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MINIATURE TRIPLE-BAND CPW-FED MONOPOLE ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—A miniature single-layer CPW-fed monopole antenna with triple-band operation for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications is presented. The proposed antenna, comprising a planar rectangular patch element embedded with dual U-shaped slot, is capable of generating three distinct operating bands, 2.37–2.53, 3.34–3.82, and 4.23–6.88 GHz covering all the 2.4/5.5/5.8 GHz WLAN bands and the 3.5/5.5 GHz WiMAX bands. The designed antenna has a simple uniplanar structure and occupies a small size of $25 \times 18\,\mathrm{mm}^2$ including the finite ground CPW feeding mechanism. Moreover, the proposed antenna shows good monopole-like radiation patterns with small cross-polarization and stable antenna gains across the three operating bands.

1. INTRODUCTION

Recently, with the rapid development of WLAN (2.4–2.484, 5.15–5.35, and 5.725–5.825 GHz) and WiMAX (2.5–2.69, 3.4–3.69, and 5.25–5.85 GHz) systems, the demands for antennas with multiband operation, small size, low cost, simple configuration and easy fabrication have increased drastically. Thus, various designs of multiband antenna suitable for WLAN/WiMAX operation have been introduced [1–10] , such as monopole antennas with double-T shaped [1], double-S shaped [2], C-shaped [3], E-shaped [4], meandered T-shaped [5] and back-to back dipole [6] radiating structures. However, none of the above available designs can provide a multi-band operation to support WiMAX application. In [7, 8], these antennas can generate wide bands to cover the WLAN and WiMAX bands, however, their

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wide operating bands cover many other existing narrowband services such as C-band satellite communications. To address this issue, additional band pass filters are required to be added into the system to avoid frequency collision and to minimize interference. Therefore several triple-band antennas which have better rejections in undesired bands for WLAN/WiMAX applications have been proposed [9–13]. In [9], the proposed coplanar inverted-F antenna is capable of generating three distinct bands for WLAN/WiMAX applications, but with poor radiation patterns and high cross-polarization across the operating bands. In [10], with the embedded rectangular and circular patches, the antenna can achieve triple frequency operation, but with poor E-plane radiation patterns especially in the upper band. In [11–13], these designs of triple band antenna are either complex in structure or large in size, which limit their availabilities for practical application.

In this paper, a miniature uniplanar printed CPW-fed antenna for WLAN/WiMAX applications is proposed. Limited to only $25 \times 18\,\text{mm}^2$ area, the proposed antenna consisting of a slotted monopole and a modified CPW ground plane is capable of generating three distinct operating bands 2.37–2.53, 3.34–3.82, and 4.23–6.88 GHz to cover the WLAN/WiMAX bands. The antenna is simple in structure with reduced size compared to that of a conventional printed monopole antenna. Good pattern performance with small cross-polarization suitable for WLAN and WiMAX systems can also be obtained. Details of the antenna design and experimental results are also presented and discussed.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed CPW-fed triple-band antenna. The antenna with a single-layered metallic structure is etched on one side of an inexpensive FR4 epoxy substrate with a relative permittivity of 4.6, a loss tangent of 0.02 a thickness of 1.6 mm, and with no metallization on the other side.

To excite the antenna, a $50\,\Omega$ CPW feed line that has a signal strip width of W_f and a gap distance of G between the signal strip and the coplanar ground plane, is used. Two equal modified finite ground planes are situated symmetrically on each side of the CPW feed line. By etching a pair of symmetrical triangles with legs T_1, T_2 on each side of the ground plane, a smooth transition from one resonant mode to another can be achieved, and good impedance matching is obtained. The basis of the antenna structure is a rectangular patch monopole which is centered and connected at the end of the CPW feed line.

To achieve the triple-band operation for WLAN/WiMAX

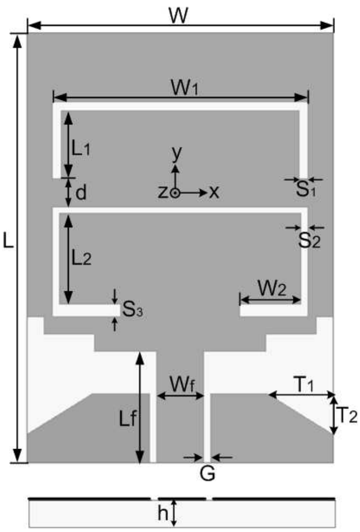

Figure 1. Geometry of the proposed antenna.

