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Multiband and Wideband Planar Antenna for WLAN and WiMAX Applications

Xueshuang Dong, Zhouying Liao, Jiabin Xu, Qibo Cai, and Gui Liu*

Abstract—In this paper, the design of a multiband antenna for WLAN and WiMAX applications is proposed. The proposed antenna comprises a circular radiating patch with a pair of rectangular slits and an inverted U-shaped slot. A hexagon-shaped slot is cut on the ground plane. By adjusting the inverted U-shaped slot, a pair of rectangular slits, and a hexagon-shaped slot, three distinct resonance frequencies centered at 2.4 GHz, 3.52 GHz, and 5.68 GHz can be generated. The measurements show that the proposed antenna can cover three frequency bands with sufficient bandwidth. The proposed antenna exhibits an omnidirectional radiation pattern and acceptable gain. The overall dimension of the proposed antenna is $25 \times 39 \times 1.59\,\text{mm}^3$.

1. INTRODUCTION

With the rapid development of wireless communication systems, wireless local area network (WLAN: 2.4–2.4835 GHz and 5.15–5.875 GHz) and worldwide interoperability for microwave access (WiMAX: 3.3–3.7 GHz) technologies have been widely used in mobile devices. Much attention has been focused on designing multiband antenna which can operate at both WLAN and WiMAX frequency bands [1, 2]. Most proposed multiband antennas in handheld devices are planar inverted-F antennas (PIFA) and monopole antennas. PIFA antennas have several significant advantages such as small size, reduced backward radiation, and low profile [1–3]. However, narrow-bandwidth characteristic of individual mode is one of the limitations for PIFA, and its 3D structure may be a fabrication challenge [4]. Numerous techniques for multiband planar monopole antenna design have been presented in literature, e.g., L- and U-shaped slots [5], an additional strip [6], multiresonator-loaded structures including a pair of symmetrical edge resonators and a T-shaped stub resonator [7], U-shaped slot with paper substrate [8], dual inverted L-shaped strips [9], two spiral ring strips [10], a modified fork-shaped strip [11], a chopped circular radiator appended with a meander line and an L-strip coupled element [12], a slot-ring antenna with single- and dual-capacitive coupled patch [13], a rhombic patch with modified minkowski fractal geometry [14], and a two-strip monopole loaded with a chip capacitor and an L-shape high-pass filter [15]. However, design of a compact multiband monopole antenna with sufficient bandwidth at three frequency bands remains a challenge.

In this paper, we propose a novel design of a planar antenna that offers multiband operation in the bands of both the IEEE 802.11 a/b/g and WiMAX bands. Microstrip monopole antennas are promising candidates for multiband antenna due to their advantages such as low profile, low cost, light weight, and ease of fabrication. The proposed antenna consists of a circular radiating patch with two rectangular slits and an inverted U-shaped slot. A hexagon-shaped slot is cut on the ground plane. By using the inverted U-shaped slot, a pair of rectangular slits, and the hexagon-shaped slot, the resonance frequencies and bandwidths of three distinct frequency bands can be tuned and controlled. Measurement results show that the antenna can effectively cover three desired frequency bands of WLAN (2.4–2.4835, 5.15–5.875 GHz) and WiMAX (3.3–3.7 GHz). It exhibits stable omnidirectional radiation patterns and acceptable gains at three distinct frequency bands.

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* Corresponding author: Gui Liu (iitgliu2@gmail.com).
The authors are with the College of Physics & Electronic Information Engineering, Wenzhou University, Wenzhou, Zhejiang 325035, P. R. China.

2. ANTENNA DESIGN

The configuration of the proposed multiband antenna is illustrated in Figure 1. The radiating element is a circular patch with a pair of rectangular slits and an inverted U-shaped slot. A hexagon-shaped slot is cut on the ground plane. To further study the effect of the length of rectangular slits, the inverted U-shaped slot, and the size of the ground plane hexagon slot on the performance of return loss, we simulated the proposed antenna with various dimensions.

