to WLAN/WiMAX applications is proposed in this paper. The antenna comprises of two semicircles: one is fed by a microstrip line, and the other is shorted to the ground. By incorporating L-shaped strips, good filter as tri-band performance is achieved. The proposed antenna shows a good multi-band property to satisfy the requirement of WLAN in the 2.4/5.2/5.8 GHz bands and WiMAX in the 2.5/3.5/5.5 GHz bands. In addition, a near omni-directional radiation characteristic is also obtained. Experimental data show that the antenna can provide three separate impedance bandwidths of 400 MHz (centered at 2.6 GHz), 400 MHz (centered at 3.4 GHz) and 1100 MHz (centered at 5.3 GHz) with two fine notched bands at the undesired bandwidths.

## 1. INTRODUCTION

Recently, wireless local area network (WLAN) (working at 2.4/5.2/5.8 GHz) and worldwide interoperability for microwave access (WiMAX) (working at 2.5/3.5/5.5 GHz) allowed for convenient portable/mobile wireless access to various digital communication systems have been becoming very attractive [1, 2]. Multi-band antennas with simple structure and superior radiation performance for WLAN/WiMAX applications have been increasingly appealing [3]. [4–7, 12, 13] are all good multi-band performance antennas, but they usually cover the WLAN 2.4/5.2/5.8 GHz and WiMAX 2.5/5.5 GHz bands, and it is relatively rare that multi-band antennas cover the 3.5 GHz WiMAX

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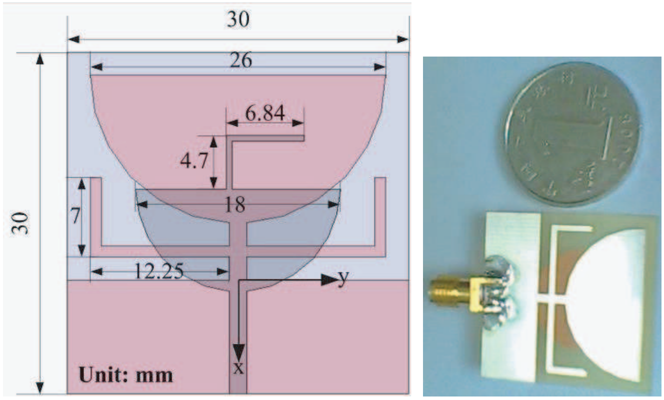
band simultaneously. In recent works [8–11], with wide-band property, monopole antennas have drawn much attention in multi-band antenna designs. To get a multi-band characteristic, [8] puts forward a dual L antenna, which gets good performance in impedance bandwidth. However, due to the dual L mutual impacts, these radiation patterns are not very good. Other antennas' radiation patterns are also affected to some extent, as mentioned in [9, 10], because of their asymmetrical constructions. [10, 14] have good performance both in impedance bandwidth and radiation pattern performance, but at their high frequency bands, the undesired frequency bands between WiMAX 3.5 GHz and WLAN 5.2 GHz are ignored, and this will undoubtedly lead to some signal interference with the near frequency bands.

In this paper, a planar semicircular monopole with a semicircular disc connected to the ground is proposed to cover the tri-band: WLAN 2.4/5.2/5.8 GHz and WiMAX 2.5/3.5/5.5 GHz. By properly introducing L-shaped strips, tri-band monopole antenna for WLAN/WiMAX applications with proper notched bands characteristics is put forward, and undoubtedly this will enhance the tri-band WLAN/WiMAX antenna performance. The tested results show that the antenna can provide three separate impedance bandwidths of about 400 MHz (2.4 GHz $\sim$ 2.8 GHz), 400 MHz (3.2 GHz $\sim$ 3.6 GHz) and 1100 MHz (4.75 GHz $\sim$ 5.85 GHz) for the tri-band applications, and with two well notched bands among the above frequency bands. Details of the antenna structure and both the theoretical and experimental results are also presented and discussed.

