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A PLANAR COMPACT TRIPLE-BAND MONOPOLE ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—A planar triple-band monopole antenna with a U-shaped stripline and a L slot is presented. The antenna is very compact with a size of $20 \times 30 \times 1.5\,\mathrm{mm}^3$ and fed by a $50\,\Omega$ microstrip line with a defected ground. The measured $-10\,\mathrm{dB}$ impedance bandwidth of the proposed antenna covers 2.33 GHz–2.51 GHz, 3.25 GHz–3.82 GHz, and 4.83 GHz–8.4 GHz, respectively, which meets the specifications of WLAN 2.4/5.2/5.8 GHz and WiMAX 3.5/5.5 GHz. The radiation characteristics shows a monopole-like pattern, and the measured results are in agreements with the simulated ones.

1. INTRODUCTION

Multiband antennas with small size, low profile and simple structures are becoming increasingly attractive for wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) applications. In order to meet the specification of the WLAN bands at 2.4 GHz (2.4–2.483 GHz), 5 GHz (5.15–5.875 GHz) and the WiMAX band at 3.4 GHz (3.4–3.7 GHz), various types of multiband monopole antennas are proposed, such as trident-shaped monopole antenna [1], T-shaped monopole antenna [2], U-shaped monopole antenna [3], and a folded strip monopole antenna with a protruding stub in the ground plane [4]. Differently shaped strips and slots are another way to realize multi-band antenna design. Antenna with C-shaped and L-shaped strips [5] and a rectangular patch antenna with dual inverted L-shaped strips [6] are investigated to meet triple-band requirements. Both of them use a defected ground to improve the

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bandwidth. A printed dipole antenna with two L-shaped elements is proposed [7]. The triple-band antenna using two U-shape slots [8], antenna with taper slot etched in ground [9], and a square slot antenna with crooked T and F-shape strips [10] are presented to realize multiband. The application of parasitic elements are also studied to obtain multiband antenna, such as a meandered strip connecting a rectangular patch on the bottom of the antenna by a plated-through via [11], a triple-band rectangular monopole with a circular resonance patch [12], a triple-band C-shape monopole antenna with inverted L-shape parasitic strip [13], and a multiband planar monopole antenna that contains some different types of branches and one parasitic element [14]. Moreover, metamaterial and fractal structure are used in the design of multi-band antennas, such as a monopole antenna uses a single-cell metamaterial loading to achieve triple-band [15], a modified fractal rhombic patch monopole antenna to realize multiband [16], and a multifrequency antenna realized by split ring resonators [17]. All of those different types of antennas can work well for WLAN and WiMAX applications. Several of the antennas mentioned above have either relatively large dimension size or complex structures, which may increase the cost and dimension size of wireless communication devices.

In this paper, a printed triple-band monopole antenna is proposed for WLAN and WiMAX applications. The performance of the proposed antenna is simulated using a commercial software CST Microwave Studio, and the prototype of the antenna is manufactured and measured. Details of the antenna design are described in Section 2. Results and analysis are provided in Section 3, and we summarize our conclusions in Section 4.

2. DESIGN OF THE ANTENNA

The proposed triple-band antenna is printed on a substrate with thickness 1.5 mm and dielectric constant $\varepsilon_r = 2.65$, as shown in Fig. 1. The whole dimension of the antenna fed by a $50\,\Omega$ microstrip line with the width of 4.1 mm is only $20 \times 30 \times 1.5\,\text{mm}^3$. In Fig. 1(a), The main radiation patch of the antenna is designed to be a rectangle patch with an elliptical edge in order to cover a wide frequency range. The simulated -10 dB impedance bandwidth of such a structure covers from 3.48 GHz to 7.74 GHz. Then a 1.5 mm wide L-slot is introduced inside the rectangle patch to split the original wide frequency band into two, 3.25 GHz–3.82 GHz and 5.0 GHz–7.74 GHz respectively. Finally, an asymmetric U-shaped strip line with width of 1 mm is added at the top of the rectangle patch to obtain the lowest resonance at the frequency band of 2.4 GHz–2.483 GHz. The initial length of U-shaped strip line and L slot is approximated according to

$$l = \frac{\lambda_p}{4} = \frac{c}{4f\sqrt{\varepsilon_r}}$$

where c is the speed of light in vacuum, f is the resonant frequency, and ε_r is the relative permittivity of the substrate. At the bottom of the antenna, a defected ground is used to adjust the highest resonance frequency. The whole antenna is optimized with the commercial software CST Microwave Studio, and values of some optimized parameters are shown in Table 1.