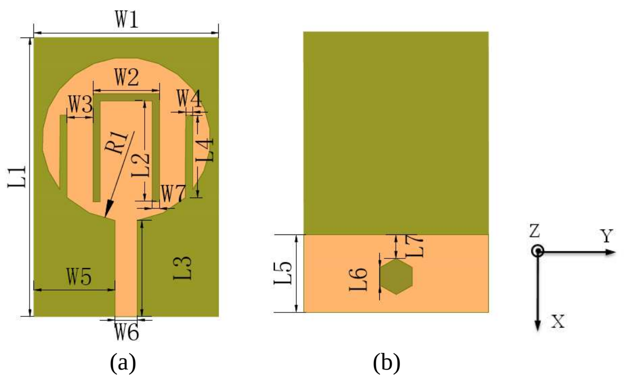


Figure 1. Geometry of the proposed antenna. (a) Top view; (b) Bottom view.

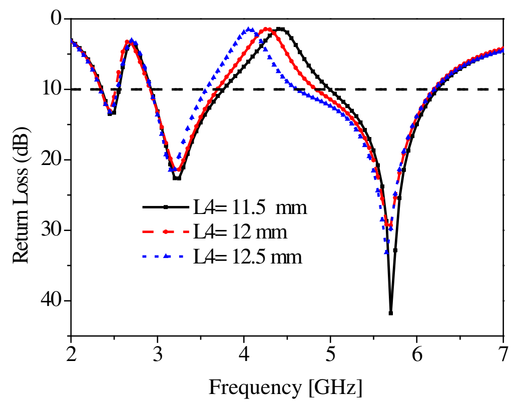


Figure 2. Simulated return loss of the proposed antenna for various length of L_4.

As shown in Figure 1, an inverted U-shaped slot is cut on the radiator to perturb the current path so as to generate a resonance frequency band without increasing antenna size. The total length of inverted U-shaped slot is set close to quarter-wavelength at 2.4 GHz. Two symmetrical slits with the width of W_4 and length of L_4 are cut at both sides of the inverted U-shaped slot to tune the resonance frequency bandwidth. Figure 2 shows the simulated return loss of the proposed antenna for various L_4 lengths. It can be seen that the length of L_4 does not affect 2.4 GHz frequency band, lower frequency of WiMAX frequency band, and higher frequency of 5.5 GHz frequency band, but it influences the higher frequency of WiMAX band and lower frequency of 5.5 GHz WLAN band. Furthermore, there is a tradeoff between the resonant bandwidths of WiMAX and 5.5 GHz WLAN frequency band. Therefore, L_4 can be used to tune the resonant bandwidths of WiMAX and 5.5 GHz frequency band to meet the requirement. The optimum length of L_4 is 12 mm.

The electromagnetic coupling between the feed line and the ground plane influences the impedance matching performance of the proposed antenna. As depicted in Figure 1, a hexagon slot is located under the feed line. The size of the hexagon slot affects the current distribution on the ground plane. Figure 3 shows the simulated return loss of the proposed antenna for different lengths of L_6 which determines the size of the hexagon slot. The size of the hexagon slot increases as the length of L_6 increases. As can be observed in Figure 3, the resonance frequencies shift to higher frequencies when the length of L_6 increases. Therefore, the return loss of the proposed antenna can be tuned to desired frequency bands by selecting a proper length of L_6.

The distance between the ground plane and the circular radiator also affects the return loss of the proposed antenna since the mutual coupling changes with the distance. As shown in Figure 4, the return loss changes greatly for 5.5 GHz WLAN frequency band, but it changes slightly for both 2.4 GHz WLAN and 3.5 GHz WiMAX frequency bands. Thus, the 5.5 GHz WLAN frequency bands can be adjusted independently and effectively by L_5.

