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COMPACT TRIPLE-FREQUENCY PLANAR MONOPOLE ANTENNA FOR WIMAX/WLAN APPLICATIONS

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Abstract—A low-profile microstrip planar monopole antenna with triple-band operation for WiMAX and WLAN applications is proposed. The antenna has a simple structure which consists of a rectangular radiation patch with an L-shaped slot and an inverted L-shaped stub extending from the ground plane. By etching an L-shaped slot on the rectangular radiation patch, the antenna can excite two resonant modes. The third resonant mode is introduced by extending an inverted L-shaped stub from the ground plane. The designed antenna has a small overall size of $17 * 30\,\mathrm{mm}^2$. A prototype is designed, fabricated, and then measured. The experimental and simulation results show good impedance bandwidth, radiation pattern and stable gain across the operating bands.

1. INTRODUCTION

Because of the prompt development of modern wireless communication systems, the demand for portable wireless devices that have small volume and multi-band operations is enormous. Wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) have widely been used in commercial, medical, and industrial applications. In order to integrate these two communication standards into a single device, multi-band antennas with good performance are needed. Various types of designed antennas have been reported for both WLAN and WiMAX applications [1–12]. Microstrip-fed planar monopole antennas with various structures [1–5] have become popular candidate in triple-frequency applications for its advantages of low-cost, low-profile, and easy fabrication, whereas the

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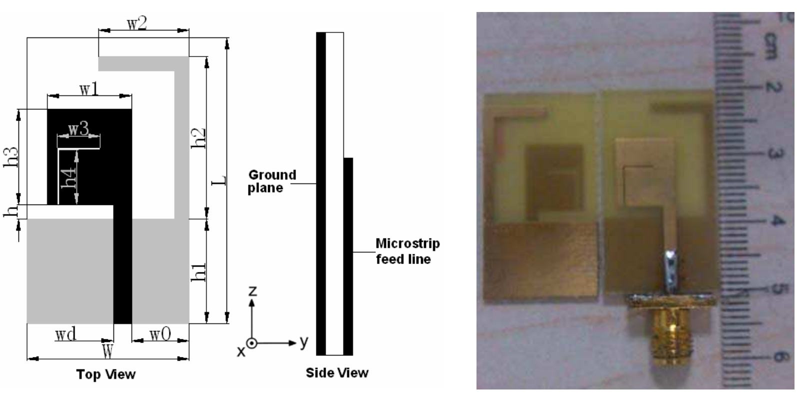
antenna size is relatively large which is not suitable to be installed in mobile wireless terminals. To further reduce the antenna size, coplanar waveguide (CPW)-fed slot antennas [6–8] are employed to meet the requirements of multi-band operation. However, in these designs, the interference suppression of nearby communication systems is worse and thus affects the system performance. In [9, 10], triple-band is achieved by etching two narrow slits with different length on a wideband monopole antenna. In these designs, the frequency collision is reduced and therefore the system performance is enhanced, but the size is still a big problem.

In this paper, a compact microstrip-fed planar monopole antenna is proposed for WLAN and WiMAX applications. Unlike the traditional monopole antenna using slot to reject undesired frequency band, in this design the slot is used to introduce two different current routes which corresponding to two different resonant modes. The additional resonant mode is excited by protruding an inverted L-shaped branch from the ground plane. By properly selecting the dimensions of the proposed antenna, good triple-frequency impedance bandwidth and radiation characteristics suitable for the two wireless communication systems can be obtained. Measured results show that the antenna has the impedance bandwidth of 270 MHz (2.4–2.67 GHz), 540 MHz (3.26–3.8 GHz), and 1970 MHz (5.03–7 GHz), which can both cover the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. Details of the antenna design, simulated results, and measured results are presented and discussed.



(a) (b)

Figure 1. (a) Geometry of the proposed triple-frequency antenna. (b) Photograph of the fabricated antenna with SMA connector.

2. ANTENNA DESIGN

As shown in Figure 1, the configuration of the proposed antenna is designed, optimized, and fabricated on a 1 mm-thick FR4 substrate with permittivity of 4.4 and a loss tangent of 0.02. The rectangular radiation patch with L-shaped slot is fed by a 50 Ω microstrip line. An inverted L-shaped stub extending from the ground plane whose length is 27 mm (about $\lambda/4$ at 2.42 GHz) is employed to produce the lowest resonant mode. The width of the inverted L-shaped stub is fixed at 1.5 mm. The overall size of the proposed antenna is $17 * 30\,\text{mm}^2$. The optimal dimensions of the antenna carried out by Ansoft HFSS V12 are as follows: $W = 17$ mm, $wd = 1.9$ mm, $w0 = 6.05$ mm, $w1 = 8.8$ mm, $w2 = 9.5$ mm, $w3 = 4.5$ mm, $L = 30$ mm, $h = 1.5$ mm, $h1 = 11$ mm, $h2 = 17$ mm, $h3 = 10$ mm, $h4 = 5.7$ mm.

