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A NOVEL TRAPEZOIDAL SLOT PATCH ANTENNA WITH A BEVELED GROUND PLANE FOR WLAN/WIMAX APPLICATIONS

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Abstract—A novel trapezoidal slot patch antenna with an embedded trapezoidal strip is proposed for satisfying wireless local area network (WLAN) and worldwide interpretability for microwave access (WiMAX) applications simultaneously. The proposed antenna consists of a rectangular radiation patch with an etched trapezoidal slot and an embedded trapezoidal strip on the top and a beveled ground on the bottom side. By carefully selecting the width of the radiation patch and length of the beveled ground, the proposed antenna can generate two separate bands. The measured results show that the 10 dB return loss bandwidths of the proposed antenna are 430 MHz (2.30–2.73 GHz) and 3460 MHz (3.21–6.67 GHz), which can cover both the WLAN bands (2.4–2.484 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz) and the WiMAX bands (2.4–2.6 GHz, 3.4–3.6 GHz, and 5.25–5.85 GHz). Furthermore, good omnidirectional radiation patterns with appreciable gain are obtained over the operating bands.

1. INTRODUCTION

In recent years, the ability to integrate more than one communication standard into a single system has become an increasing demand for a modern portable wireless communication device. In order to satisfy the IEEE 802.11 WLAN standards in the 2.4/5.2/5.8 GHz operating bands and the WiMAX standards in the 2.5/3.5/5.5 GHz bands, multiband antennas with large impedance bandwidth and excellent radiation characteristic are required. For this, many promising dual- or multiband antennas for WLAN/WiMAX applications such as the

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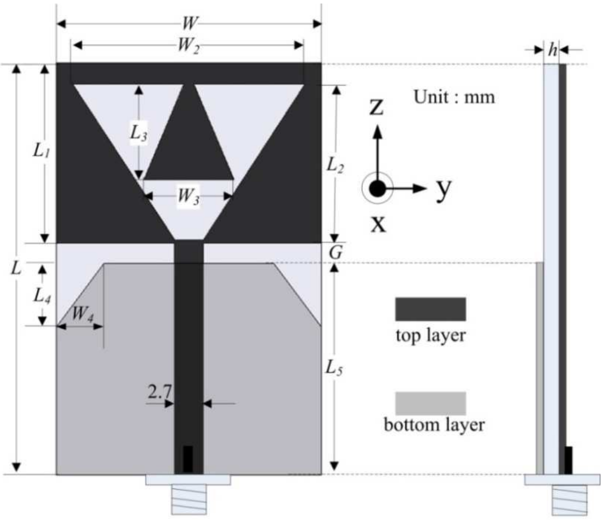
meander antennas [1–3], the slot antennas [4–6], the ring patch antennas [7,8], and the planar inverted-F antennas (PIFAs) [9–11] have been studied. However, most of them are either complex in physical structure or large in overall size for practical applications. Considering that the slot patch structure has a low cost, low profile, ease of fabrication and wide bandwidth, it has received much attention recently [12,13]. Meanwhile, for microstrip-fed printed antennas with partial ground plane, it has been reported in [14,15] that the configuration of the ground plane can affect the characteristics of the antenna and broaden the impedance bandwidth. It is therefore feasible for designing a simple and compact dual-band antenna by composing both the slot patch structure and the beveled ground.

In this paper, a simple dual-band design of a trapezoidal slot patch antenna consisting of an embedded trapezoidal strip on the radiation patch and a beveled ground on the opposite side for WLAN/WiMAX applications is presented. By properly adjusting the width of the trapezoidal slot and the embedded trapezoidal strip, two separate bandwidths can be obtained. Besides, with the use of a pair of triangular notches on the ground plane, a new resonant frequency close to the high resonant frequency can be excited and good dual-band impedance bandwidths as well as suitable radiation characteristics for use in 2.4 (2.4–2.484)/5.2 (5.15–5.35)/5.8 (5.725–5.825) GHz WLAN and 2.5 (2.4–2.6)/3.5 (3.4–3.6)/5.5 (5.25–5.85) GHz WiMAX operations can be achieved. Details of the antenna design and experimental results are presented and discussed.

2. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Figure 1. The overall dimensions of the antenna are $39(L) \times 25(W)\,\mathrm{mm}^2$. The antenna which locates in y-z plane and symmetrical with respect to the longitudinal direction (z-direction), is printed on a 1-mm-thick Teflon substrate with the dielectric constant (ε_r) of 2.65 and the loss tangent ($\tan\delta$) of 0.001. The basis of the antenna structure, which is printed on the top side of the substrate, is a rectangular patch with an etched trapezoidal slot. The length of the trapezoidal slot is set to be L_2 with the width of W_2. A trapezoidal strip with the size of $L_3 \times W_3$ is embedded on the radiation patch. It can be proven that, due to the presence of the trapezoidal strip, two separate bandwidths can be easily excited. A rectangular ground with a pair of triangular notches is printed on the bottom side of the substrate. With the use of two triangular notches ($L_4 \times W_4$) on the upper side of the ground plane, the high frequency impedance bandwidth can



(a) (b)

Figure 1. Configuration of the proposed antenna.

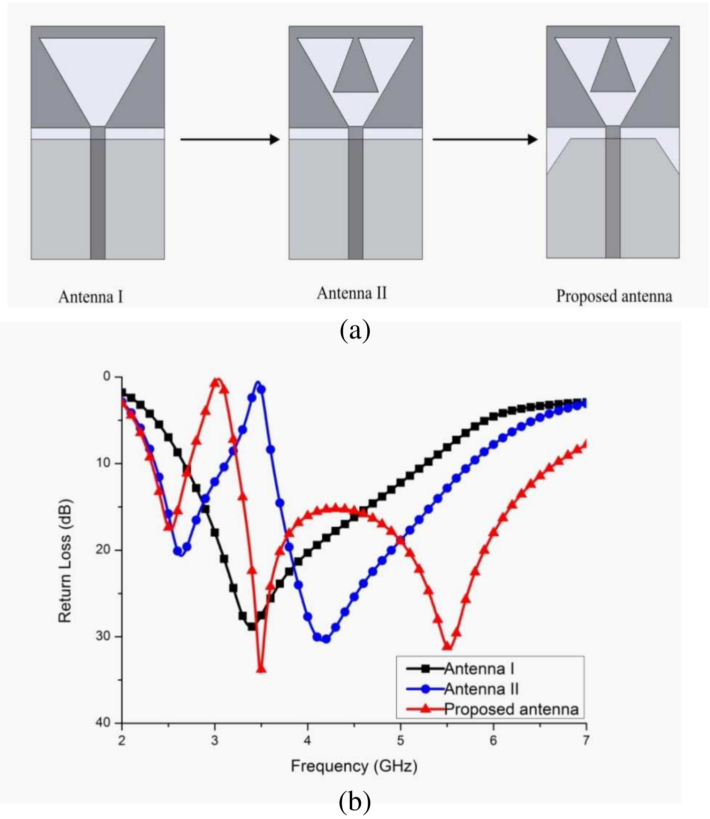
Table 1. Optimal geometrical parameters of the proposed antenna.

Parameters	L	W	L_1	L_2	W_2	h
Unit (mm)	39	25	17	15	22	1
Parameters	L_3	W_3	G	L_4	W_4	L_5
Unit (mm)	9	8.5	1.9	6	4.5	20

be widened. In addition, a $50\,\Omega$ microstrip transmission line with a width of 2.7 mm is used for feeding the antenna. For detailed design, all geometrical parameters of the proposed antenna are optimized using the electromagnetic simulation software Ansoft HFSS, and the optimum design parameters are shown in Table 1.

