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DUAL-WIDEBAND SYMMETRICAL G-SHAPED SLOTTED MONOPOLE ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—A novel dual-wideband printed monopole antenna is proposed for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The proposed antenna consists of a T-shaped monopole on top and dual combined G-shaped slots etched symmetrically on the ground plane to achieve a dual-wideband performance. Prototype of the proposed antenna has been constructed and tested. The measured 10 dB bandwidths for return loss are 1.76 GHz from 2.13 to 3.89 GHz and 0.92 GHz from 5.03 to 5.95 GHz, covering all the 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5.5 GHz WiMAX bands. And this antenna also has omni-directional patterns over the lower operating range.

1. INTRODUCTION

Recently, modern wireless communication systems have been developed rapidly and dual- or multi-band antennas applied in 2.4/5.2/5.8 GHz (2.4–2.484 GHz, 5.15–5.35 GHz, 5.725–5.825 GHz) WLAN and 2.5/3.5/5.5 GHz (2.5–2.69 GHz, 3.4–3.69 GHz, 5.25–5.85 GHz) WiMAX applications have aroused more interest. Due to the advantages of low profile, good monopole-like pattern, easy fabricate and low cost, many printed patch antennas have been proposed in [1–7]. However, most of them are addressed to the needs of 2.4/5 GHz WLAN applications, antenna designs with a whole coverage of 2.5/3.5/5.5 GHz for WiMAX operation are scant. In [8–14], several sorts of dual- or

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multi-band antennas have been designed to meet the requirements of both WLAN and WiMAX applications. However, the antennas in [8] and [9] can only meet the 3.5/5.5 GHz WiMAX standard. In [11], a semi-circular slot antenna with dual arc-shaped strips is presented for 2.4/3.5/5 GHz bands, but the antenna is large in size. And in [12] the ground is large and the structure is complex by coupling a stub-loaded open-loop resonator on the back side of the monopole. The asymmetric structures applied in [13] (Γ-shaped and I-shaped slits) and [14] (trapezoidal ground plane and rectangular horizontal strips) make the radiation patterns poor omni-directional in the azimuthal plane.

In this paper, a novel dual-wideband printed monopole antenna for WLAN and WiMAX applications is proposed. Owing to the dual combined G-shaped slots etched symmetrically on the ground plane, a new resonant mode can be excited to cover both 2.4 GHz WLAN and 2.5/3.5 GHz WiMAX operating bands. And with the use of a T-shaped monopole on the opposite side, 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX operating bands also can be obtained. By adjusting the parameters of the G-shaped slots and the tuning stub, good impedance match can be achieved. Furthermore, the radiation patterns are almost omni-directional in the azimuthal plane with the dual symmetrical slots. Details of the proposed antenna, both the simulated and measured results are presented and discussed.

2. ANTENNA DESIGN

The geometry of the proposed antenna is illustrated in Figure 1. The antenna is designed and fabricated on a substrate with dielectric constant of 2.65, thickness of 1 mm, and area of $36 \times 42\,\mathrm{mm}^2$. A T-shaped monopole, which consists of a horizontal strip and a vertical strip, is on the top side of the substrate. This monopole comprises a horizontal strip (width 1.5 mm and length 12 mm) and a vertical one (width 1.5 mm and height 17.9 mm). In the design, the width of the two strips is fixed at 1.5 mm so as to make the monopole match well with the $50\,\Omega$ connector. The vertical microstrip line protruded into the slot is fixed at 7.9 mm which is nearly 1/4 of the guided wavelength at 5.5 GHz. The horizontal strip is applied to tune the impedance match for the proposed antenna. And this monopole mainly contributes to the upper operating band of the proposed antenna. Dual combined G-shaped slots are etched on the ground plane, which comprise a rectangular slot with an I-shaped strip and a pair of L-shaped strips embedded. By applying these strips, the current patch distributed on the ground plane can be extended, thus effectively lowering the lower resonant band. And for the same reason the size of the antenna can