## 2. ANTENNA DESIGN AND SIMULATION

The prototype and photograph of the proposed antenna are shown in Fig. 1. The antenna is printed on an inexpensive FR-4 substrate of thickness 0.8 mm, relative permittivity 4.6 with the total size of 30 mm $\times$ 30 mm. The detailed design parameters are depicted in Fig. 1. In the figure, the top layer of the PCB is composed of a 50 $\Omega$ feed line, a semicircle and an L strip, while its back one (bottom layer) consists of a half circle with double L-shaped strips shorting to the ground. Theoretical analysis indicates that these L-shaped strips have great impacts on the antenna performance of impedance bandwidths.

To study the influence of L-shaped strips on the antenna performance intensively, commercially available EM simulation software Ansoft HFSS V11.0 is adopted. Fig. 2 displays the simulated VSWR curves of the antenna with or without top layer L-shaped strip, bottom layer double L-shaped strip and with only top layer semicircle respectively. From the comparison in the figure, it is clear




(a) (b)

**Figure 1.** The (a) structure and (b) photograph of the proposed antenna.

to see the effects of top, bottom L-shaped strips and the bottom inserted semicircle layer on the antenna impedance performance. Approximately, the double L-shaped strips at the bottom layer mainly affect the VWSR at about 3 GHz, while the L-shaped strip on the top layer primarily influences the higher frequency band. However, it was more sensitive compared with the bottom one. Without all the L-shaped strips, the antenna behaves more as an ultra wideband antenna but with a little defected performances. Obviously, these L-shaped strips behave as band-notched functions. However, because of the special shorting semicircular construction, the required resonating lengths of L-shaped strips at each notched frequency point are decreased. The length of the L-shaped strip on the top layer and the double L-shaped strips on the bottom layer are only 0.14 wavelength at about 3.8 GHz and 0.19 wavelength at about 3 GHz respectively. Without bottom semicircle layer, it is clear to see that the antenna's feature of VSWR has a severe frequency shift.

As well known, in most cases, an ultra wideband antenna is not always preferred for the tri-band application because of its easy interference with the near frequency bands. In this design, it is more attractive that the antenna has two sharp stop bands compared with the antenna without, and this will surely improve the performance of tri-band application systems.

Figure 3 illustrates the current distribution of the proposed antenna at different frequencies. From the figure, the shorting semicircle at the bottom layer obtains energy form the top semicircle

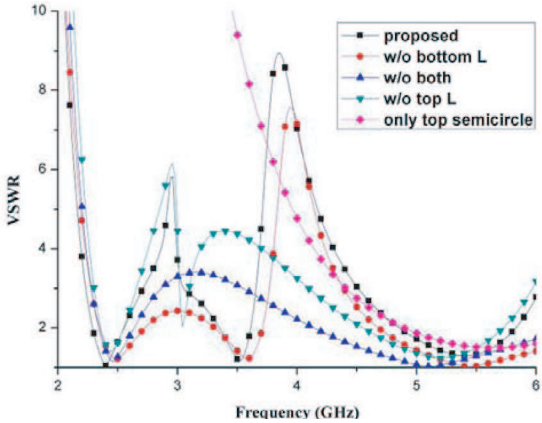
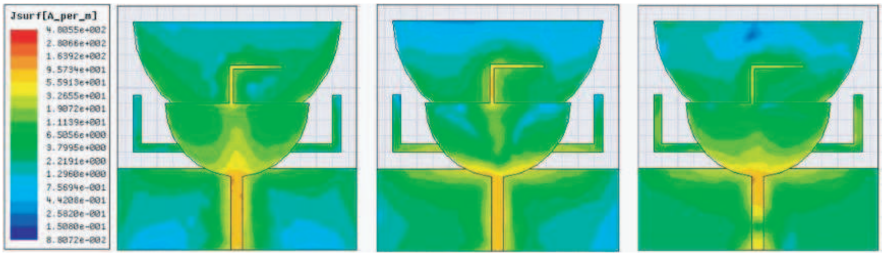



