

A MULTI-BAND MONOPOLE ANTENNA WITH TWO DIFFERENT SLOTS FOR WLAN AND WIMAX APPLICATIONS

S.-M. Zhang^{*}, F.-S. Zhang, W.-M. Li, W.-Z. Li, and H.-Y. Wu

National Laboratory of Antennas and Microwave Technology, Xidian University, Xi'an, Shaanxi 710071, P. R. China

Abstract—A compact triple-band monopole antenna with two different slots for WLAN and WiMAX applications is proposed and experimentally studied. The proposed antenna with a size of $30\text{ mm} \times 25\text{ mm} \times 1\text{ mm}$ is excited by a $50\ \Omega$ microstrip feed line. The designed antenna obtains three frequency bands through loading an inverted E-shaped slot and an inverted C-shaped slot which incise the surface current and change the path of the current on the rectangle patch. The obtained results show that the designed antenna has impedance bandwidths of 2.4 GHz, 5.8 GHz for WLAN and 3.5 GHz for WiMAX. The return loss, radiation patterns and peak antenna gains are presented using computer simulations and measurements.

1. INTRODUCTION

With rapid development of wireless communications, multiband handsets or customer premise equipments (CPEs) are needed in the era of digital convergence. Therefore, the RF front-end of transceiver/receiver needs a multiband or broadband antenna with small size to transmit/receive signals of different systems, included GSM900, DCS-1800, PCS-1900, UMTS, Bluetooth/WLAN, and WiMAX [1–4]. Recently, wireless communication for wireless local area network (WLAN) and world Interoperability for Microwave Access (WiMAX) have experienced tremendous growth [5–7]. It is desirable for an antenna to be able to achieve multi-band operations, low-profile, lightweight and single-feed to fit the limited equipment space of WLAN and WiMAX devices [8]. In [9, 10], the antenna was driven by a $50\ \Omega$

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* Corresponding author: Si-Ming Zhang (zsm02061378@163.com).

coplanar waveguide (CPW) transmission line, but the dimension of the ground is expanded. In [11, 12], by employing short pin or wall, the antenna radiates more frequency bands, but it will make the structures of these antennas more complicated.

In this article, a compact monopole antenna consisting of a rectangular patch with two different shaped slots and a $50\ \Omega$ microstrip feed line is presented in detail. The inverted E- and C-shaped slots incise and change the path of the surface current on the rectangle patch. Furthermore, the path of the surface current is also expanded due to the two slots. Thus, three resonant modes are excited, and the dimensions of the slots have a great effect on the matching performance of the proposed antenna. The designed monopole antenna is achieved which operates in the frequency bands of 2.4 GHz–2.484 GHz, 5.15 GHz–5.825 GHz for WLAN and 3.4 GHz–3.69 GHz for WiMAX. The simulation software Ansoft HFSS is used in the design and simulation processes of the designed antenna. The simulated and measured results on the radiation patterns and return loss indicate a good agreement with each other. The designed and experimental results of the proposed antenna are fully explained in the following sections.

2. ANTENNA DESIGN

The final design of the triple-band monopole antenna with a size of $30\ \text{mm} \times 25\ \text{mm}$ is illustrated in Figure 1. The proposed antenna is

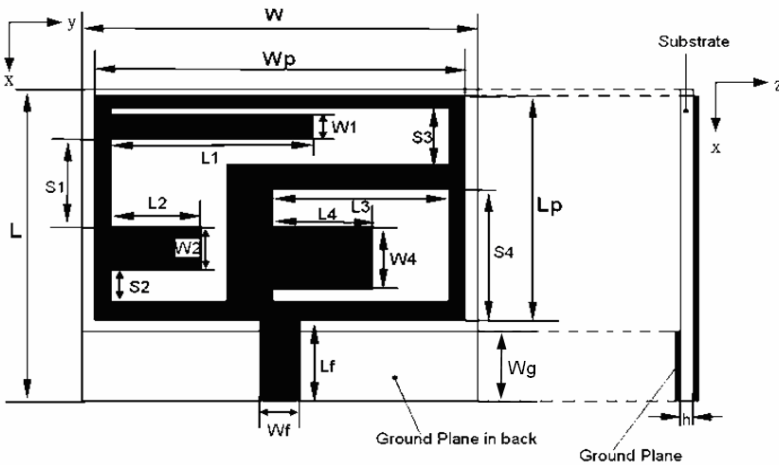


Figure 1. Geometry and dimensions of proposed antenna.

printed on the substrate with relative dielectric constant of $\epsilon_r = 2.65$ and thickness of 1 mm. On the top of the substrate, a rectangular monopole antenna consisting of a rectangular patch with the inverted E- and C-shaped slots is printed to create three appropriate frequency bands. This structure is fed by a single microstrip line of 50Ω . On the opposite side of the substrate, a conducting partial ground plane of width W_g and length W is placed. The inverted E-shaped slot deals with the bands of 2.4 GHz–2.484 GHz and 3.4 GHz–3.69 GHz, while the inverted C-shaped slot deals with the bands of 3.4 GHz–3.69 GHz and 5.15 GHz–5.825 GHz.