3. PARAMETRIC STUDY

The design evolution of the proposed antenna and its corresponding simulated frequency response of return losses are presented in Figure 2. It begins with the design of Antenna I, which consists of a trapezoidal slot patch and a rectangular ground plane. As shown in Figure 2(b), only one impedance bandwidth of 263 MHz (2.65–5.28 GHz) with the resonant frequency excited at 3.45 GHz is obtained. By embedding a trapezoidal strip on the radiation patch (Antenna II), the antenna can excite another resonant mode and does not increase the size. It is clearly seen that the impedance bandwidths of Antenna II are 77 MHz (2.35–3.12 GHz) centered at 2.65 GHz and 213 MHz (3.63–5.76 GHz) centered at 4.17 GHz, the first resonant frequency shifts to the lower frequency. It is worth mentioning that the configuration of the ground plane also affects the characteristics of the antenna. In our design, a pair of triangular notches are placed on the upper side of the rectangular ground plane, to achieve good impedance matching and broaden the bandwidth meanwhile. Because the beveled ground plane filters out some undesired frequencies, a new resonant frequency close to the high resonant frequency is excited, and the



(a)

(b)

Figure 2. (a) Design evolution of the proposed antenna and (b) its corresponding simulated return loss results.

impedance characteristic of the high band is improved significantly. From the Figure 2, it can be seen that the proposed antenna has much better impedance performance during the operating bands. It is because of the introduction of an inner trapezoidal strip and a beveled ground plane that the dual-band antenna can meet the requirements for the WLAN/WiMAX standards. The effects of the key structure parameters on the antenna performances are analyzed and presented.

3.1. Parameters for the Radiating Patch: W_2, W_3

In this section, the function of the radiating patch is investigated. The return loss characteristics of this antenna for various W_2 are demonstrated in Figure 3. It is observed that the lower resonance frequency can be adjusted by the width of the trapezoidal slot. As the width of the trapezoidal slot (W_2) increases from 20 mm to 24 mm, the resonance frequency of the lower band shifts down dramatically while the impedance bandwidth of the high frequency resonance mode changes slightly. As a matter of fact, the trapezoidal slot is used for the lower band operation. From the results shown in Figure 4, it is observed that the trapezoidal strip is involved for the higher band operation. With an increase in W_3, the higher resonant frequency shifts down obviously, which indicates that the width of the trapezoidal strip affects the performance of the higher band greatly. So it can be concluded that we can tune W_2 to gain the lower resonance frequency, and adjust W_3 to improve the impedance bandwidth of the higher band.

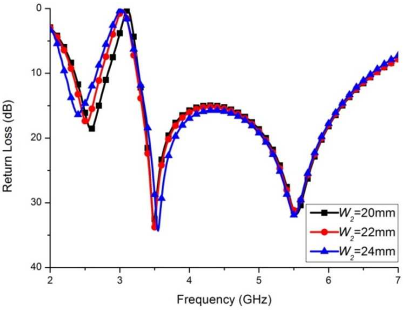


Figure 3. Simulated return loss for different values of W_2.

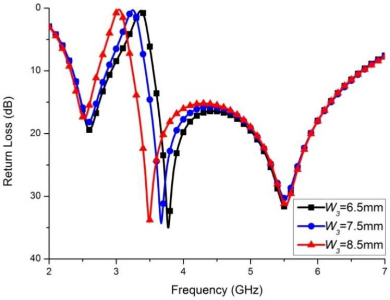


Figure 4. Simulated return loss for different values of W_3.

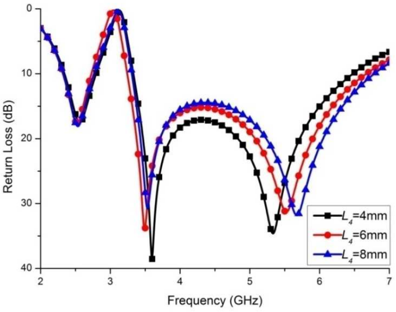


Figure 5. Simulated return loss for different values of L_4.

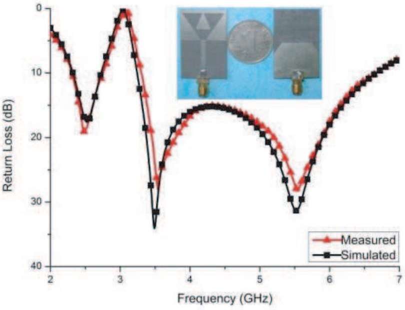


Figure 6. Simulated and measured return losses of the proposed antenna.