To demonstrate the above design, the current distributions at different frequencies are illustrated in Fig. 2. Fig. 2(a) shows that the current distributes mainly along the U-shaped strip line at 2.45 GHz. The current flowing along the strip line is opposite to but much larger than the current along the patch, so it can radiate electromagnetic energy efficiently at the lower band of 2.4 GHz. Fig. 2(b) and Fig. 2(c) tell us that the current flowing along the L-shaped slot contribute mainly to the radiation at the middle band of 3.5 GHz, while the current concentrated along the elliptical edge contributes to the radiation at the upper band of 5.5 GHz.

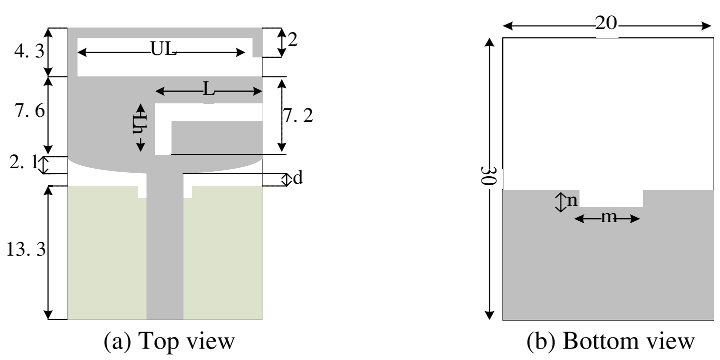
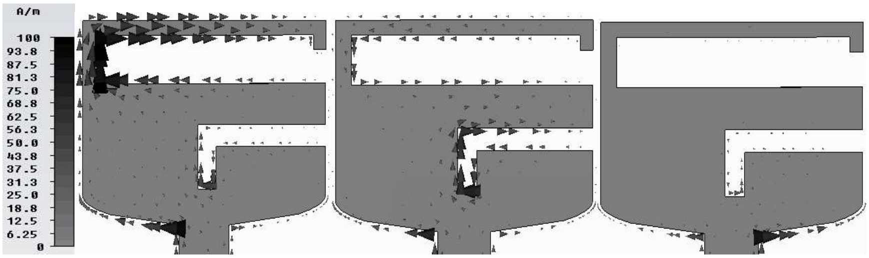


Figure 1. The geometry of the proposed triple-band antenna (unit: mm).

Table 1. The values of parameters for the design of the proposed antenna (mm).

Parameter	UL	L	Lh	d	m	n
Dimension	18	10.5	4.4	2.7	5	1.7



(a) 2.45GHz (b) 3.5GHz (c) 5.5GHz

Figure 2. Simulated surface current distribution at the different frequency for the proposed antenna.

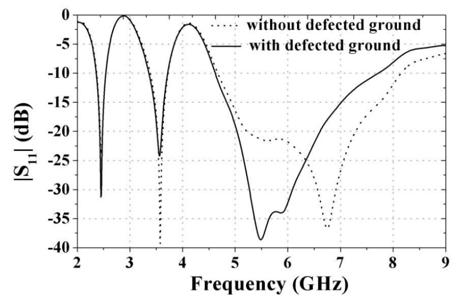


Figure 3. The return losses of antenna with and without the defected ground.