The following table is optimal parameters of the proposed antenna to reach the desirable performance.

3. ANTENNA PERFORMANCES

An important feature of the proposed antenna is the capability of impedance matching at three resonate frequencies using the two slots which are presented above. Figure 2 shows the simulated return loss for the proposed antenna with different dimensions of the slots. Figure 3 shows the simulated surface current distributions on the

Table 1. Optimal parameters of the proposed antenna (unit: mm).

| W | L | W_p | L_p | W_f | L_f | S_1 | S_2 | S_3 | S_4 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 30 | 25 | 28 | 18 | 3 | 6.5 | 7 | 2.5 | 4.5 | 9 |
| W_1 | L_1 | W_2 | L_2 | W_3 | L_3 | W_4 | L_4 | W_g | |
| 2 | 15.3 | 3.5 | 6.8 | 2 | 13.3 | 5 | 7.5 | 6 | |

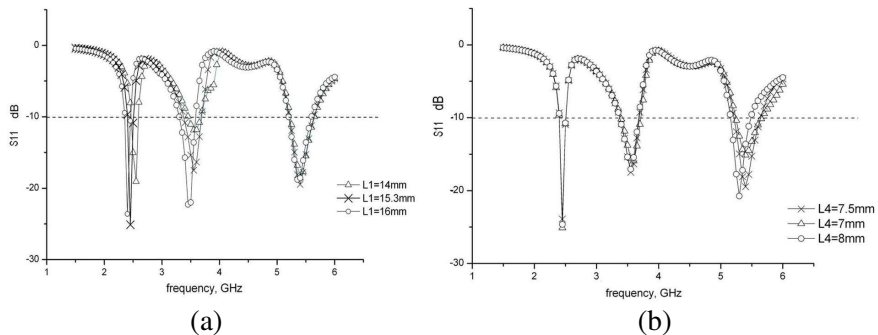


Figure 2. Simulated return loss for the antenna with various lengths (L_1 and L_4). Other parameters are the same as in Table 1.

radiating patch for the proposed antenna with optimal dimensions. It can be seen that the stripes (L_1 , L_2 , L_3 and L_4) which are etched on the patch primarily result in the three resonant modes excited, and the dimensions of the slots have a great effect on the matching performance of the proposed antenna. The longest strip (L_1) has an effect on the lower frequency bands (2.45-GHz and 3.5-GHz). While the length of L_1 is shortened, the center frequency will be higher. And the strip (L_4) affects the higher frequency band (5.5-GHz). The center frequency will be lower, while the length of L_1 is lengthened. In addition, the proposed antenna with good impedance matching of the three resonate frequencies can be implemented when the lengths of stripes are approximately equal to one-quarter medium wavelength. When the length of the strips (L_1 , L_2 , L_3 and L_4) are about 15.3 mm,

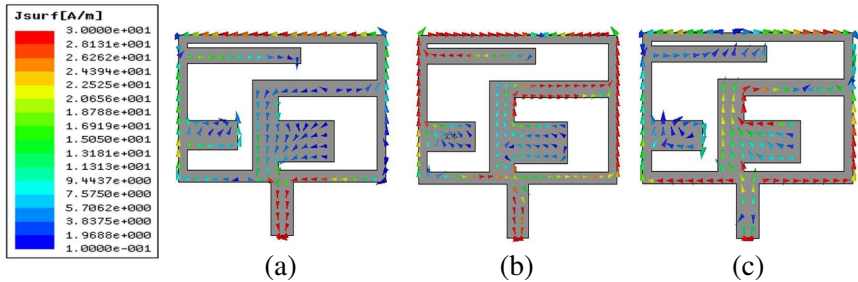


Figure 3. Simulated surface current distributions on the radiating patch for the proposed antenna with optimal dimensions. (a) 2.45 GHz. (b) 3.5 GHz. (c) 5.5 GHz.