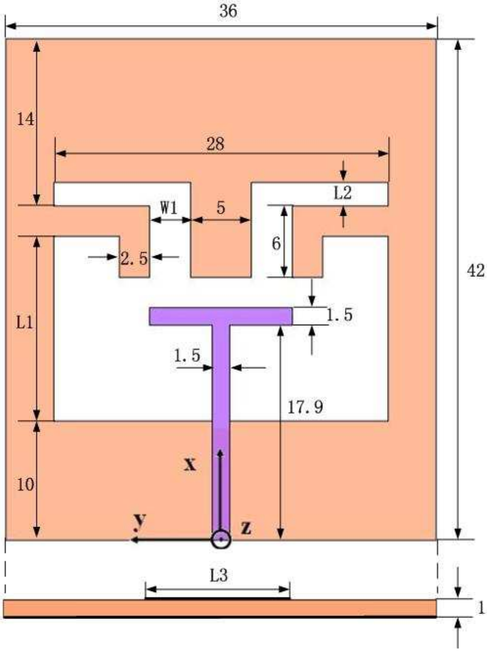


Figure 1. Geometry of the proposed antenna (Unit: mm).

be miniaturized.

As can be seen from Figure 2, the design steps of the proposed slot antenna are presented. And Figure 3 displays the corresponding frequency responses. The first antenna (#1) consists of a monopole and a rectangular slot etched on the ground plane. This antenna generates a quite broad single band operation centered at 5.7 GHz. With dual L-shaped strips embedded in the slot (#2), another resonant frequency is excited at 4.2 GHz because the strips offer the current flow path for this lower frequency and the center frequency of the upper resonant band shifts to 6.5 GHz. In order to provide a wider frequency bandwidth to satisfy both the lower 2.4 GHz WLAN and 2.5/3.5 GHz WiMAX applications, an I-shaped strip is inserted into the slot to form another lower frequency band ranging from 2.3 GHz to 3.5 GHz (#3). However the impedance match within the lower band is not satisfied, thus a tuning stub is connected to the monopole to adjust the impedance match (#4). Finally, all the WLAN and WiMAX bands can be covered by the proposed antenna. Figure 4 plots the simulated impedance charateristics on the Smith chart, from the curves it can be observed that the origin antenna #1 can produce a single loop within the return

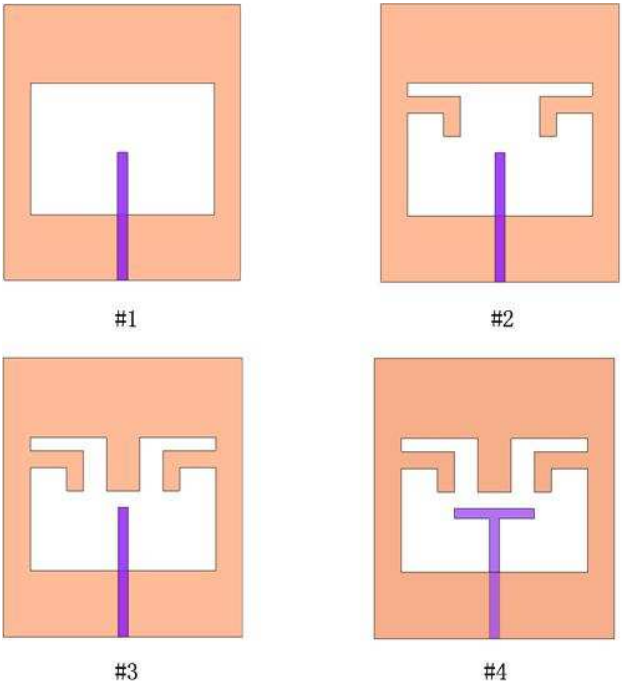


Figure 2. Design steps of the proposed antenna. #1 initial monopole antenna with a rectangular slot, #2 slot antenna with embedded dual L-shaped strips, #3 slot antenna with embedded dual L-shaped strips and an I-shaped strip, #4 slot antenna with embedded strips and a tuning stub.

loss circle (VSWR = 2). And with the use of dual L-shaped strips and an I-shaped strip, antenna #2 and antenna #3 both have 2 loops. This demonstrates that more excitation modes of the proposed slot antennas have appeared. Futhermore, the optimum impedance match of antenna #4 can be achieved by applying the tuning stub.

