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A Compact Dual-Band Printed Monopole Antenna for WiMAX/WLAN Applications

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Abstract—A compact printed dual-band antenna for WiMAX/WLAN applications is proposed in this paper. The dual-band monopole antenna consists of a triangular patch and two folding arms shorted to the ground plane. The proposed antenna features a low profile and compact dimension. To avoid via process in the fabrication, the triangular patch and two folding arms are separately constructed on the two sides of a FR4 substrate. By employing this structure, five different resonances can be yielded. The triangular patch provides two resonant modes (4.62 GHz and 7.05 GHz). The two folding arms produces three resonances at 2.43GHz, 3.43 GHz, and 6.59 GHz. A prototype of the dual-band antenna is experimentally fabricated and tested. The measured results shows good impedance bandwidth and radiation pattern.

1. INTRODUCTION

In the last decades, wireless communication systems have been developed rapidly. The integration of several communication standards into a single system has become a trend. Now the most popular designs focus on wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) operations. As one of the most important devices, multi-band antenna has attracted much interest. To cover desirable bands and reduce the size, various promising antennas, such as printed monopole antenna [1–5], CPW-fed antenna [6, 7], slot antenna [8–10], inverted-F antenna [11], have been proposed. For example, an printed monopole antenna of size of $38 \times 25\,\text{mm}^2$ was developed in [1], its triple-band operation was achieved by a circular ring, Y-shape-like strip and a defected ground plane. In [6], a compact CPW-fed slot antenna with size of $25 \times 20\,\text{mm}^2$ was developed, and three L-shaped slots and a rectangular slot were fabricated on the substrate to cover WLAN/WiMAX bands. The designs of a square-slot antenna in [10] used a square slot, a pair of L-strips, and a monopole radiator to yield three different resonances to cover the desired bands. However, the above designs occupy large space.

In this paper, a compact monopole antenna with a size of $10 \times 30\,\text{mm}^2$ is proposed. It begins with a simple structure. Through adopting coupled-fed and adding strips, the antenna can cover 3.5/5.5-GHz (3.3–3.7 GHz/5.25–5.85 GHz) WiMAX and the 2.4/5.2/5.8-GHz (2.4–2.485 GHz/5.15–5.35 GHz/5.725–5.825 GHz) WLAN bands. The antenna is simulated using Ansoft HFSS and fabricated. The simulated and measured results are presented and are in good agreement. The rest of the paper is organized as follows. Section 2 presents antenna design. Section 3 gives current distribution analysis. Section 4 shows the simulated and measured results. Conclusion is given in Section 5.

2. ANTENNA DESIGN

The geometry of the proposed antenna is illustrated in Fig. 1. Fig. 2 shows the prototype of the designed antenna.

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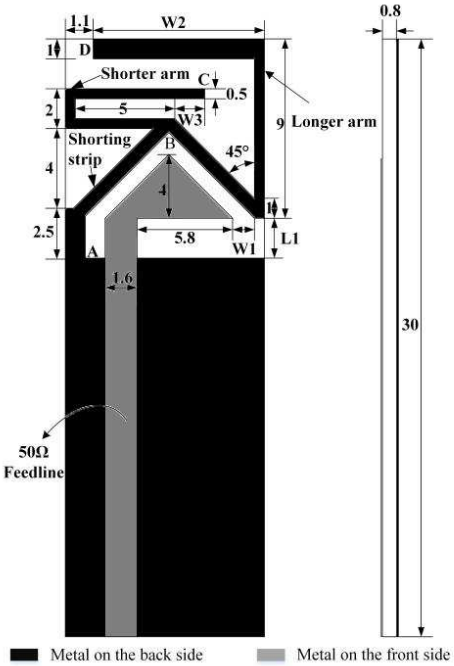
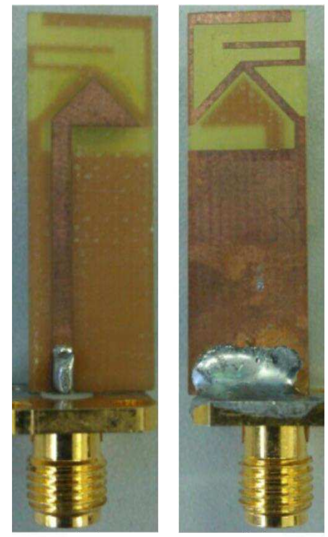
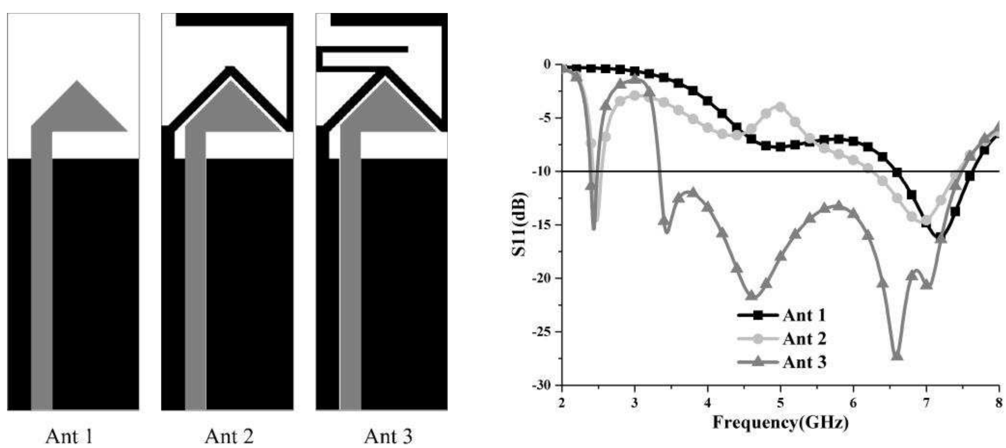