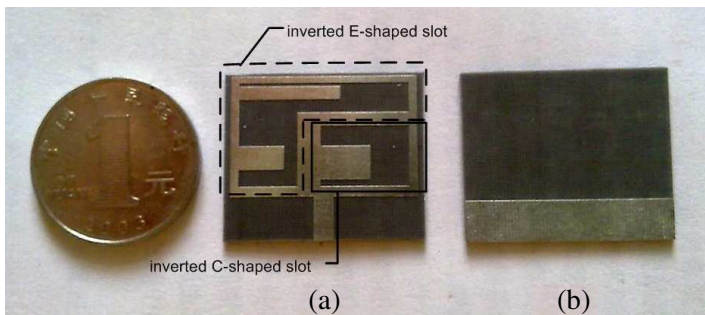


Figure 4. Photograph of the fabricated printed triple-band microstrip antenna with optimal dimensions. (a) Top view and (b) ground plane on the bottom side.

6.8 mm, 13.3 mm and 7.5 mm, respectively, the proposed antenna has an optimal performance. It can also be seen that the corresponding slots are only active at the desired frequency while the others are inactive, which confirm the independence of the three frequency bands.

The fabricated printed triple-band monopole antenna with optimal dimensions is shown in Figure 4. The proposed triple-band monopole antenna is measured by a network analyzer Agilent N5230A (10 MHz–50 GHz). The simulated result of the designed antenna is also shown for comparison. As seen in Figure 5, the measured return loss and simulated result reasonably agree with each other with an acceptable frequency discrepancy, which may be due to the difference between the measured and simulated environments. The measured operating frequencies are 2.45-GHz, 3.5-GHz, and 5.5-GHz. In the 2.4-GHz band, 10 dB bandwidth is 110 MHz (2.40–2.51 GHz) or about 4.5% for the center frequency of 2.45 GHz, which meets the bandwidth requirement for IEEE 802.11b/g. The impedance bandwidth (10 dB return loss) for the 3.5-GHz band reaches 260 MHz (3.45–3.71 GHz), or about 7.3% referred to the centre frequency at 3.58 GHz. In the 5-GHz band, 10 dB bandwidth is as much as 550 MHz (5.31–5.86 GHz) or about 10% for the center frequency of 5.58 GHz, which reasonably agree with the bandwidth requirement for IEEE 802.11a.

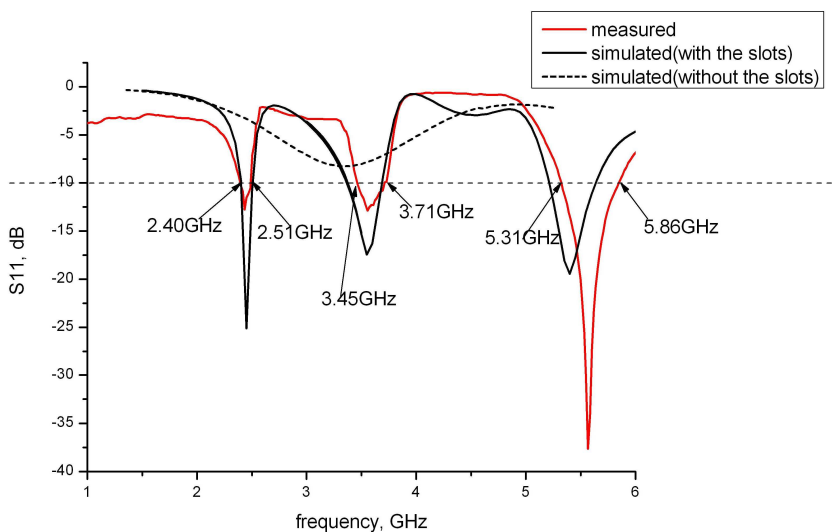


Figure 5. Simulated and measured return loss of the triple-band monopole antenna with optimal dimensions.