A series of parametric studies are carried out to attain desired antenna performance, particularly tuning the resonant frequencies and return loss characteristics. Most of the parameters are fixed at the optimized values so that the antenna can achieve a good dual-band performance. And as shown in Figure 1, by adjusting the parameters L_1, L_2 and W_1 of the dual G-shaped slots and L_3 of the tuning stub, the optimum impedance match can be obtained within the operating bands.

The required numerical analysis and proper geometrical parame-

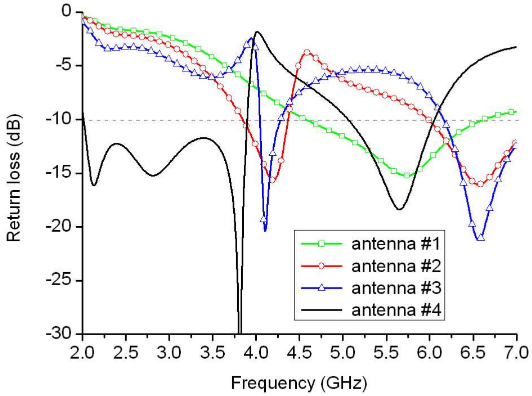


Figure 3. Simulated return loss for antenna #1, #2, #3 and #4.

ters of the proposed antenna are studied with the aid of Ansoft High Frequency Structure Simulator (HFSS) software. A prototype of the demonstrated antenna is fabricated according to the aforementioned design result, as shown in Figure 5.

3. RESULTS AND DISCUSSION

The prototype of the demonstrated antenna has been constructed and experimentally studied. With the help of the HFSS and WILTRON37269A vector network analyzer, the simulated and measured return loss (S_{11}) curves are shown in Figure 6. From the measured curve, it can be observed that the lower frequency band for $S_{11} < -10\,\text{dB}$ ranges from 2.13 to 3.89 GHz with multi-band performance, which meets the bandwidth requirements for 2.4 GHz WLAN and 2.5/3.5 GHz WiMAX operation. And the upper frequency band extends from 5.03 to 5.95 GHz with center frequency at 5.67 GHz, which covers both 5.2/5.8 GHz WLAN and 5.5 GHz WiMAX operating bands. The simulated curve agrees with the measured one, and the slight difference within the lower frequency band is probably due to the tolerance of fabrication and test environment.

Figures 7–10 show the return loss curves for the proposed antenna with various parameters L_1, L_2 and W_1 of the dual combined G-shaped slots and L_3 of the tuning stub. As indicated in Figure 7, L_1 has a great effect on the impedance match of the upper resonant band. When L_1 is increased, the upper frequency band moves toward lower frequency direction with lower band almost invariable. And L_1 is fixed at 15.5 mm to cover upper WLAN (5.15–5.35 GHz, 5.725–5.825 GHz) and WiMAX