Figure 1. Geometry of the proposed antenna.



(a) (b)

Figure 2. Prototype of the antenna.



(a) (b)

Figure 3. Comparison of simulated return loss with different configurations.

The antenna is printed on an FR4 substrate with dielectric constant of 4.4, loss tangent 0.02, thickness 0.8 mm, and size of $10 \times 30\,\mathrm{mm}^2$. The antenna consists of a triangular patch and two folding arms shorted to the ground, and the energy is fed by a 50-Ω coaxial feed line coupling from triangular patch to shorting strips. The gap between the triangular radiator and two folding arms affects the impedance and resonant frequencies.

The design evolution of the proposed antenna and its corresponding return losses are presented in Fig. 3. As depicted in Ant 1, it consists of triangular patch, and the structure provides two resonant modes at 4.6 GHz and 7.2 GHz, but only one resonance at 7.2 GHz is excited successfully. Adding a quarter-wavelength longer folding arm on the basis of Ant 1, shown in Ant 2, leads to a resonant frequency at 2.43 GHz, and the reflection coefficient of Ant 2 verifies this resonance. In order to cover the 3.5 GHz WiMAX band, another quarter-wavelength shorter folding arm is introduced, shown in

Ant 3. From the reflection coefficient plot of Ant 3, the third resonance at 4.62 GHz and the harmonic at 6.59 GHz produced by folding arms are also excited. Besides, owing to these resonances are closely spaced, wide-impedance bandwidth ranging from 3.35 GHz to 7.48 GHz is attained.

The parametric study is important because it provides some understanding of the antenna characteristics. Therefore, several parameters are investigated.

Figure 4 presents the results of effects of the separation between the triangular patch and two folding arms on the matching condition. Varying W_1 from 0.1 to 0.5 mm with a increment of 0.2 mm, the dimension of the corresponding triangular patch changes. The resonant mode, occurring at around 4.6 GHz, is clearly seen to move toward the upper frequency when W_1 getting larger. However, the mismatch of the frequency band between the second resonance at 3.43 GHz and the third resonance at 4.6 GHz becomes stronger.

Figure 5 depicts the variation of S_{11} for different values of W_2. Note the resonant frequency at 2.43 GHz, 3.43 GHz and 7.02 GHz decreases when W_2 increases. It can be concluded that the longer folding arm have some impact on the other two frequencies except for the determination of the resonant mode at 2.43 GHz.

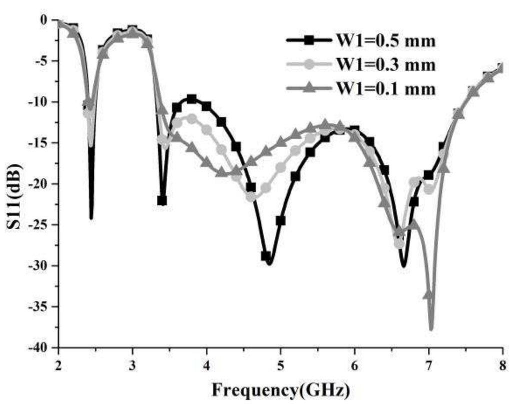


Figure 4. Return loss against frequency with different W_1.