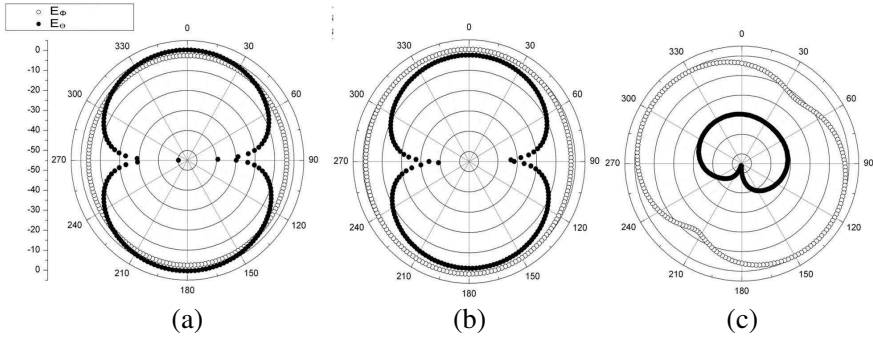


Figure 6. Radiation patterns for the proposed antenna at the frequency of 2.45 GHz. (a) x - z plane. (b) y - z plane. (c) x - y plane.

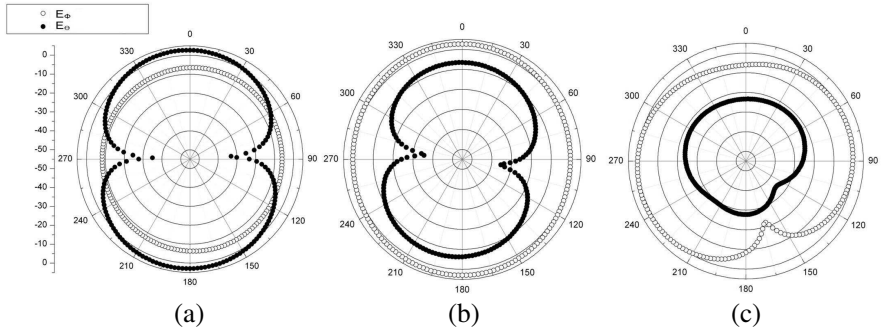


Figure 7. Radiation patterns for the proposed antennas at the frequency of 3.5 GHz. (a) x - z plane. (b) y - z plane. (c) x - y plane.

The far-field radiation characteristics of the proposed triple-band monopole antenna are also investigated. Figures 6–8 show the simulated radiation patterns including the vertical (E_{Θ}) and horizontal (E_{Φ}) polarization patterns in the x - z , y - z , and x - y planes of the proposed antenna at 2.45, 3.5 and 5.5 GHz, respectively. It is seen that in the y - z plane, the proposed antenna, in general, shows radiation patterns with nearly omnidirectional radiation for all frequencies. In the x - z plane, the radiation for E_{Θ} polarization is symmetric with respect to the x -axis at all frequency bands. Rather symmetrical radiation patterns are seen in the x - z and y - z planes as depicted in the plots. In addition, it is also found that the E_{Θ} and E_{Φ} components of the radiation patterns in both x - z and y - z planes seem to be rather comparable. This feature is attractive for better

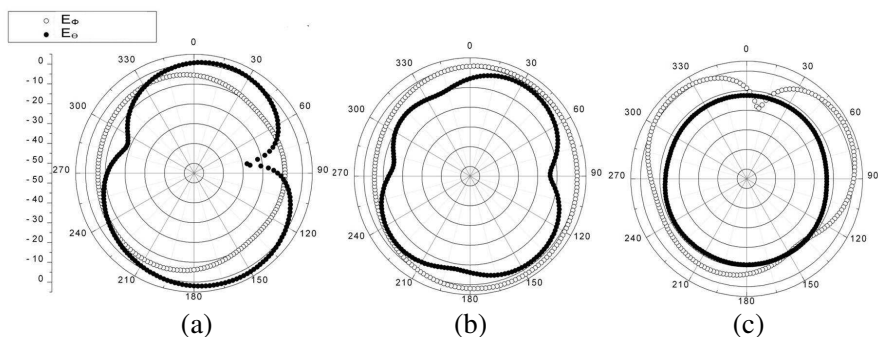


Figure 8. Radiation patterns for the proposed antenna at the frequency of 5.5 GHz. (a) $x-z$ plane. (b) $y-z$ plane. (c) $x-y$ plane.

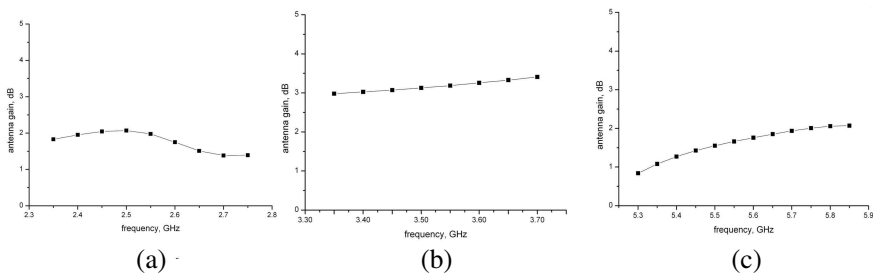


Figure 9. Peak antenna gains for frequencies across the three bands for the proposed antenna. (a) 2.45–2.51 GHz. (b) 3.45–3.71 GHz. (c) 5.31–5.86 GHz.

transmission capabilities for wireless communication systems in a multi-path environment. Also note that the radiation patterns at other operating frequencies across the bandwidth of each band are very similar to those plotted here, i.e., stable radiation patterns have been obtained for the proposed antenna.