3.2. Parameter for the Ground Plane: L_4

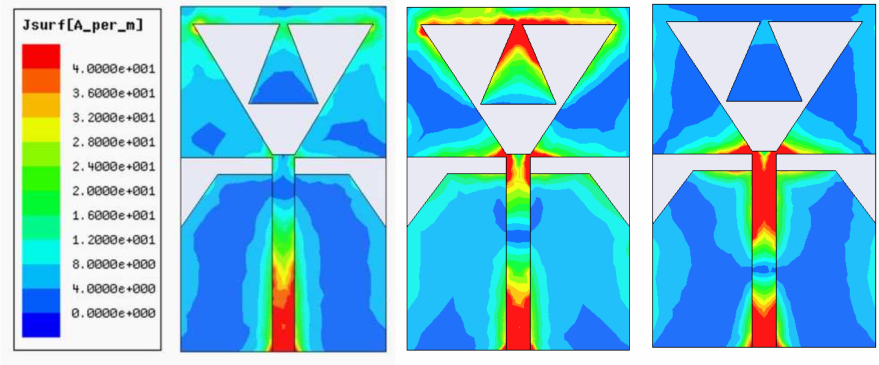
To demonstrate the effect of the beveled ground on broadening the impedance bandwidth, Figure 5 shows the return loss characteristics of the proposed antenna for different values of L_4. From the figure, it can be observed that, as the length of the notch (L_4) increase from 4 mm to 8 mm, the new resonant mode which close to the higher resonant mode shifts up quickly. The impedance bandwidth of the higher frequency resonance mode can be extended dramatically. By properly choosing the length of the notch, the higher band which can fulfill the 5.2/5.8 GHz WLAN and 3.5/5.5 GHz WiMAX standards has been obtained.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The prototype of the proposed antenna has been fabricated according to the optimum design results. The return loss is measured with WILTRON 37269A vector network analyzer. Figure 6 presents the simulated and measured return losses of the proposed antenna. From the measured result, it can be seen that the 10 dB return loss bandwidths of the proposed antenna are 430 MHz (2.30–2.73 GHz) and 3460 MHz (3.21–6.67 GHz), respectively, which makes it easy to cover the required bandwidths for both WLAN and WiMAX applications. The difference between measured and simulated responses may be attributed to the fabrication tolerance of the fabricated antenna prototype and the test environment.

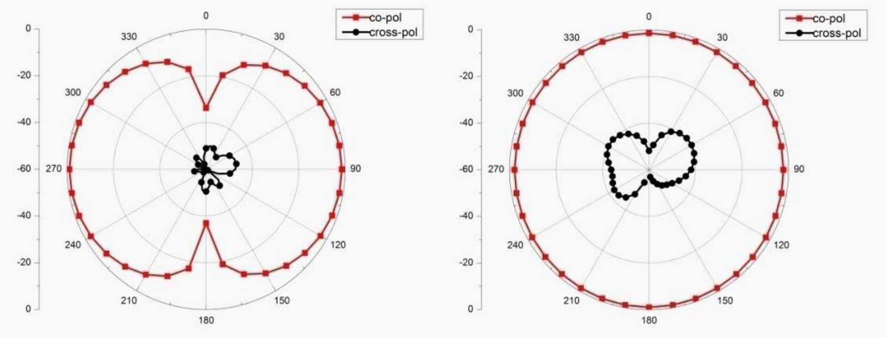
In order to further understand the property of the proposed antenna, the simulated current distributions on the whole proposed antenna at frequencies of 2.5, 3.5, and 5.5 GHz are given in Figure 7. It can be observed that the current has different distributions along the antenna in different bands. The current showed in Figure 7(a) flows along the trapezoidal slot so that the low frequency resonant mode at about 2.5 GHz for WLAN (2.4–2.484 GHz) and WiMAX (2.4–2.6 GHz) operations can be excited. As can be seen in Figure 7(b), the current distribution is around both the trapezoidal slot and the trapezoidal strip, and therefore the middle resonant mode at about 3.5 GHz for WiMAX (2.4–2.6 GHz) operation can be excited. Results in Figure 7(c) reveal that the current of the third resonant mode (5.5 GHz) is mainly distributed on the upper side of the beveled ground and the trapezoidal slot, and thus the high frequency resonant mode at 5.5 GHz for WLAN (5.15–5.35 GHz and 5.725–5.825 GHz) and WiMAX (5.25–5.85 GHz) operations can be excited.

