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Compact CPW-Fed Tri-Band Antenna for WLAN/WiMAX Applications

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Abstract—A novel CPW-fed antenna capable of triple-band operation for WLAN/WiMAX applications is presented and investigated in this paper. The proposed antenna simply consists of three elements viz. folded open stub, L-shaped open stub, and Y-shaped resonator. By using the three elements, triple-band antenna operating at 2.5/3.5/5.5 GHz can be achieved. The antenna impedance bandwidths for $|S_{11}| \leq -10$ dB are 2.39–2.69, 3.38–3.73 and 5.0–5.99 GHz, covering all the WLAN/WiMAX operation bands. The tri-band antenna has good omnidirectional radiation patterns in H-plane and moderate gains across all the operation bands with compact size of $30 \times 18\,\text{mm}^2$. Experimental results show that the antenna is successfully simulated and measured, and the tri-band antenna can be achieved by adjusting the lengths of the three elements and gives good gains across all the operation bands.

1. INTRODUCTION

With the rapid development of modern wireless communications, the demand for antennas with multi-frequency, low cost, and compact size has increased. The coplanar waveguide (CPW)-fed antennas not only are suitable for easy integration with the circuit, but also have simple structures and compact size. Also, CPW transmission lines have less dispersion and lower radiation losses than microstrip lines. So, many researchers paid lots of attention to CPW-fed antennas. Thus, several dual-band antennas [1–3] and tri-band antennas [4–13] have been proposed to cover the bands for WLAN or WiMAX applications. The modified planar monopole pattern is constantly adopted to realize dual-band operation because of its easy fulfilment, such as the folded open ended stub monopole [1], T-shaped monopole [2], triangular monopole and U-shaped monopole [3]. Although these antennas have the advantage of simple structure, only two bands are included, which leads to low working modes in the communication terminal systems. Several approaches have been demonstrated to achieve tri-band antennas, such as a parasitic circular patch with an inverted-L strip [4], a rectangular ring with an S-shaped strip [5], a modified rectangular slot with an inverted-L strip [6], and a square-ring slot antenna with an asymmetric ground plane [7]. However, these techniques supporting tri-band antennas still suffer from large size. Slot techniques are also used to design and implement tri-band antennas [8–10]. Slot techniques can realize miniaturization, but the antennas are always in complex structures. To solve this problem, different kinds of microstrip resonators are proposed, such as fork-shaped resonator antenna [11], two spiral ring strips resonator antenna [12, 13], and three inverted-L stubs resonator antenna. The proposed antenna also uses the technique of resonators. The above-mentioned techniques supporting tri-band antennas have not only simple structures, but also compact sizes. Ultra-wideband (UWB) antennas [14] can also cover all operating bands. However, when the UWB antennas are used in WLAN/WiMAX systems, frequency interference cannot be avoided.

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Therefore, a novel compact planar triple-band CPW-fed antenna with compact size and simple structure based on open ended resonators for WLAN/WiMAX applications is proposed. The presented antenna consists of a folded open stub, an L-shaped open stub, and a Y-shaped resonator. By adjusting the lengths of the different stubs, the centre frequency can be tuned. Good triple bands impedance bandwidths covering 2.39–2.69, 3.38–3.73, and 5.0–5.99 GHz and stable gains across all the operating bands can be obtained. Good agreement between the simulated and measured results is observed. Experimental results for the presented antenna are demonstrated in this paper, showing the proposed antenna suitable for WLAN/WiMAX applications.

2. ANTENNA DESIGN AND SIMULATION

Figure 1 shows the geometry of the tri-band CPW-fed antenna for WLAN/WiMAX applications, which is printed on a $30 \times 18\,\text{mm}^2$ FR-4 substrate with a thickness of 1.6 mm, a dielectric permittivity of 4.4 and a loss tangent of 0.02. The proposed antenna is formed by a folded open stub, an L-shaped open stub, and a Y-shaped resonator The width of $50\,\Omega$ CPW transmission line is 3.5 mm, and the gap between the feed line and the ground plane is 0.5 mm.