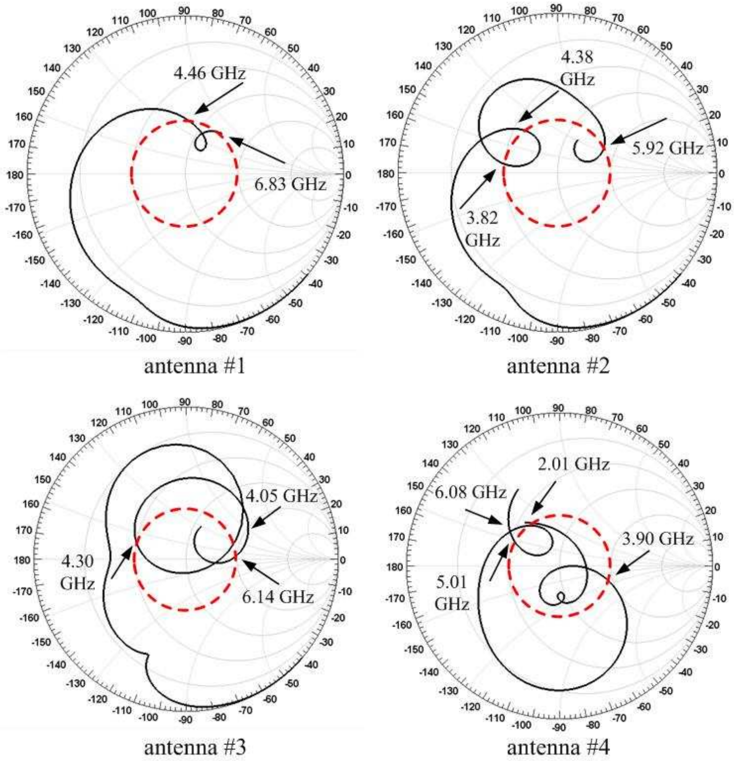


Figure 4. Simulated impedance locus on Smith chart.

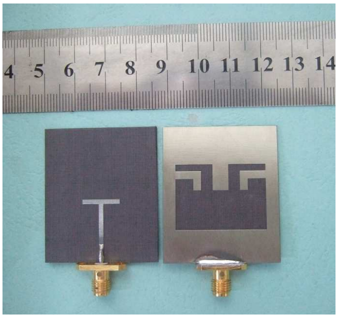


Figure 5. Prototype of the proposed antenna.

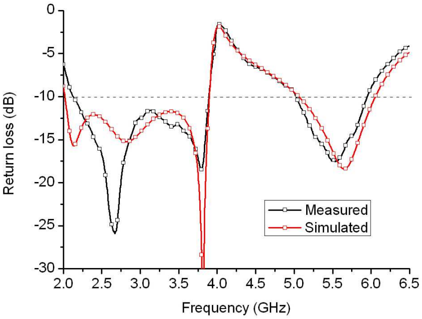


Figure 6. Simulated and measured return loss of the proposed antenna. ($L_1 = 15.5\,\text{mm}$, $L_2 = 2\,\text{mm}$, and $W_1 = 3.5\,\text{mm}$).

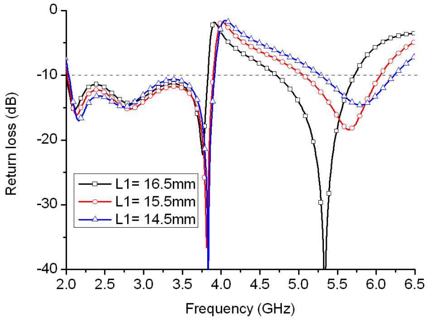


Figure 7. Simulated return loss for different values of L_1. ($L_2 = 2\,\mathrm{mm}$, $W_1 = 3.5\,\mathrm{mm}$ and $L_3 = 12\,\mathrm{mm}$).

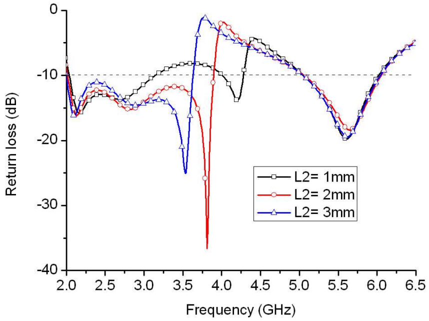


Figure 8. Simulated return loss for different values of L_2. ($L_1 = 15.5\,\mathrm{mm}$, $W_1 = 3.5\,\mathrm{mm}$ and $L_3 = 12\,\mathrm{mm}$).