3. SIMULATION AND MEASUREMENT RESULTS

The proposed antenna was fabricated on FR4 substrate with dielectric constant 4.4, loss tangent 0.02, and thickness 1.59 mm. Figure 5 shows the photographs of the proposed antenna. The final parameters

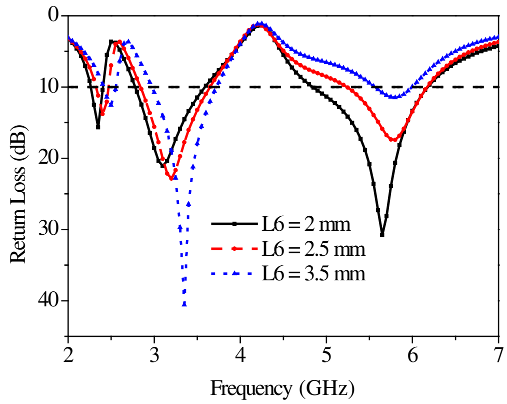


Figure 3. Simulated return loss of the proposed antenna for various length of L_6.

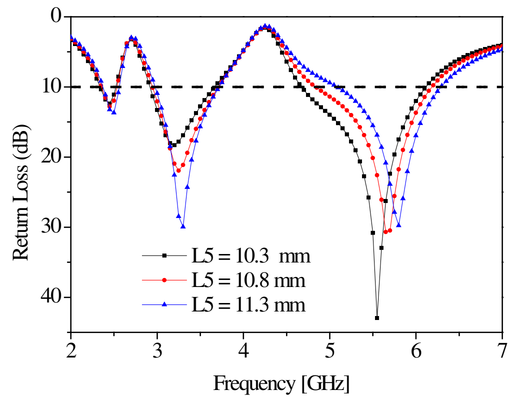
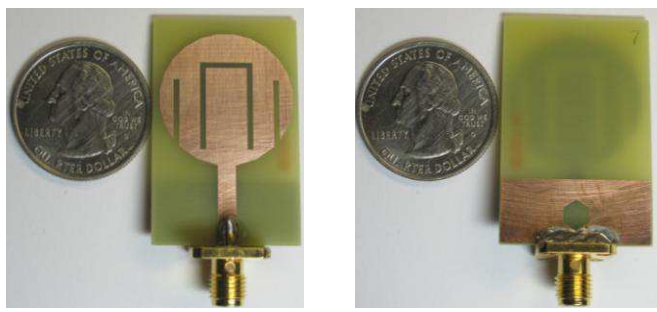
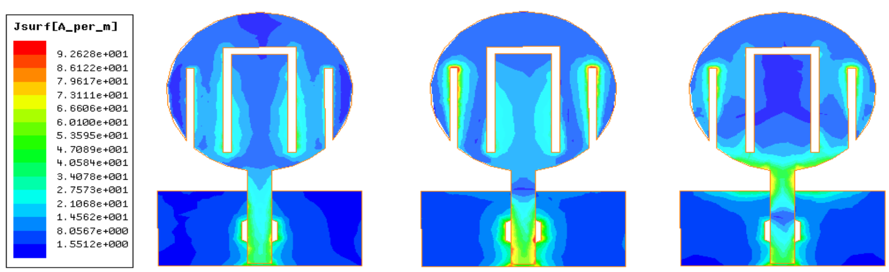


Figure 4. Simulated return loss of the proposed antenna for various length of L_5.



(a) (b)

Figure 5. Photograph of the proposed antenna. (a) Top view; (b) Bottom view.



(a) (b) (c)

Figure 6. Current distribution of the proposed antenna at (a) 2.45 GHz. (b) 3.5 GHz. (c) 5.65 GHz.

of the proposed antenna are as follows: $L_1 = 39$ mm, $L_2 = 14$ mm, $L_3 = 13.36$ mm, $L_4 = 11.46$ mm, $L_5 = 10.8$ mm, $L_6 = 2.5$ mm, $L_7 = 3.3$ mm, $W_1 = 25$ mm, $W_2 = 9$ mm, $W_3 = 3.5$ mm, $W_4 = 1$ mm, $W_5 = 11$ mm, $W_6 = 3$ mm, and $W_7 = 1$ mm. The overall size of the proposed antenna is $25 \times 39\,\text{mm}^2$.