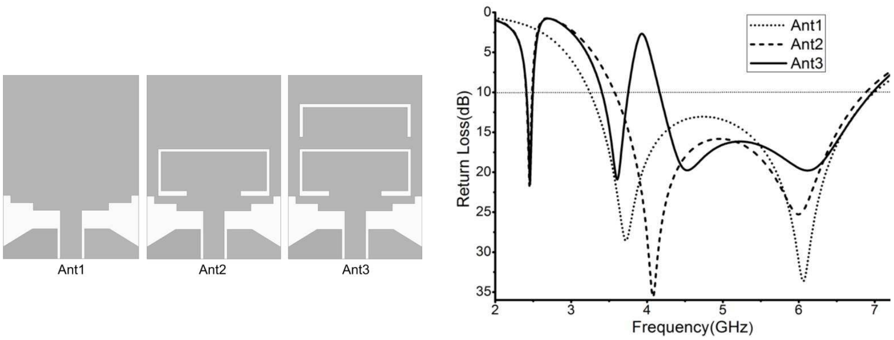

Figure 2. Simulated return loss of the antennas involved in the design evolution process.

applications, as shown in Fig. 2, firstly, a rectangular patch monopole antenna (denoted as Ant1) is designed. The staircase patterns notched on the bottom of the rectangular patch plays an important role in improving the impedance matching. This design can excite two resonant modes, and it is worth noting that the two resonant modes are deliberately made to merge as a single wideband ranging from 3.2 GHz to 7.0 GHz. Secondly, by introducing a modified U-shaped slot in Ant1, the antenna (denoted as Ant2) can excite another 2.4 GHz

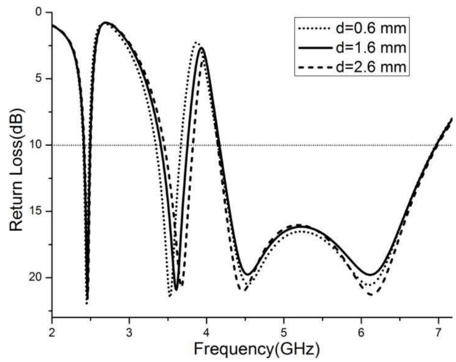

Figure 3. Simulated return loss against frequency for the proposed antenna with various d.

resonant mode without increasing the antenna size, and can provide two frequency bands to satisfy all the WLAN standards. Finally, the second U-shaped slot is added to Ant2 for generating a band-notching at 4 GHz to reject the interference out of operating bands [14], and then the Ant3 (proposed antenna) is capable of generating three distinct bands to cover the 2.4/5.2/5.8 GHz WLAN bands and the 3.5/5.5 GHz WiMAX bands.

The optimal dimensions of the proposed antenna are as follows: $L = 25.0$ mm, $L_1 = 4.0$ mm, $L_2 = 5.3$ mm, $T_1 = 3.9$ mm, $T_2 = 2.4$ mm, $L_f = 6.5$ mm, $d = 1.6$ mm, $W = 18.0$ mm, $W_1 = 15.0$ mm, $W_2 = 3.6$ mm, $W_f = 2.8$ mm, $S_1 = 0.5$ mm, $S_2 = 0.4$ mm, $S_3 = 0.7$ mm, $G = 0.4$ mm.

In addition, the effect of the gap height d on the performance of the proposed triple band antenna are presented in Fig. 3. As shown in the figure, varying d from 0.6 mm to 2.6 mm with an increment of 1 mm and remaining the other parameters unchanged, the middle resonant mode shifts toward the higher frequencies, while the lower resonant mode and the upper resonant mode remain nearly the same. This indicates that the coupling effects between the upper U-shaped slot and the lower modified U-shaped slot can influence the impedance matching for the proposed antenna.