The dimensions of the proposed antenna are shown in Figure 1, and the simulated reflection coefficient of the single-/dual-/triple-band antennas using HFSS 13 software is shown in Figure 2. The proposed antenna can be obtained through three steps. Firstly, the lower band at about 2.39–2.69 GHz is designed by folded open stub, and the configuration of antenna 1 and simulated reflection coefficient are shown in Figure 2. In order to achieve the miniaturization of the proposed antenna, the open stubs in antenna 1 are folded. Additionally, the length of each resonator strip is nearly equal to a quarter of the guided wavelength, i.e., λ_g (m) calculated at the desired resonant frequency f (Hz).

$$f = \frac{c}{\sqrt{\varepsilon_{eff}} \cdot \lambda_g} \tag{1}$$

$$\sqrt{\varepsilon_{eff}} \approx \frac{\varepsilon_r + 1}{2} \tag{2}$$

where ε_{eff} denotes the effective dielectric constant and c (m/s) the speed of light in free space. Secondly, the configuration and reflection coefficient of antenna 2 are shown in Figure 2. Based on antenna 1, an

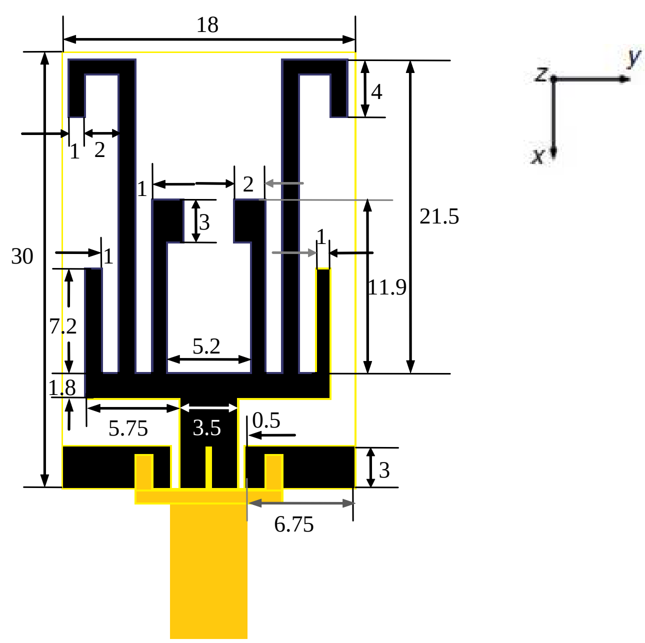


Figure 1. Schematic configurations of proposed antenna (unit: mm).

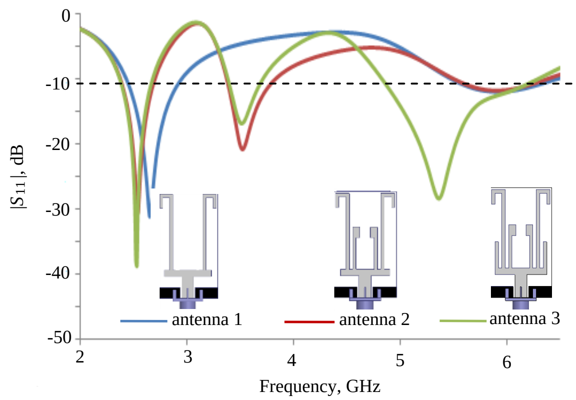


Figure 2. Simulated reflection coefficient of involved antennas.

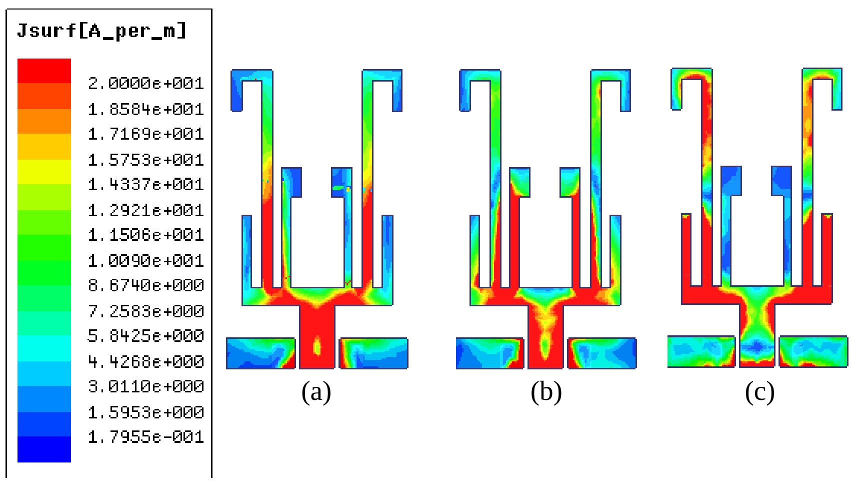


Figure 3. Simulated surface current distribution of the proposed antenna at (a) 2.5 GHz, (b) 3.5 GHz, (c) 5.5 GHz.