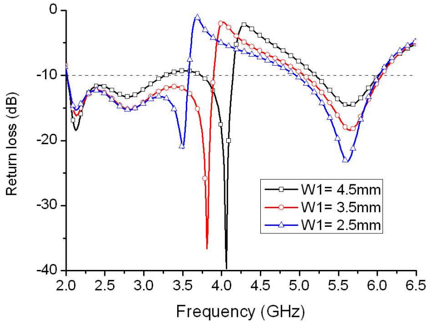


Figure 9. Simulated return loss for different values of W_1. ($L_1 = 15.5\,\mathrm{mm}$, $L_2 = 2\,\mathrm{mm}$ and $L_3 = 12\,\mathrm{mm}$).

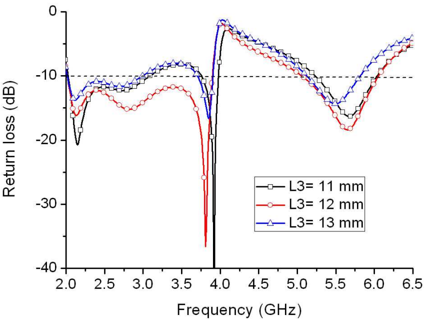
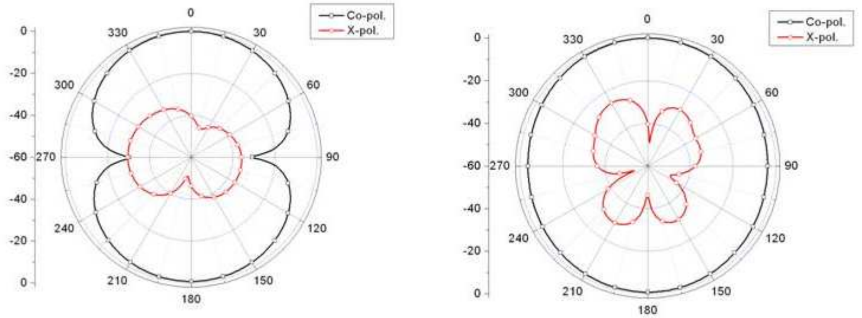


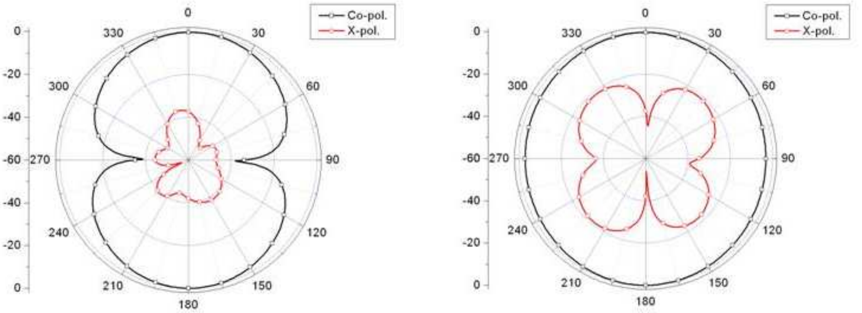
Figure 10. Simulated return loss for different values of L_3. ($L_1 = 15.5\,\mathrm{mm}$, $L_2 = 2\,\mathrm{mm}$ and $W_1 = 3.5\,\mathrm{mm}$).

(5.25–5.85 GHz) bands. It can be observed from Figure 8 that with a decrease of L_2, the bandwidth of the lower frequency band expands and the impedance changes. For L_2 is fixed at 2 mm, a coverage and good impedance match within almost all lower WLAN (2.4–2.484 GHz) and WiMAX (2.5–2.69 GHz, 3.4–3.69 GHz) bands can be achieved. As shown in Figure 9, W_1 affects the bandwidth of the lower frequency band and impedance match of both lower and upper bands. And it can be found when $W_1 = 3.5\,\mathrm{mm}$, good impedance match can be obtained for both lower and upper frequency bands. As the horizontal strip of the T-shaped monopole is employed to tune the impedance match, and its optimum length L_3 can be obtained for the optimized performance.