3. RESULT AND DISCUSSION

According to the designing dimensions given above, a prototype of the proposed triple-band antenna has been fabricated and measured. The photograph of the prototype for the proposed antenna is shown

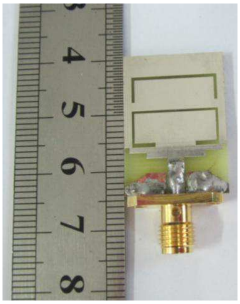

Figure 4. Photograph of the proposed antenna.

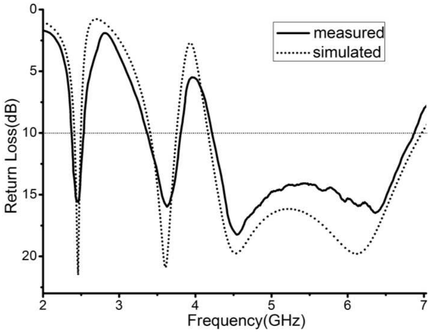

Figure 5. Measured and simulated results of the proposed antenna.

in Fig. 4. Fig. 5 describes the simulated and measured return loss against the frequency for the fabricated prototype antenna, and there are some slight discrepancies between simulated and measured results due mainly to errors in fabricating process and the effects of the SMA connector which introduces a varying reactance, leading to the change of performances. The measured impedance bandwidths of the three distinct operating bands with 10 dB return loss are about 16 MHz (2.37–2.53 GHz), 480 MHz (3.34–3.82 GHz) and 2650 MHz (4.23–6.88 GHz). Obviously, the achieved impedance bandwidths are wide enough to cover the requied bandwidths of all the WLAN standards (2.4–2.484, 5.15–5.35, and 5.725–5.825 GHz) and the WiMAX standards of (3.4–3.69 GHz) and (5.25–5.85 GHz) bands.

In order to explain the excitation mechanism of the antenna in more detail, the simulated surface current distributions of the proposed antenna at 2.45 and 4 GHz are given in Fig. 6. For the 2.45 GHz operation, most of the surface currents are concentrated along the modified U-shaped slot at the bottom of the rectangular patch monopole as shown in Fig. 6(a), which indicates that the embedded modified U-shaped slot does effectively provide the electrical current path for producing the 2.45 GHz resonant mode. At the rejected frequency (4 GHz), the surface currents showed in Fig. 6(b) mainly flow along the edge of the U-shaped slot at the top of the rectangular patch monopole indicating that the upper U-shaped slot is responsible for generating the stopband. Hence, the antenna can generate three distinct bands to cover the 2.4/5.2/5.8 GHz WLAN bands and the 3.5/5.5 GHz WiMAX bands.

The measured far-field radiation patterns of the fabricated prototype at 2.45, 3.5, and 5.5 GHz in x-z plane (H-plane) and the

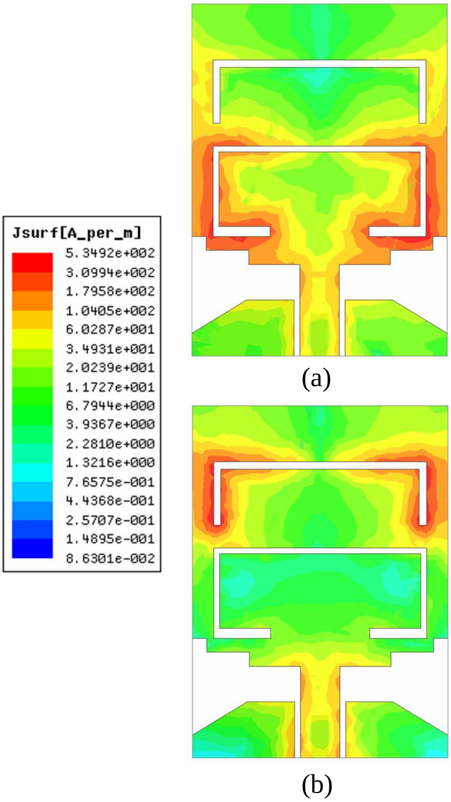

Figure 6. Simulated surface current distributions of the proposed antenna at (a) 2.45 GHz and (b) 4 GHz.

y-z plane (E-plane) are shown in Fig. 7, respectively. As shown in the figure, the antenna displays good omnidirectional radiation patterns in the x-z plane and bidirectional radiation patterns in the y-z plane, which attribute to the symmetry in the proposed monopole antenna structure. Moreover, stable radiation patterns across the 2.45, 3.5, and 5.5 GHz bands are achieved, and the cross-polarization radiation patterns are relatively small.