improved structure is presented for realizing the second resonant mode. Antenna 2 can realize a higher resonant frequency than the first one, whose dual-band centre frequencies at 2.5/3.5 GHz can be earned. Tri-band antenna can be obtained based on antenna 3. The reflection coefficient and configuration of antenna 3 are exhibited in Figure 2. At last, by adjusting the dimensions of the proposed antenna, i.e., the lengths of folded open stub, L-shaped open stub, and Y-shaped resonator and the width of ground plane, the triple-band antenna with centre frequencies at about 2.5/3.5/5.5 GHz is achieved.

In order to further explain the behaviour of the proposed antenna, the surface current distributions at the frequencies of 2.5, 3.5, and 5.5 GHz, respectively, were studied. Figure 3 shows the results of the surface current distributions. From this plot, one can clearly observe that the surface current distributions at three frequencies are different. For the first resonant element, most of the surface current is distributed on antenna 1, whereas for the middle and higher frequencies, the surface current distribution becomes more concentrated on antenna 2 and antenna 3 respectively. From Figure 3(c), it can be observed that the impact of antenna 1 on the third resonant frequency cannot be ignored, and Figure 4(a) illustrates their relationship.

The performances of the proposed antenna are affected by different parameters shown in Figure 4. Figure 4(a) depicts the simulated reflection coefficients of the antenna when the value of L_1 varies. It can be clearly seen that with the increase of L_1, the resonant frequency of the lower band gradually decreases and vice versa. So, we can tune the centre frequency of the first band by changing the value of L_1. It can also be observed that the third resonant frequency is also influenced by L_1. However, it floats at about 5.5 GHz, and the influence is little compared with that caused by L_3. As shown in Figures 4(b)