The simulated x-z plane (E-plane) and x-y plane (H-plane) radiation patterns of the proposed antenna at 2.5, 3.5, and 5.5 GHz are shown in Figure 8, respectively. The results show that the radiation patterns are monopole-like in the x-z plane and omnidirectional in the x-y plane. The antenna gains are simulated at several discrete frequencies across the operating bands we concerned. Stable gain variation across the dual operating bands can be achieved. For the low working band of 2.3–2.73 GHz, the antenna gain varies from 2.75 to 2.91 dBi. For the high working band of 3.21–6.67 GHz, the gain variation is from 3.17 to 5.23 dBi for the antenna. Hence, the proposed antenna with dual band property and stable gain variation is suitable for WLAN/WiMAX applications.

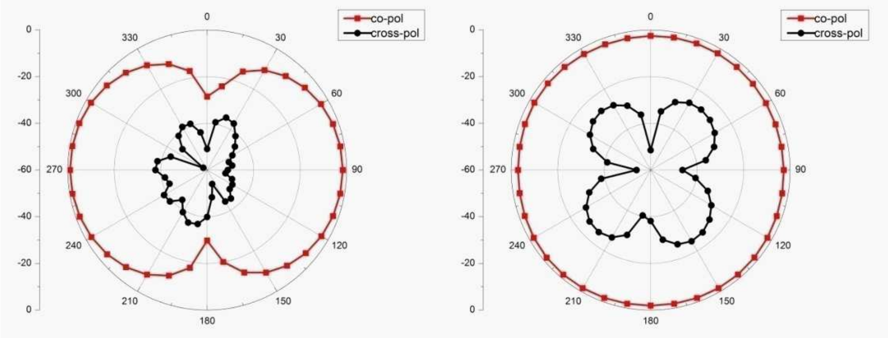


(a) (b) (c)

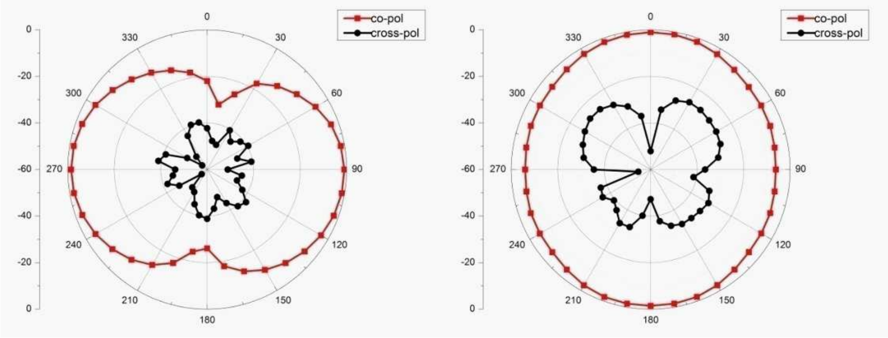
Figure 7. Simulated current distributions at (a) 2.5 GHz, (b) 3.5 GHz and (c) 5.5 GHz.



2.5 GHz *x*-*z* plane 2.5 GHz *x*-*y* plane



3.5 GHz *x*-*z* plane 3.5 GHz *x*-*y* plane



5.5 GHz *x*-*z* plane 5.5 GHz *x*-*y* plane

Figure 8. Simulated radiation patterns at 2.5 GHz, 3.5 GHz, and 5.5 GHz.

5. CONCLUSION

A novel trapezoidal slot patch antenna with an embedded trapezoidal strip for WLAN/WiMAX applications has been designed, manufactured and measured successfully. By using a trapezoidal strip embedded in the trapezoidal slot on the top side of the substrate and a beveled ground plane on the bottom side of the substrate, two separate impedance bands which can meet the requirements for WLAN and WiMAX standards are obtained. The design evolutions of the proposed antenna are illustrated. The effects of varying dimensions of key structure parameters on the antenna performance are also studied. Moreover, the proposed antenna has the advantages of simple structure, compact size, easy design and excellent radiation patterns. Accordingly, the proposed antenna is expected to be an excellent candidate for WLAN/WiMAX wireless communication systems.

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