Finally, the measured peak gains against the frequency for the proposed antenna across the three bands are shown in Fig. 8. As can be seen, stable gain variations across the three desired bands have been achieved. The obtained average gains are about 3.73 dBi (3.60–3.80 dBi), 3.2 dBi (3.11–3.25 dBi) and 4.20 dBi (3.64–4.43 dBi), respectively, within the bandwidths of 2.45, 3.5 and 5.5 GHz operating bands. As a result, the proposed antenna with stable gain is very suitable to be integrated into the portable wireless terminals for WLAN/WiMAX application systems.

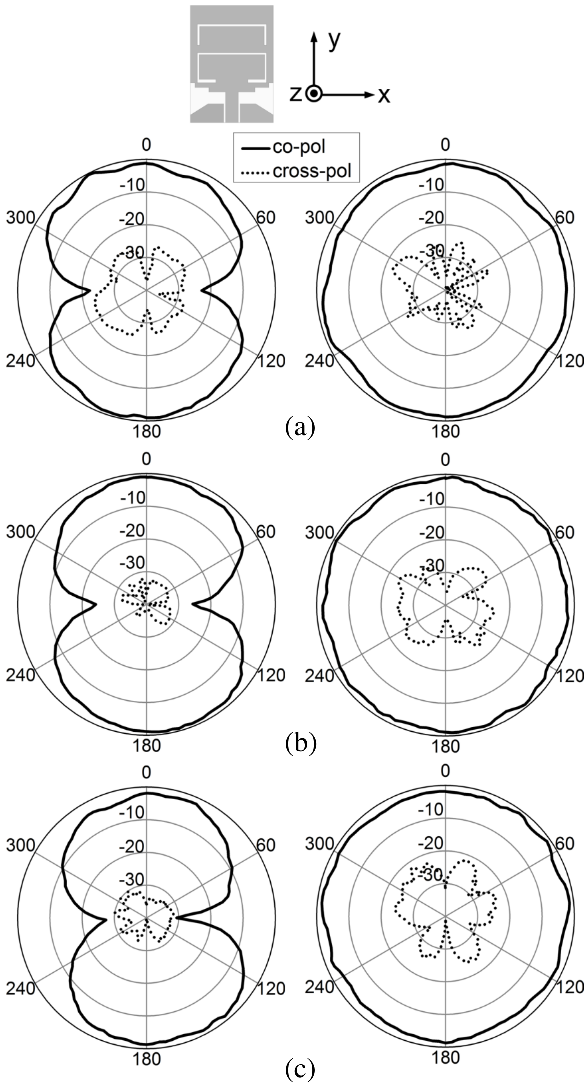

Figure 7. Measured radiation patterns of the proposed antenna at (a) 2.45 GHz, (b) 3.5 GHz, and (c) 5.5 GHz.

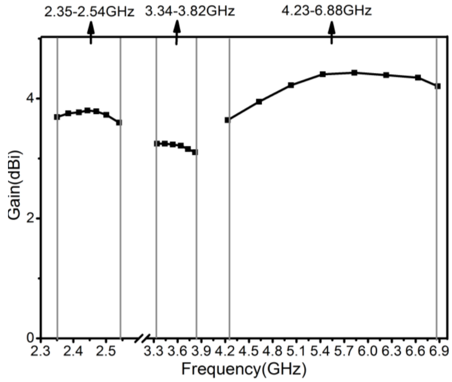

Figure 8. Measured gains of the proposed antenna.

4. CONCLUSION

A simple triple-band CPW-fed monopole antenna for WLAN/WiMAX applications has been presented. By simply embedding two U-shaped slots into a rectangular patch, the antenna can generate three distinct bands to cover the 2.4/5.2/5.8 GHz WLAN bands and the 3.5/5.5 GHz WiMAX bands. The small size, simple structure, multiband coverage, almost monopole-like radiation properties and stable antenna gains across the operating bands make the proposed antenna to be an attractive candidate for practical applications in the WLAN/WiMAX communication system.

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