As shown in Figure 6, the operations of the proposed antenna at three resonant frequencies are further studied by surface current distribution. Figure 6(a) shows that the current is mainly concentrated along the inverted U-shaped slot at the lowest resonant frequency (2.45 GHz). At 3.5 GHz, Figure 6(b) shows the current mainly flows along the rectangular slits, thus the length of current path can be tuned by using parameter L_4. As depicted in Figure 6(c), the surface current is mainly concentrated along the lower edge of the radiating patch, the upper edge of the ground plane, and the hexagon-shaped slot on the ground plane, which contributes to the corresponding radiation at 5.65 GHz.

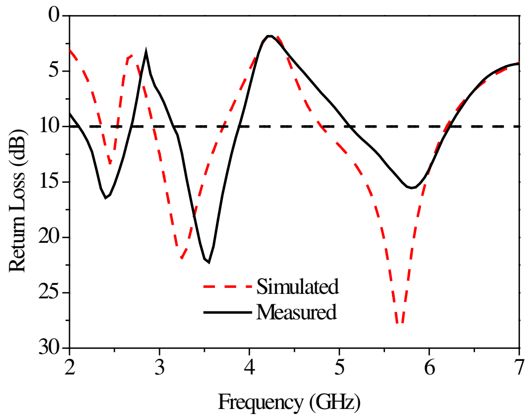
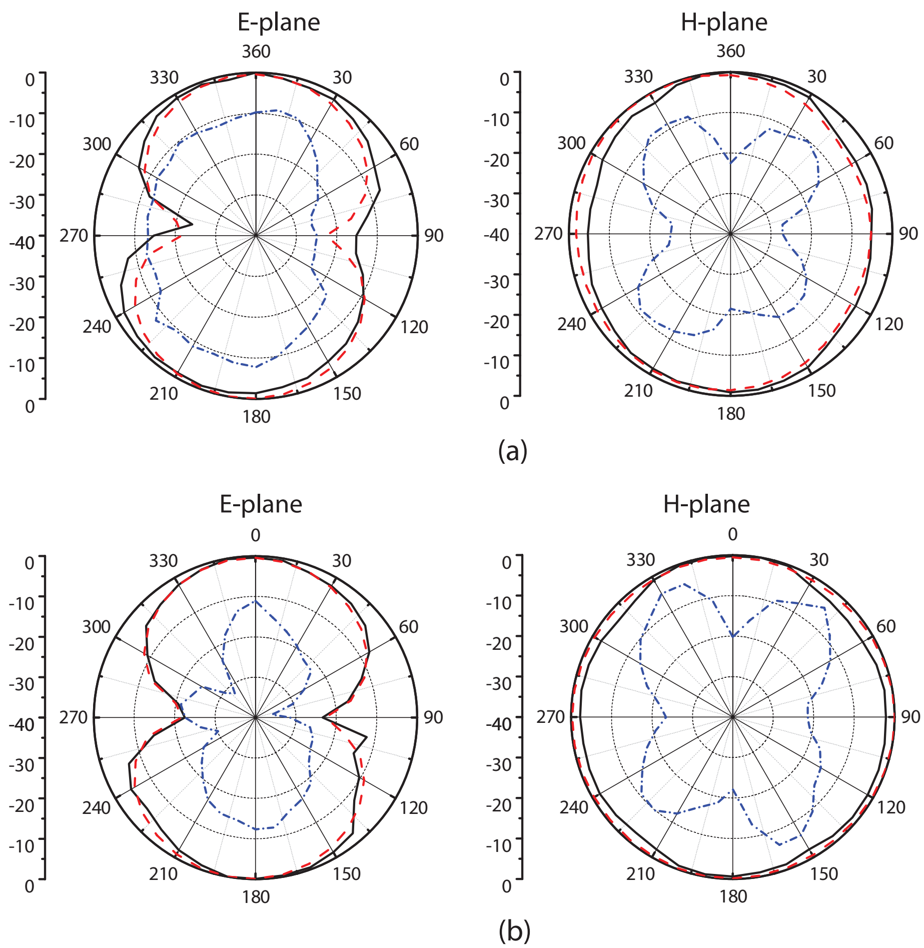


Figure 7. Simulated and measured return loss of the proposed antenna.