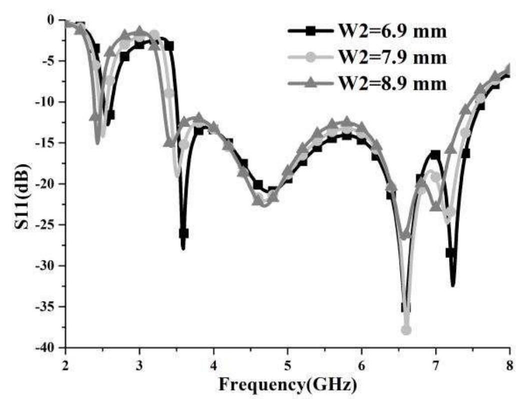


Figure 5. Return loss against frequency with different W_2.

Figure 6 demonstrates the effect of various W_3 on S_{11}, implying that its variation affects resonant mode in 3.43 GHz. Also, by increasing W_3, the resonant frequency at 3.43 GHz will shift to lower frequency.

Figure 7 displays the return loss at different L_1 between the triangular patch and the ground plane. It can be observed that as L_1 decreases, the level of return loss around 4 GHz shifts up and causes mismatch. In addition, the two upper resonances draw close to each other and merge together, and the whole bandwidth declines.

3. CURRENT DISTRIBUTION ANALYSIS

To further comprehend the working mechanism of the proposed antenna, surface currents for the proposed antenna are analyzed. Note that the current has different distributions along the antenna in different resonant frequencies. The strong surface current shown in Fig. 8(a) flows along the longer folding arm. It is indicated that the longer folding arm generates the fundamental mode of 2.43 GHz. For the 3.43 GHz operation [see Fig. 8(b)], strong surface currents can be observed along the shorter folding arm, and its electrical length is roughly quarter-wavelength at 3.43 GHz. In Fig. 8(c), the current mainly distributes along the triangular patch. The current distribution in Fig. 8(d) is similar to dipole antenna. The current path has minimum at the shorted end A and opened end C, D, while has maxima at the center of the shorter arm BC and the longer arm BD, thus, the resonant frequency at 6.59 GHz is the harmonic generated by two folding arms together. Similarly, the result in Fig. 8(e) is caused by the triangular patch and two folding arms.

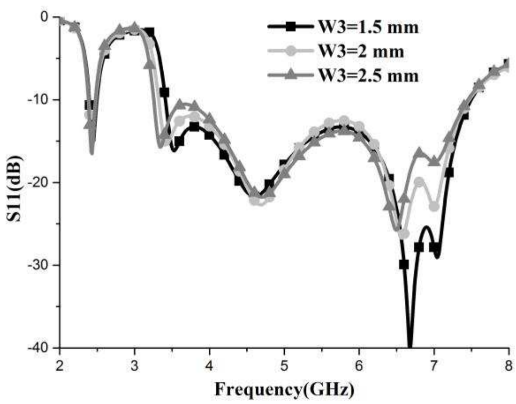


Figure 6. Return loss against frequency with different W_3.

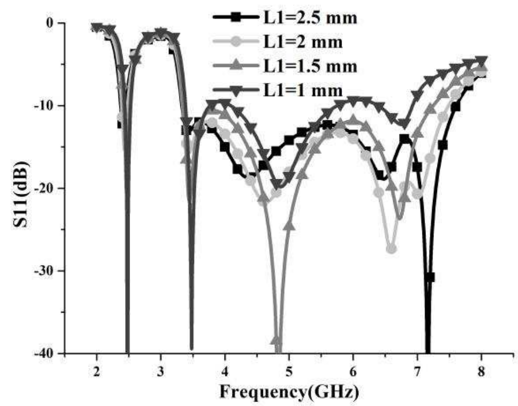


Figure 7. Return loss against frequency with different L_1.