Finally, the simulated antenna gains for frequencies across the three bands for the proposed antenna are shown in Figure 9. The antenna gains are about 1.4–2.1 dB for the 2.4-GHz band, 3.0–3.4 dB for the 3.5-GHz band, and 0.8–2.1 dB for the 5.5 GHz band. For the 2.4-GHz and 3.5 GHz bands, the gain variations observed are less than 1 dB, respectively, while for the 5.5-GHz band, the gain variations are less than 1.5 dB. These slight differences of antenna gains can be attributed to the effects of conductor and dielectric loss.

4. CONCLUSION

The characteristics of a triple-band printed monopole antenna with two different slots at WLAN/WiMAX frequencies have been proposed and verified with simulation and measurement. The proposed antenna has a small size ($30\text{ mm} \times 25\text{ mm} \times 1\text{ mm}$) and simple geometry which is easy to be designed. By employing the inverted E- and C-shaped slots, the proposed antenna creates three appropriate frequency bands, 2.4 GHz, 5.8 GHz for WLAN, and 3.5 GHz for WiMAX. The effects of different dimensions of the slots on the feature of the proposed antenna have also been discussed. Good antenna performances of the operating frequencies across the three operating bands have been obtained. The measurements on the fabricated printed monopole antenna have a good agreement with the simulated results. The electrical performance and superior frequency characteristics make the proposed antenna desirable for wireless applications.

REFERENCES

1. Yu, Y.-C. and J.-H. Tarng, "A novel modified multiband planar inverted-F antenna," *IEEE Antennas and Wireless Propagation Letters*, Vol. 8, 2009.
2. Li, J.-Y. and Y.-B. Gan, "Multi-band characteristic of open sleeve antenna," *Progress In Electromagnetics Research*, Vol. 58, 135–148, 2006.
3. Alkanhal, M. A. S., "Composite compact triple-band microstrip antennas," *Progress In Electromagnetics Research*, Vol. 93, 221–236, 2009.
4. Wang, C.-J. and S.-W. Chang, "Studies on dual-band multi-slot antennas," *Progress In Electromagnetics Research*, Vol. 83, 293–306, 2008.
5. Kim, T.-H. and D.-C. Park, "Compact dual-band antenna with double L-slits for WLAN operations," *IEEE Antennas and Wireless Propagation Letters*, Vol. 4, 2005.
6. Wu, Y.-J., B.-H. Sun, J.-F. Li, and Q.-Z. Liu, "Triple-band omni-directional antenna for WLAN application," *Progress In Electromagnetics Research*, Vol. 76, 477–484, 2007.
7. Lee, Y.-C. and J.-S. Sun, "Compact printed slot antennas for wireless dual- and multi-band operations," *Progress In Electromagnetics Research*, Vol. 88, 289–305, 2008.
8. Foroozesh, A., M. N. M. Kehn, and L. Shafai, "Application of artificial ground planes in dual-band orthogonally-polarized

- low-profile high-gain planar antenna design,” *Progress In Electromagnetics Research*, Vol. 84, 407–436, 2008.
9. Chaimool, S. and K. L. Chung, “CPW-fed mirrored-L monopole antenna with distinct triple bands for WiFi and WiMAX applications,” *Electronics Letters*, Vol. 45, No. 18, 2009.
 10. Antoniadou, M. A. and G. V. Eleftheriades, “A multiband monopole antenna with an embedded reactance-cancelling transmission-line matching network,” *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 2010.
 11. Ji, J. K., G. H. Kim, and W. M. Seong, “A compact multiband antenna based on DNG ZOR for wireless mobile system,” *IEEE Antennas and Wireless Propagation Letters*, Vol. 8, 2009.
 12. Kim, T.-H. and D.-C. Park, “Compact dual-band antenna with double L-slits for WLAN operations,” *IEEE Antennas and Wireless Propagation Letters*, Vol. 4, 2005.