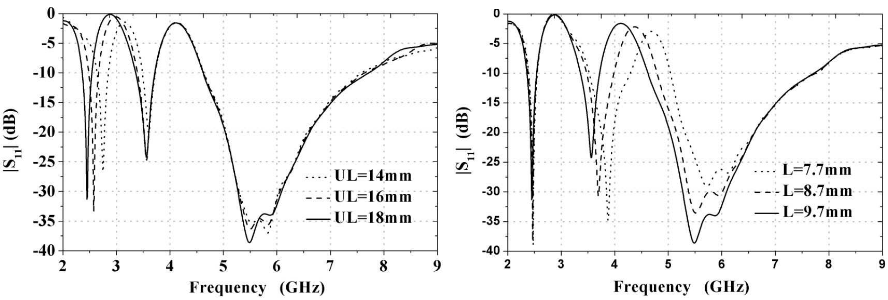
3. RESULTS AND ANALYSIS

Effects of some important structure parameters on impedance of the proposed antenna are investigated. Firstly, the comparison of the return loss between antenna with and without defected ground is shown in Fig. 3. Cutting a small rectangle part off the top of the ground can move the highest resonance from 6.8 GHz to 5.5 GHz, and keep the required bandwidth at the mean time.

Secondly, the effect of parameter UL and L on the performance of the proposed antenna are studied and results are shown in Fig. 4(a) and Fig. 4(b) respectively. As mentioned above, UL is the length of main part of the U-shaped strip line. Fig. 4(a) shows that the change of UL has an affect mainly on the lowest resonance, and a little on middle and highest band. That again demonstrate the U-shaped strip line contributes to the radiation at the 2.4 GHz band.

As for the effect of L, the length of horizontal part of L-slot, Fig. 4(b) tells us that both the middle and highest resonance increase as L decreases. That implies the L-slot only affect the middle and highest resonant frequency, as we expected in antenna design section. However, the lowest resonant frequency hardly moves as L decreases, but the resonance peak becomes sharper.

Figure 5 shows the prototype picture of the proposed antenna. The $|S_{11}|$ of the manufactured antenna is measured using Agilent Vector Network Analyzer N5230, and both simulated and measured results are shown in Fig. 6. We can see that the simulated resonant frequencies agree well with measured ones at lower and middle bands, while differs a lot at higher band. The reason for that phenomenon may be caused by the welding of the SMA adaptor. Then the $|S_{11}|$ of the antenna is simulated again, but this time the simulation model is added a SMA adaptor. The result is shown in Fig. 6 as a dash-dot-plot. We can see that two resonances appear due to the current flows down the outside of the SMA, which implies that the coaxial cable influence



(a) (b)

Figure 4. The effects of main parameters on return loss of the antenna: (a) effect of UL, and (b) effect of L.

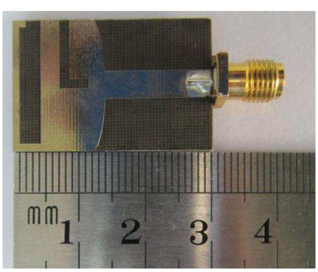


Figure 5. Prototype picture of the proposed antenna.

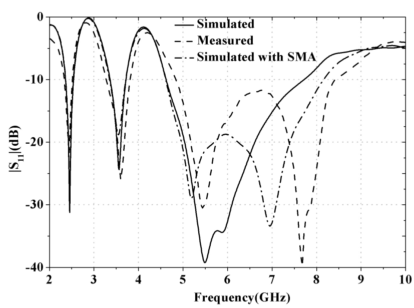
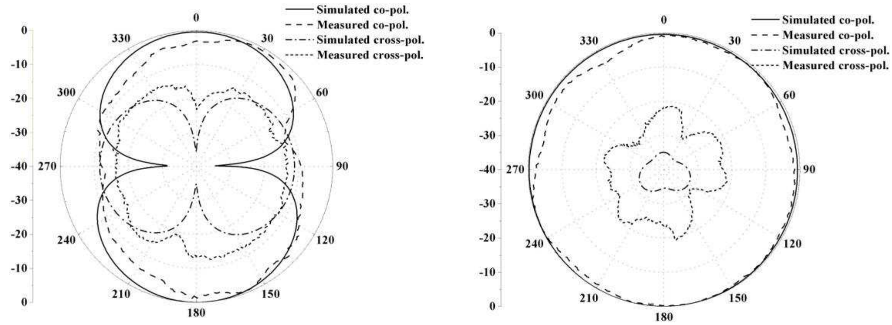
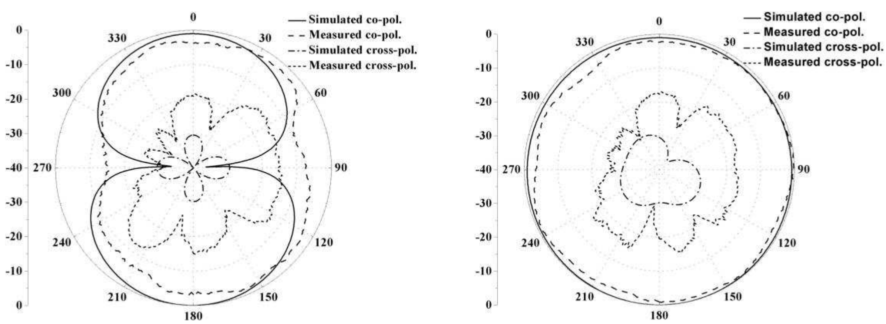