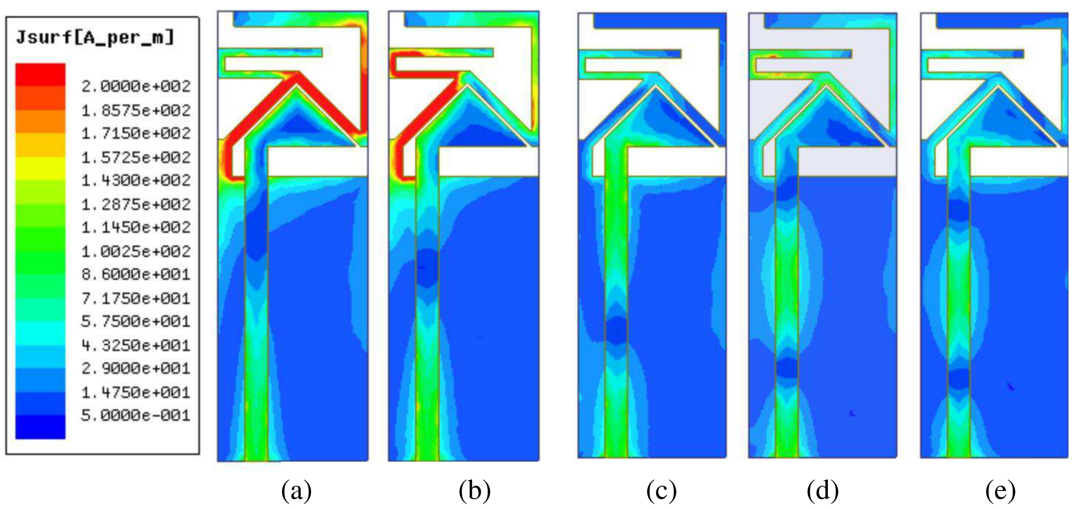


Figure 8. Surface current distribution on the proposed antenna at various resonant frequencies: (a) 2.43 GHz, (b) 3.43 GHz, (c) 4.62 GHz, (d) 6.59 GHz, and (e) 7.05 GHz.

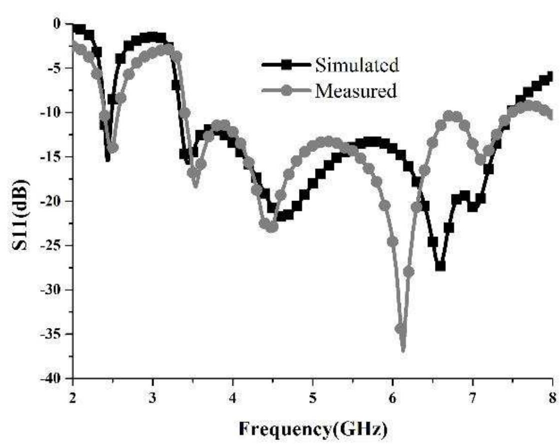


Figure 9. Measured and simulated S_{11} of the proposed antenna.

4. MEASURED AND SIMULATED RESULTS

The comparison between the simulated and measured return loss characteristics of the proposed antenna, obtained by HFSS and Agilent 5230A vector network analyzer, is shown in Fig. 9. The measured −10 dB return loss is given as follows: 2.39–2.54 GHz and 3.39–7.49 GHz. The discrepancy between the measured and simulated results is due to fabrication and measurement deviation.

Size and gain are compared between the proposed antenna and recent published literatures as shown in Table 1. The developed antenna has the smallest size, and the gain can meet with the standards for

Table 1. Comparing size and gain between the proposed antenna and literatures.

Ref.	Dimensions (mm^3)	Gain (dBi)		
		2.4 ∼ 2.5 GHz	3.4 ∼ 3.7 GHz	5.15 ∼ 5.85 GHz
Proposed	10 × 30 × 0.8	1.65	2.56	3.97
[1]	25 × 38 × 1.59	1.85	2.19	2.57
[2]	45 × 40 × 0.4	2.98	5.60	5.50
[3]	30 × 38 × 1.6	2.7	2.85	4.3
[4]	15 × 30 × 1.2	2.35	1.68	4.23
[5]	13 × 27.5 × 1.6	0.71	1.95	2.36
[6]	20 × 25 × 1.6	2.6	2.1	3.2