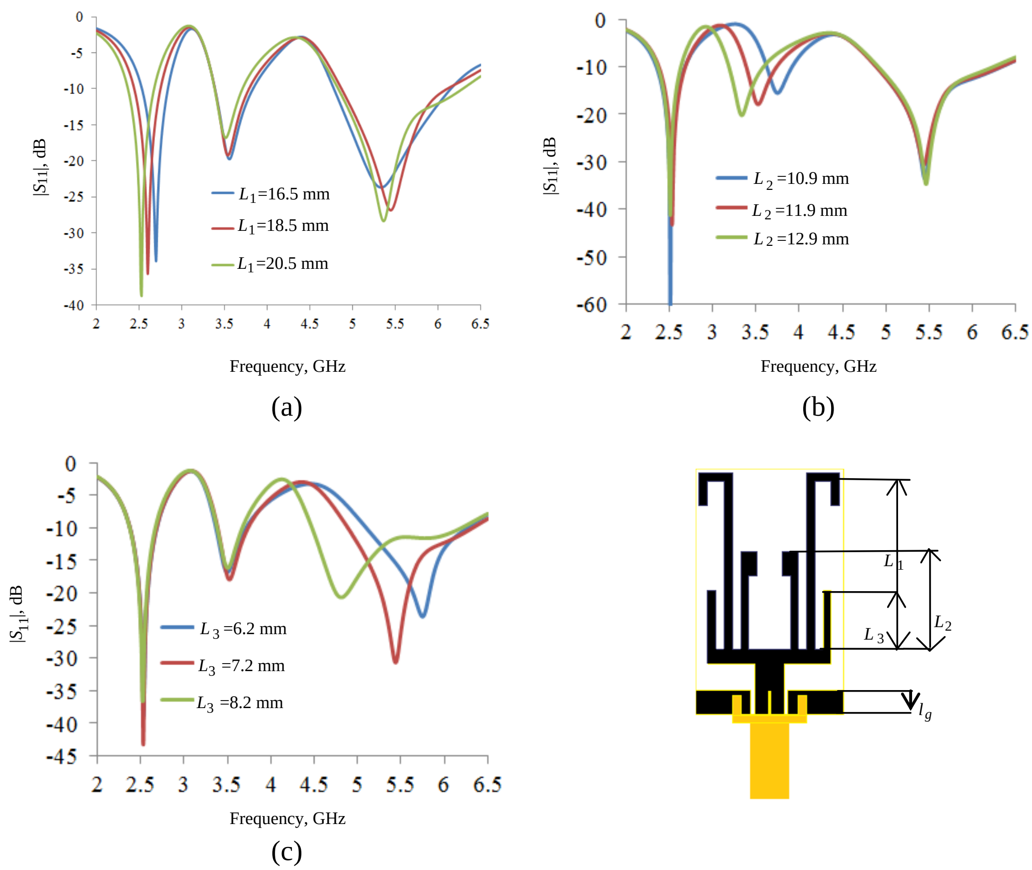


Figure 4. Simulated reflection coefficients of the proposed antenna with varied (a) L_1, (b) L_2, and (c) L_3.

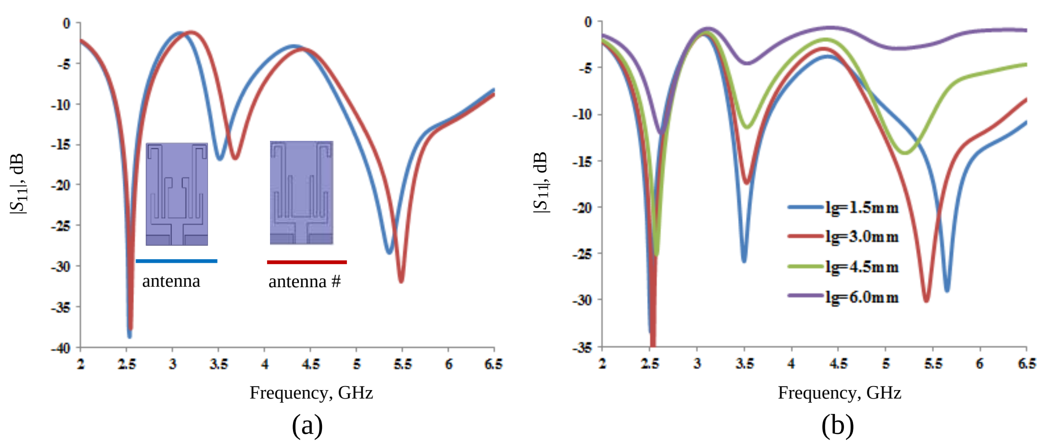


Figure 5. (a) Simulated reflection coefficients of the proposed antenna and antenna #. (b) Simulated reflection coefficients of the proposed antenna with varied l_g.

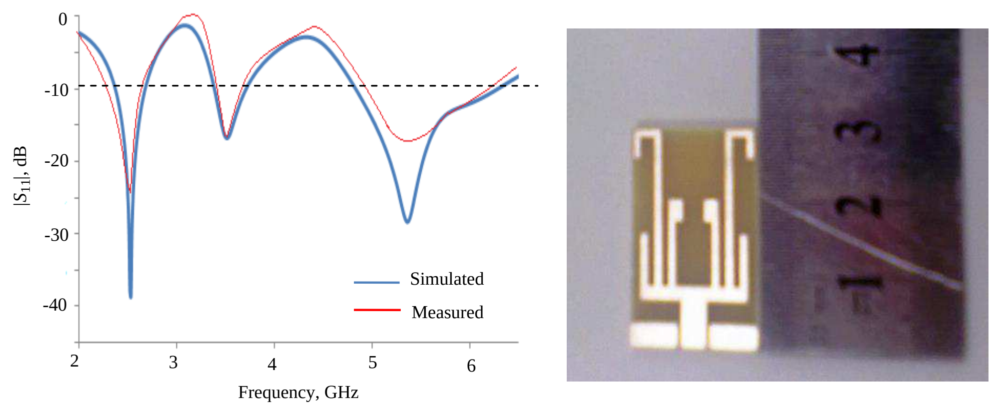
and (c), the middle and higher bands are influenced by L_2 and L_3, respectively. Additionally, the resonant frequencies of the middle and higher bands decrease with the increase of L_2 and L_3.

Figure 5(a) illustrates the simulated reflection coefficients of the proposed antenna using stepped-impedance lines in comparison with antenna # using uniform-impedance lines. The dimensions of these two antennas are the same. From Figure 5(a), it can be seen that the stepped-impedance lines can miniaturize circuit size comparatively under the same resonant frequencies. Figure 5(b) shows the simulated reflection coefficients of the proposed antenna with varied ground plane width l_g (see in Figure 4). One can clearly observe that the performance deteriorates with the increase of l_g. The proposed antenna is capable for WLAN/WiMAX applications when $l_g = 3\,\text{mm}$. Thus, l_g is chosen as 3 mm in this work.