Figure 6. Simulated and measured return loss of the proposed antenna.

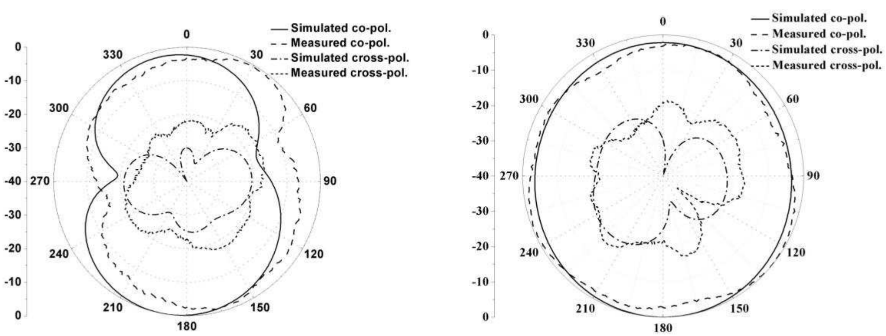
the impedance at the upper frequency band a lot. Even though the difference between the simulated and measured results at the upper band, the measured result indicates that the $-10\,\mathrm{dB}$ bandwidth of the prototype antenna meets all the specifications of WLAN and WiMAX applications.



(a) 2.45 GHz



(b) 3.5 GHz



(c) 5.5 GHz

Figure 7. Simulated and Measured E/H-plane radiation pattern: (a) 2.45 GHz, (b) 3.5 GHz, (c) 5.5 GHz.

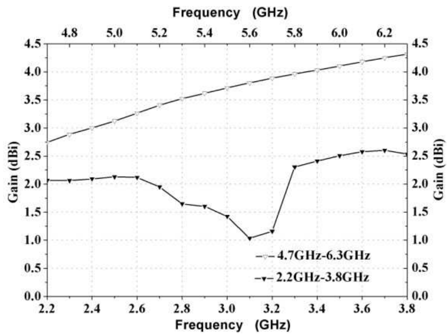


Figure 8. Simulated gain of the proposed antenna.

Figure 7 shows the measured and simulated radiation patterns at 2.45 GHz, 3.5 GHz, and 5.5 GHz, respectively, and the SMA adaptor is considered in the simulation. It can be clearly seen in Fig. 7 that the radiation pattern is omni-directional in the H-plane and bidirectional in E-plane. The measured results agree with simulated ones, which validate the proposed antenna structure. Finally, the simulated gain of the proposed antenna at operating frequency bands is shown in Fig. 8. We can learn that the gain is about 2.1 dBi at 2.4 GHz, 2.5 dBi at 3.5 GHz, and increases to more than 3.4 dBi at band from 5.2 GHz to 6.2 GHz.

4. CONCLUSION

A compact triple-band monopole antenna with simple structure is proposed in this paper. The measured −10 dB bandwidths of prototype antenna covers three bands of 2.33–2.51 GHz, 3.25–3.82 GHz and 4.83–8.4 GHz, which meets the requirements of WLAN/WiMAX applications. Both the measured return loss and radiation patterns are in agreements with that of simulated ones.

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