Figure 7 shows the simulated and measured return losses of the proposed antenna. The simulated results agree well with the measurements. The small discrepancies could be attributed to the inherent numerical error of the electromagnetic simulator, fabrication and measurement tolerances. As can be observed in Figure 7, the antenna operates in three distinct frequency bands centered at 2.4 GHz, 3.52 GHz, and 5.68 GHz with impedance bandwidths of 24% (2.11–2.69 GHz), 21% (3.15–3.89 GHz), and 19.3% (5.13–6.23 GHz), respectively. These frequency bands can cover the desired WLAN (2.4–



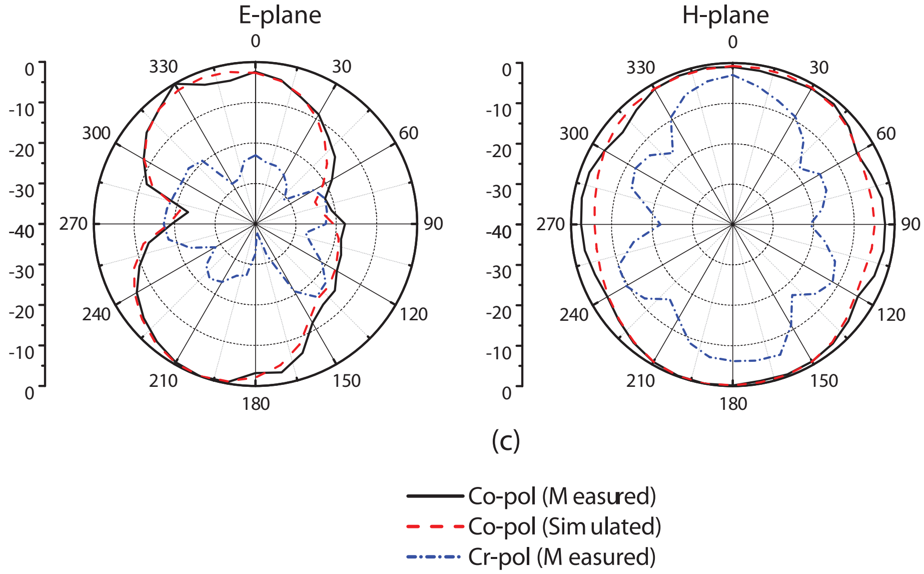


Figure 8. Normalized measured co- and cross polarization radiation pattern at (a) 2.45 GHz, (b) 3.5 GHz, (c) 5.5 GHz.

2.4835 GHz, 5.15–5.875 GHz) and WiMAX (3.3–3.7 GHz) frequency bands.

The radiation patterns of the proposed antenna were measured in anechoic chamber. Figure 8 shows the normalized radiation pattern for co- and cross polarizations in the E-plane (xz-plane) and H-plane (yz-plane) at the frequencies of 2.45 GHz, 3.5 GHz and 5.5 GHz, respectively. As shown in Figure 8, the antenna exhibits a bidirectional radiation pattern in E-plane and a stable omnidirectional radiation pattern in H-plane. The measured peak gains at the frequencies of 2.45 GHz, 3.5 GHz and 5.5 GHz are 3.2 dBi, 2.1 dBi, and 5.6 dBi, respectively. Therefore, the proposed antenna can provide sufficient gain and stable omnidirectional radiation patterns to receive or transmit signals for the WLAN 2.4/5.5 GHz frequency bands and the WiMAX 3.5 GHz frequency band.

4. CONCLUSION

In this paper, we present a planar multiband antenna with a pair of rectangular slits and an inverted U-shaped slot in the circular radiator, and a hexagon slot in the ground plane. By using the pair of rectangular slits and the defected ground plane with a hexagon slot, the multiband resonance frequency and bandwidth can be tuned and controlled. The proposed antenna shows an omnidirectional radiation pattern and acceptable gain. The proposed antenna features simple structure, broad operating bandwidth, stable radiation patterns, and acceptable gain, which make it a good candidate for WLAN/WiMAX applications.

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