3. RESULTS AND DISCUSSION

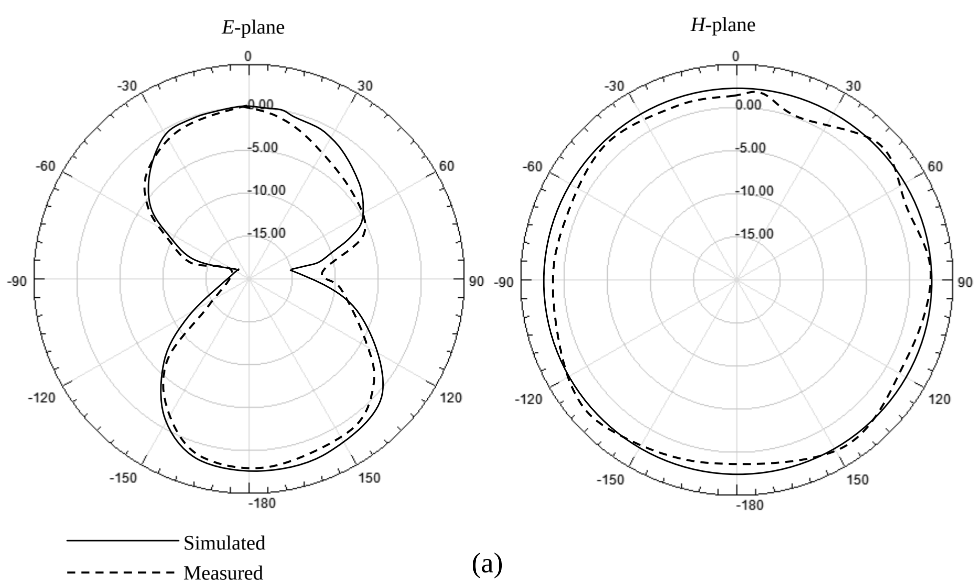
The simulated and measured impedance bandwidths for $|S_{11}| \leq -10\,\text{dB}$ of the proposed CPW-fed triple-band antenna are exhibited in Figure 6(a). Figure 6(b) shows the photograph of the proposed antenna. Its performance is obtained in an Anechoic Chamber with an Agilent E8362C. From Figure 6(a), the impedance bandwidths of three bands are about 30 MHz (2.39–2.69 GHz) resonated at 2.5 GHz, 350 MHz (3.38–3.73 GHz) centre frequency at 3.5 GHz, and 990 MHz (5.0–5.99 GHz) resonated at 5.5 GHz, respectively. The three bands fulfil all the WLAN (2.45–2.4835, 5.16–5.35, and 5.725–5.85 GHz) and WiMAX (2.5–2.69, 3.4–3.69, and 5.28–5.85 GHz) operating bands. Moreover, Figure 6(a) shows good agreement between simulated and measured results, and good isolation level between two different bands.

The simulated and measured *E*- and *H*-plane far-field radiation patterns of the proposed CPW-fed antenna at center frequencies about 2.5/3.5/5.5 GHz are normalized and illustrated in Figures 7(a), (b),



(a) (b)

Figure 6. (a) Simulated and measured reflection coefficient of the proposed antenna. (b) Photograph of the fabricated triple-band antenna.



(a)