**Figure 2.** Simulated VSWRs of the antenna under different conditions.



(a) (b) (c)

**Figure 3.** Current distribution at different frequencies (a) 2.5 GHz, (b) 3.5 GHz, (c) 5.5 GHz.

and acts as part of the resonating structure. Obviously, as the resonating frequency increases, the required resonating length decreases at each frequency. Moreover, due to the semicircular tapered construction, a relatively uniform symmetrical current distribution is obtained, thus fine radiation patterns can be attained.

## 3. RESULTS AND DISCUSSION

The proposed tri-band antenna is fabricated and measured using the WILTRON-37269A Vector Network Analyzer. Fig. 4 depicts a good agreement between the measured and simulated VSWRs of the antenna. The results show that the antenna can provide three separate

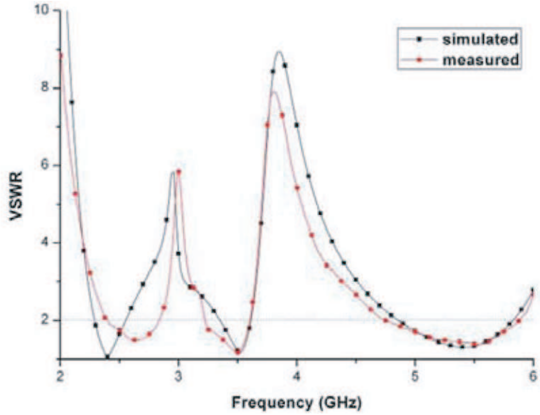
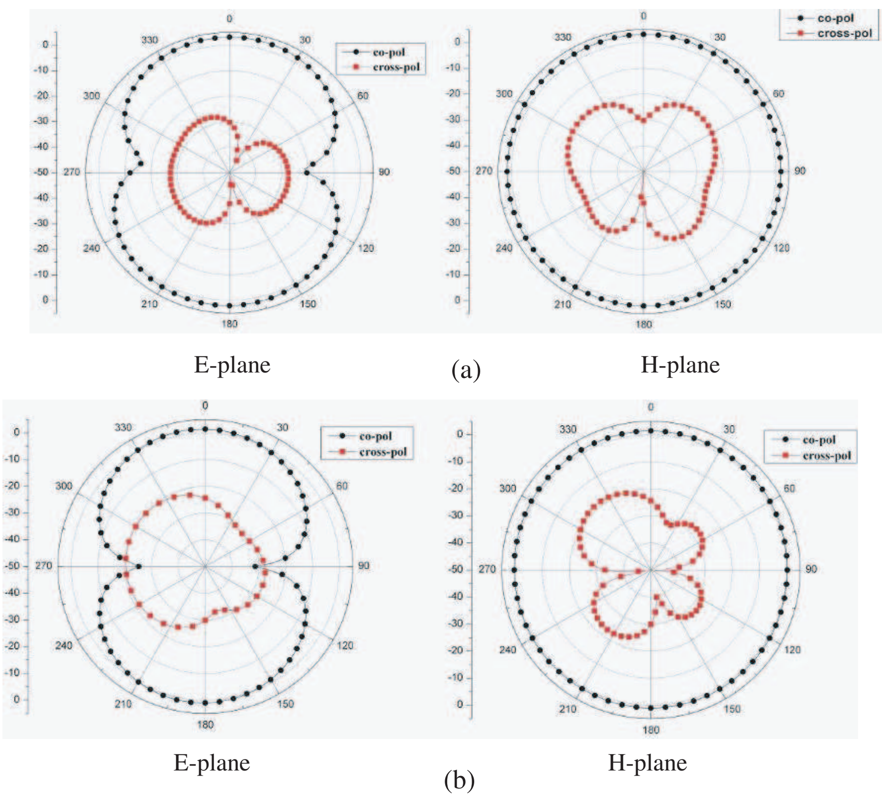
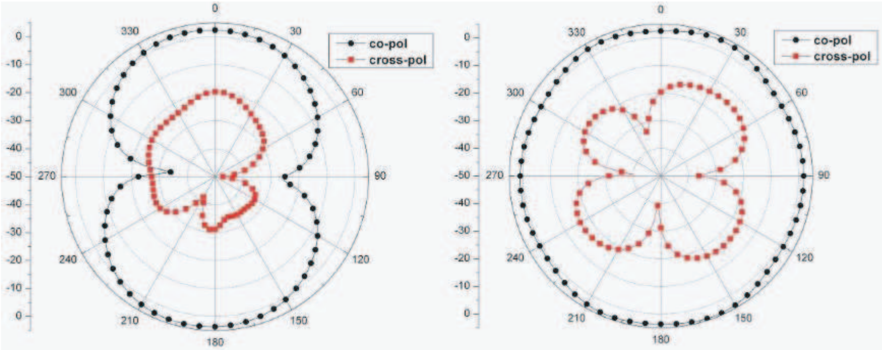