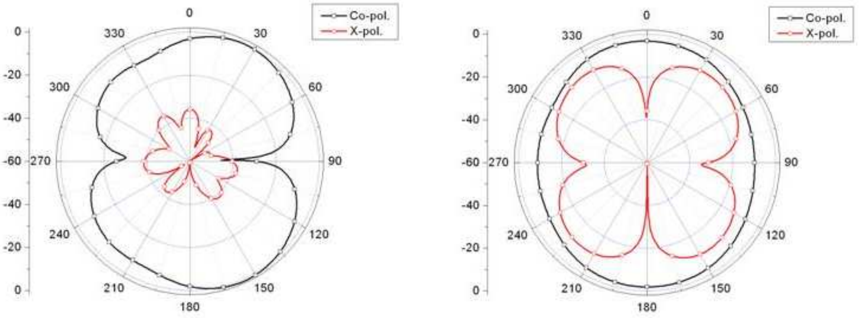
2.5GHz E-plane (x-z plane)

2.5GHz H-plane (y-z plane)



3.5GHz E-plane (x-z plane)

3.5GHz H-plane (y-z plane)



5.5GHz E-plane (x-z plane)

5.5GHz H-plane (y-z plane)

Figure 11. Far-field radiation patterns of the proposed antenna.

As displayed in Figure 10, L_3 has an obvious effect on the impedance match especially within the lower resonant band. The impedance characteristic of the antenna will become worse if this length is not designed appropriately, and the desired performance can be achieved

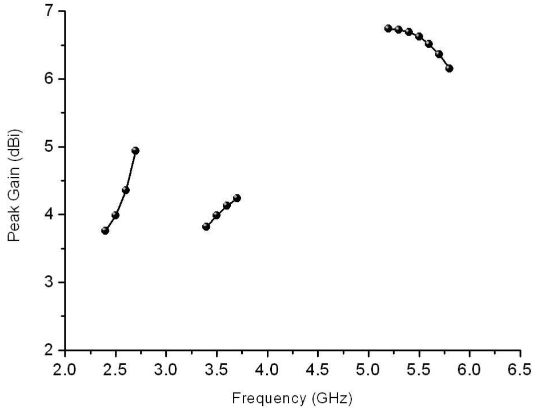


Figure 12. Peak gains of the proposed antenna.

when L_3 is fixed at 12 mm.

The radiation characteristics of the proposed antenna are also investigated. The far-field radiation patterns for the antenna at 2.3, 3.5and 5.5 GHz are displayed in Figure 11. It can be observed that the radiation patterns at lower frequencies (2.5/3.5 GHz) are almost omni-directional in the H-plane (y-z plane) and bi-directional in the E-plane (x-z plane). And the cross-polarization component at upper frequency (5.5 GHz) becomes higher because of the y-directed current path of upper resonant band. The peak antenna gains against frequency are plotted in Figure 12. The results indicate the peak gains of the proposed antenna range approximately from 3.8 to 4.9 dBi at 2.4–2.7 GHz, 3.8 to 4.2 dBi at 3.4–3.7 GHz, and 6.7 to 6.2 dBi at 3.4–3.7 GHz, respectively.

4. CONCLUSION

A novel dual-wideband printed monopole antenna with dual combined G-shaped slots is presented, manufactured and measured. The design steps of the antenna are illustrated, and a parametric study on the slots and the tuning stub is also displayed to achieve the desired performance. The measured results show that the lower and upper frequency bandwidths can reach about 1.76 and 0.92 GHz, which are sufficient to cover both the WLAN and WiMAX operating bands. Further, the radiation patterns are almost omni-directional over the lower service band. Simulated and measured results indicate the antenna can be a good candidate for the WLAN and WiMAX applications.

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