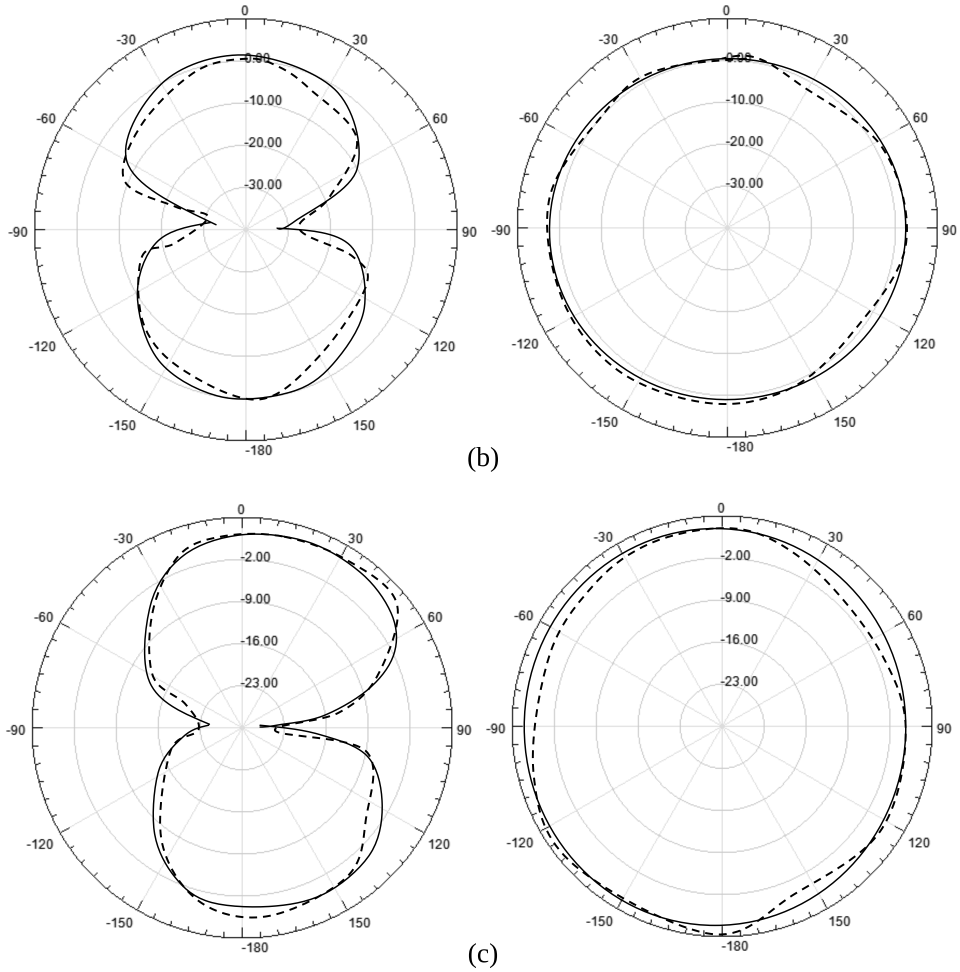


Figure 7. Simulated and measured radiation patterns of proposed antenna at 2.5, 3.5, and 5.5 GHz. (a) 2.5 GHz. (b) 3.5 GHz. (c) 5.5 GHz

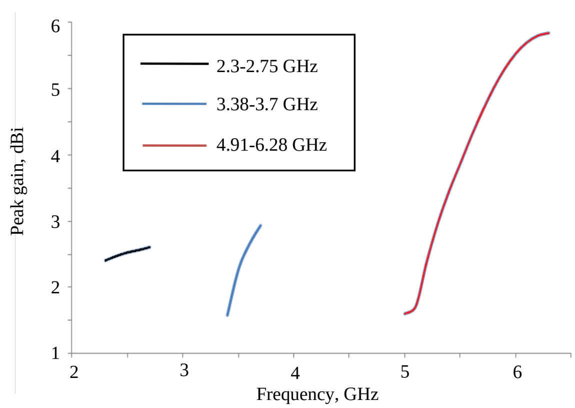


Figure 8. Peak gain of the proposed antenna.

and (c), respectively. Figure 7 reveals that the radiation patterns in E-plane across all the operating bands are always figure-eight, and the radiation patterns in H-plane have nearly omnidirectional characteristic at 2.5/3.5/5.5 GHz. The peak gains of the proposed antenna across three bands are plotted in Figure 8. The average peak gains of the three bands are 2.52, 2.37, and 4.15 dBi, respectively.

4. CONCLUSION

In this paper, a compact CPW-fed tri-band antenna for WLAN/WiMAX applications is presented with simulated and measured results. By introducing a folded open stub, an inverted L-shaped open strip, and a deformed Y-shaped resonator, the three working bands can be obtained successfully. The antenna has a compact size of $30 \times 18\,\mathrm{mm}^2$ and simple structure. The measured results agree well with the simulated ones. Measured results demonstrate that the proposed antenna can obtain three operating bands centered at about 2.5 GHz, 3.5 GHz and 5.5 GHz which cover all the WLAN and WiMAX bands. The antenna shows good omnidirectional radiation characteristics in H-plane, and reasonable gains in all the operating bands, which demonstrates that the proposed antenna is quite suitable for modern wireless communication systems.

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