Figure 2 shows the design evolution of the proposed antenna and its corresponding simulated return losses. Obviously, only a fundamental resonant is excited at 3.88 GHz by the radiator of the rectangular patch (Antenna 1). By etching an L-shaped slot on the rectangular radiation patch, the antenna (Antenna 2) can excite two resonant modes at 3.56 and 5.3 GHz. The size of the antenna does not increase for the introduction of new resonant modes. When extending an inverted L-shaped stub from the ground plane (Proposed antenna), the lowest resonant mode at 2.42 GHz appears, and three separate working bands for the WiMAX and WLAN applications are obtained. The simulated impedance bandwidths for $S_{11} \leq -10$ dB are about

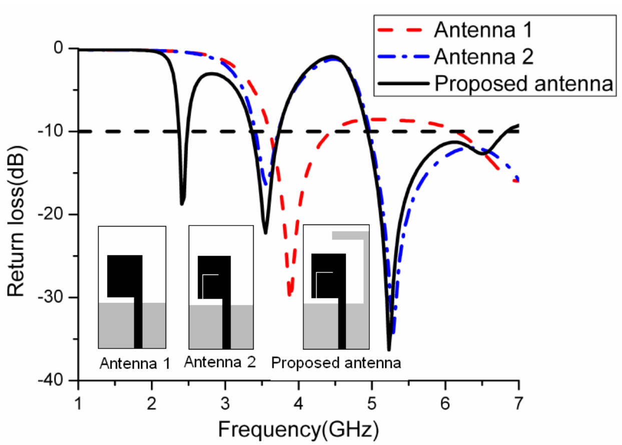


Figure 2. Design evolution of the proposed antenna and its corresponding simulated return losses.

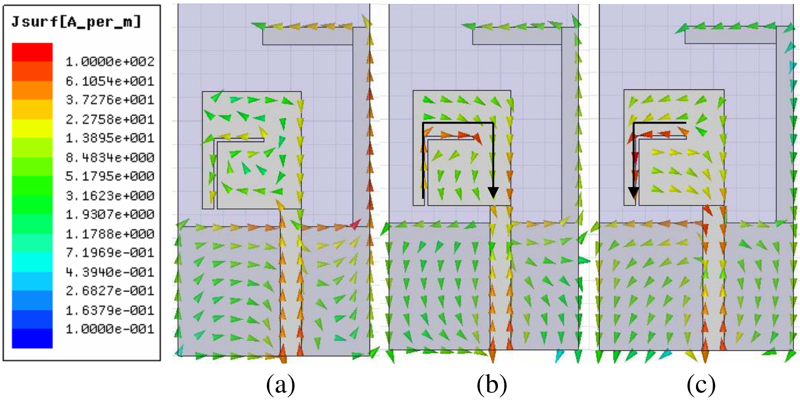


Figure 3. Simulated surface current distribution of the proposed antenna at (a) 2.42 GHz, (b) 3.55 GHz, and (c) 5.25 GHz.

120 MHz (2.37–2.49 GHz), 360 MHz (3.36–3.72 GHz), and 2030 MHz (4.85–6.88 GHz).

Figure 3 shows the simulated surface current distribution of the proposed antenna at 2.42, 3.55 and 5.25 GHz. By analyzing the surface current distribution of the antenna at different frequencies, we can further examine the excitation mechanism [11]. The strong surface current shown in Figure 3(a) flows along the inverted L-shaped branch. It is indicated that the inverted L-shaped branch generates the lowest resonant mode at 2.42 GHz. It can be seen from Figures 3(b) and (c) that due to the introduction of the L-shaped slot, two different current routs are obtained. In Figure 3(b), the length of the current route is about 15.9 mm ($2 * h4 + w3$), which is about $\lambda/4$ at 3.55 GHz. In Figure 3(c), the length of the current route is about 10.2 mm ($h4+w3$), which is about $\lambda/4$ at 5.25 GHz. According to the phenomenon we observed above, it can be conclude that the dimensions of the inverted L-shaped stub and the L-shaped slot will affect the impedance matching condition of the three resonant modes. The length of the inverted L-shaped stub is defined as $L1 = w2 + h2$. As shown in Figure 4(a), the lowest resonant mode is shifted toward the lower frequency band when $L1$ increases, whereas the other two resonant modes are also affected. The length of the L-shaped slot is defined as $L2 = w3 + h4$. With the increase of the $L2$, both the second and third resonant modes are shifted to lower frequency.