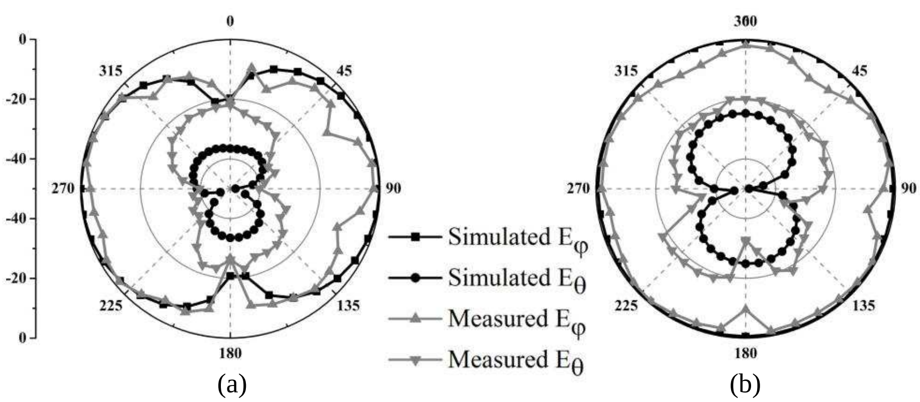


Figure 10. Measured and simulated radiation patterns at 2.45 GHz.

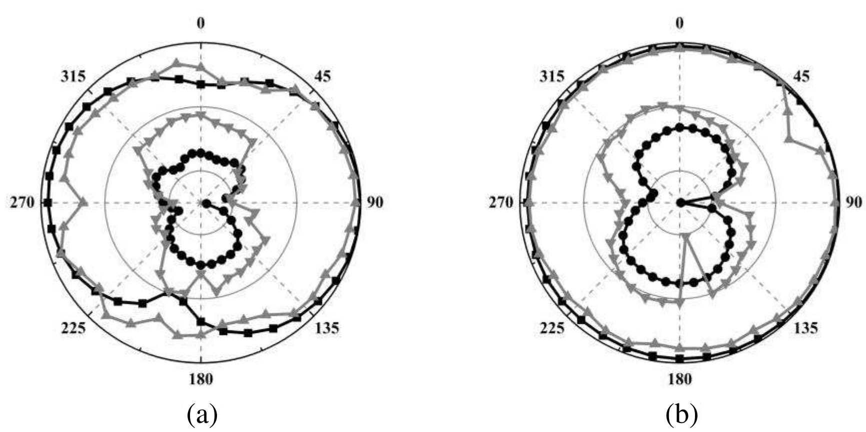


Figure 11. Measured and simulated radiation patterns at 3.5 GHz band.

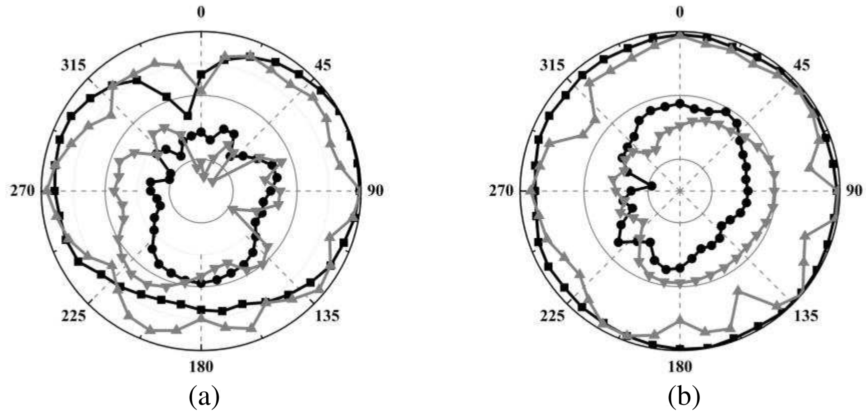


Figure 12. Measured and simulated radiation patterns at 5.5 GHz band.

WiMAX/WLAN applications.

The measured and simulated radiation patterns in two principal planes, namely, yz and xy planes, for 2.45, 3.5, and 5.5 GHz are normalized and plotted in Figs. 10–12, respectively. For the yz plane, nearly omnidirectional pattern is observed in all the frequency band, and dumbbell-like radiation pattern is achieved for the xy plane, which is similar to monopole radiation pattern. The radiation efficiencies of the proposed antenna at 2.45 GHz, 3.5 GHz, and 5.5 GHz are 85%, 89%, and 96%, respectively.

5. CONCLUSION

A compact printed dual-band antenna with a size of $10 \times 30 \times 0.8\,\text{mm}^3$ for WiMAX/WLAN applications is proposed. The antenna utilizes a triangular radiating patch and two folding arms shorted to the ground plane to yield five different resonances, then covering the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. The proposed antenna features compact size, excellent radiation patterns, and good gains, indicating it can be a good candidate for WLAN/WiMAX applications.

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