**Figure 4.** The measured and simulated VSWR of the antenna.






E-plane H-plane

(c)

**Figure 5.** Radiation patterns of the proposed antenna at (a) 2.5 GHz, (b) 3.5 GHz and (c) 5.5 GHz.

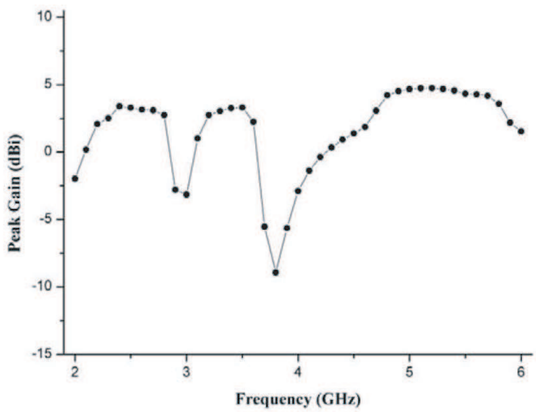



**Figure 6.** Gains of the antenna versus different frequencies.

impedance bandwidths of about 400 MHz (2.4 GHz ∼ 2.8 GHz), 400 MHz (3.2 GHz ∼ 3.6 GHz) and 1100 MHz (4.75 GHz ∼ 5.85 GHz) for the tri-band applications, and with two well notched bands among the above frequency bands. Fig. 5 demonstrates the simulated $E$-plane ($x$-$z$) and $H$-plane ($y$-$z$) radiation patterns at 2.5 GHz, 3.5 GHz, 5.5 GHz. Apparently, good dipole as radiation patterns are obtained at these frequencies with $E$-plane being bidirectional and $H$-plane omnidirectional. Fig. 6 indicates the measured peak gains of the proposed antenna at different frequencies. At the desired WLAN/WiMAX bands, they are about 3.15 dBi, 3.3 dBi and 4.3 dBi at 2.5 GHz, 3.5 GHz and 5.5 GHz, respectively. And at other frequency bands, there are visible drops on its peak gains.

## 4. CONCLUSION

A novel compact tri-band antenna for WLAN 2.4/5.2/5.8 GHz and WiMAX 2.5/3.5/5.5 GHz applications with enhanced performance has been presented in this paper. By adjusting L-shaped strips, good filter-like tri-band performance with two well notched bands is achieved. Results show a wide bandwidths of 15.4% at center frequency 2.6 GHz, 11.7% at center frequency 3.4 GHz and 20.7% at center frequency 5.3 GHz. In addition, good dipole-like radiation patterns as bidirectional $E$-plane and omnidirectional $H$-plane are obtained. The tested VSWR and radiation patterns confirm that the proposed antenna is a good candidate for multi-band communication systems.

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