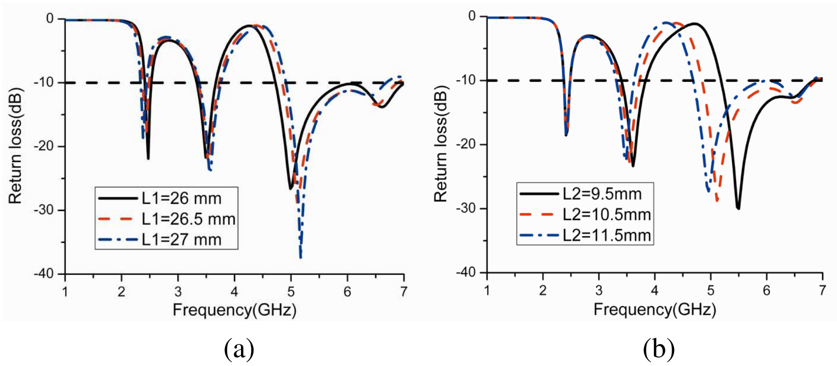


Figure 4. (a) Simulated return losses for different $L1$. (b) Simulated return losses for different $L2$.

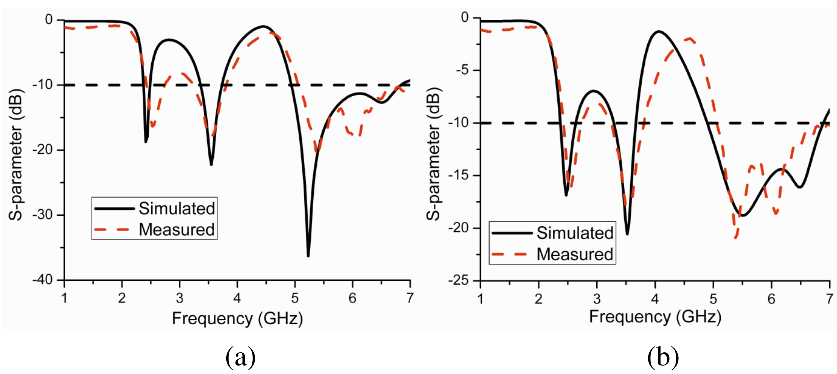


Figure 5. Simulated and measured return losses of the proposed antenna. (a) Simulated without SMA connector. (b) Simulated with SMA connector.

3. RESULTS AND DISCUSSION

The prototype of the proposed antenna with optimal dimensions is fabricated and then measured by an Agilent vector network analyzer (VNA) E8363B. Figure 5(a) shows the comparison of simulated and measured return losses. Measured results show this fabricated antenna has multiple impedance bandwidths for 10 dB return loss are about 270 MHz (2.4–2.67 GHz), 540 MHz (3.26–3.8 GHz), and 1970 MHz (5.03–7GHz), respectively, which can both cover the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands, where this is in good agreement with the prediction in previous simulation. Nevertheless,

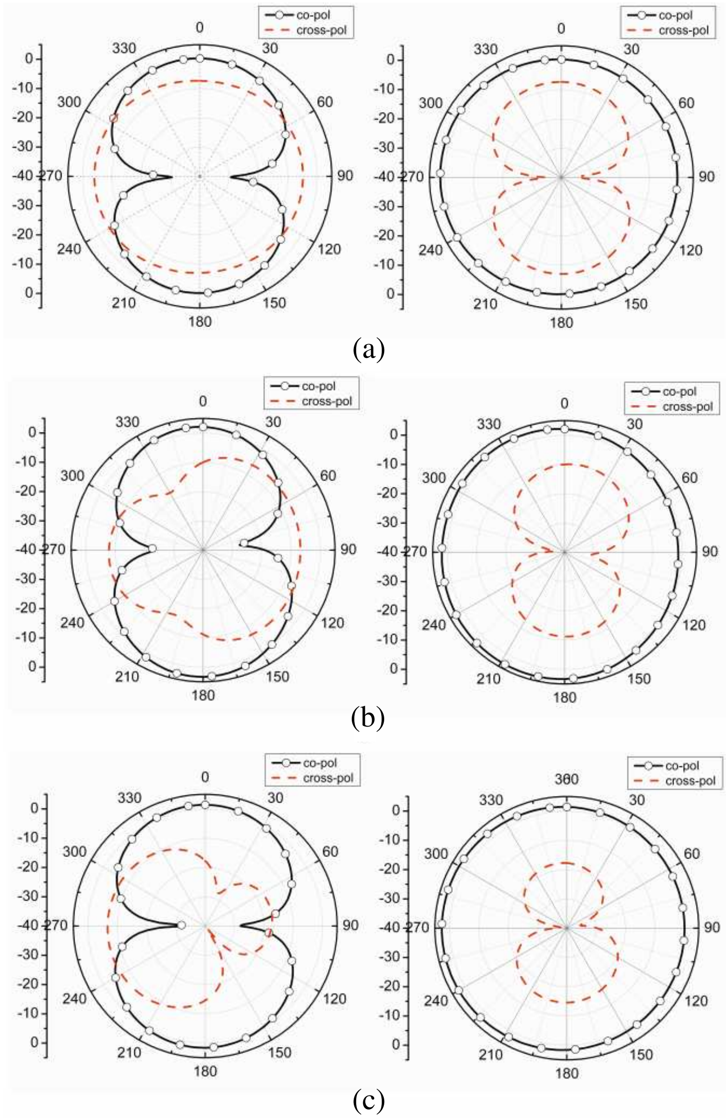


Figure 6. Simulated radiation patterns of the proposed antenna (a) at 2.45 GHz, (b) at 3.5 GHz, and (c) at 5.5 GHz.

some discrepancy is found, implemented results show the first working band is from 2.37–2.49 GHz and the second working band is from 3.36–3.72 GHz, these two pass bands are slightly different from measurements. Also the return loss of the notched-band centered

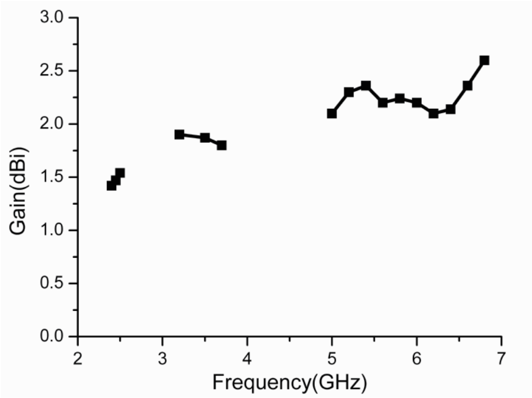


Figure 7. Simulated peak gains of the proposed antenna.

at 2.8 GHz is −3.1 dB in the simulation while in the measurement the notched-band is centered at 2.96 GHz and the return loss is −8 dB. Taking consideration with the condition between software implementation and experiment, one difference needs to be pointed out. Experimental measurements require a waveguide connector, where an SMA connector is used here shown in Figure 1(b). To see the effect of such a connector, a comparison is presented in Figure 5(b), which shows when taking into consider the effect of the SMA connector the simulated result at the first working band is from 2.37–2.63 GHz, and the second working band is from 3.28–3.7 GHz. It can also be seen from Figures 5(a) and (b) that the SMA connector does not affect the third working band in the simulation. The above analysis indicates the simulation with SMA connector can make a better prediction of the factual result than the simulation without SMA connector.

The radiation patterns of the proposed antenna at 2.45, 3.5, and 5.5 GHz are shown in Figure 6. It is observed that the proposed antenna shows monopole-like radiation pattern in the E-plane (XOZ plane) and nearly omni-directional radiation pattern in the H-plane (XOY plane). The cross-polarization is a little high due to the contribution of the x-components of the surface current on the antenna [12]. It should be noted that strict polarization purity is not normally required for handheld devices. The peak gain against frequency for the proposed antenna across the three working bands is shown in Figure 7. The ranges of peak gains are about 1.42–1.54, 1.8–1.9, and 2.1–2.6 dBi with an average value of 1.48, 1.86, and 2.26 dBi, respectively.

4. CONCLUSION

A compact triple-band planar monopole antenna suitable for WiMAX/WLAN applications has been presented. In this design, by etching an L-shaped slot on the rectangular radiation patch and stretching an inverted L-shaped stub from the ground plane, three resonant modes with good impedance performance are achieved. The proposed antenna is capable of covering the WLAN communication standard (2.4–2.484 GHz, 5.15–5.35 GHz, and 5.727–5.825 GHz) and WiMAX communication standard (3.4–3.69 GHz, and 5.25–5.85 GHz). The antenna is very small in size and simple in structure, making it suitable for multi-band mobile wireless device applications.

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