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# CROSSED OVAL-RING SLOT ANTENNA WITH TRIPLE-BAND OPERATION FOR WLAN/WIMAX APPLICATIONS

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**Abstract**—This paper presents the design of a crossed oval-ring microstrip slot antenna to achieve triple-frequency operation for WLAN/WiMAX applications. The proposed antenna is composed of a rectangular microstrip feed line and a ground plane on which three crossed oval-ring slots are etched. The three crossed slot loops finally excite three resonant modes and the resonant frequencies of the proposed antenna are mainly controlled by the dimensions and locations of the slot loops. The antenna prototype is fabricated and the characteristics are experimentally verified. The measured impedance bandwidths for triple operating bands can reach 840/670/940 MHz with return losses larger than 10 dB, which is enough for WLAN/WiMAX communication. In addition, good radiation characteristics with moderate peak gains are obtained and the measured and simulated results show a good agreement.

## 1. INTRODUCTION

In modern wireless communication systems, the multiband antenna has become one of the most important circuit elements and attracts many attentions. The IEEE 802.11 wireless local area network (WLAN) standards consist of 2.4–2.484 GHz, 5.15–5.35 GHz and 5.725–5.875 GHz frequency bands, while the Worldwide Interoperability for Microwave Access (WiMAX) standards consist of 2.5–2.69 GHz, 3.3–3.69 GHz and 5.25–5.85 GHz frequency bands. Multiband antennas with simple structure and superior radiation performance, which can cover the working bands described above, are required. Microstrip antennas are very attractive because of their low profile, low weight,

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conformal to the surface of objects and easy production. Compared to the patch antennas, the antennas with slot configurations demonstrate enhanced characteristics, including wider bandwidth, better isolation and easy to realize multiband operation. Various microstrip slot antennas to achieve dual-band or triple-band operations are studied and proposed, such as coplanar waveguide (CPW) fed L-shaped slot antenna [1], rectangular slot loops antenna [2], microstrip line fed semi-circular slot antenna [3] and H-shaped slot antenna [4]. However, the multiband antennas available have some drawbacks, such as narrow impedance bandwidths [1, 4], large size [3], achieving multiband but not covering all the required bands for WLAN/WiMAX applications [2]. In recent years, annular-slot antennas [5–8] loaded by split ring slot have attracted significant interest because of their appealing features such as relatively wide bandwidth, lightweight and ease of fabrication [9–11]. Other annular-slot antennas with strip-loaded [12, 13] or different structure of tuning stub [14] are proposed for better impedance matching. Although, novel in structure or clever in feeding design, these antennas do not obtain large bandwidths for the three bands simultaneously or be large in size.

In this paper, a novel triple-band microstrip antenna with three etched oval-ring slots on the ground plane is proposed for WLAN and WiMAX applications. Compared to the antennas published, the proposed antenna in this paper achieves triple wide bands simultaneously and the structure is easy to fabricate. Meanwhile, the measured results represent that the antenna shows a good multiband characteristic which can satisfy the requirements of WLAN and WiMAX applications. Details of the antenna design and experimental results are presented and discussed.

## 2. ANTENNA DESIGN

Figure 1 shows the schematic of the proposed crossed oval-ring slot triple-band antenna. The antenna is designed and fabricated on a square microwave substrate with thickness of 1 mm, relative permittivity of 2.65 and a loss tangent of 0.02. At top side of the substrate a 50 Ω microstrip feed line with a width of 2.7 mm is adopted for centrally feeding the antenna, which is in turn connected to a coaxial cable through a standard 50 Ω SMA connector. Three oval-ring slots are etched crosswise and symmetrically on the ground plane to provide different surface current paths so as to produce the triple operating bands. The lengths of the semi-major axis and semi-minor axis of the oval-ring slots are shown in Figure 1(c), which measured from the outer edge of the slots. In the frequency range of interest,

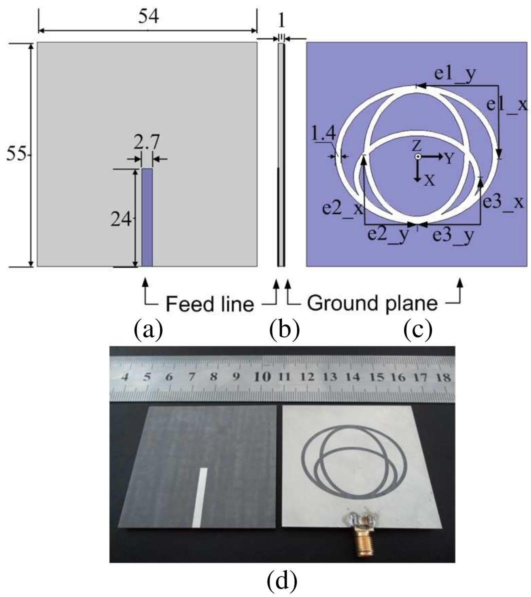



**Figure 1.** Configuration of the proposed crossed oval-ring slot triple-band antenna (units: mm). (a) Top view. (b) Side view. (c) Bottom view. (d) Fabricated antenna.

the proposed antenna has three resonant modes, whereas the antenna with the only outer slot possesses two resonant modes [6]. Usually, the resonant frequencies are mainly determined by the circumference length of the annular-slot. For the proposed oval-slot antenna, the first mode is mainly determined by the circumference of the outer slot-ring. The second mode is very similar to the second resonant mode excited by the antenna with the only outer slot. Finally, the inner two crossed slot loops and coupling among the split slots introduce the third resonant mode. By adjusting the length of microstrip feed line, the oval-ring slot width, and the perimeter of the oval-ring slots, three resonant frequencies of the proposed antenna can be generated with good impedance matching. The measured results are given in the following section.

## 3. EXPERIMENTAL RESULTS AND ANALYSIS

A prototype is built and tested based on the design dimensions shown in Figures 1(a), (b) and (c). The photograph of the proposed antenna is shown in Figure 1(d). Figure 2 shows the measured and simulated return losses for the proposed antenna. It is clearly seen that three

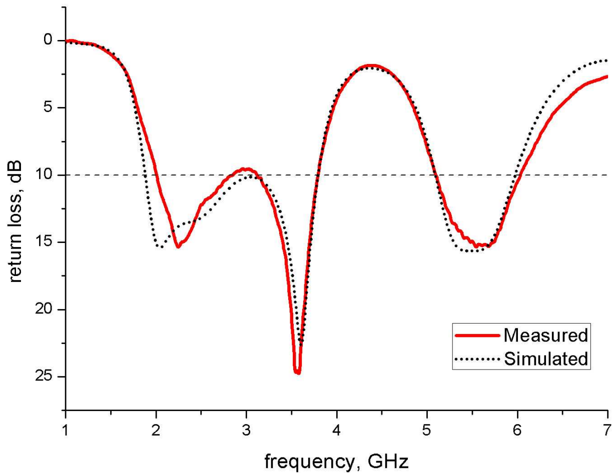



**Figure 2.** Measured and simulated return losses of the proposed antenna ($e1\_x = 17$ mm, $e1\_y = 20$ mm, $e2\_x = 16.5$ mm, $e2\_y = 13$ mm, $e3\_x = 11.5$ mm, $e3\_y = 15.5$ mm).

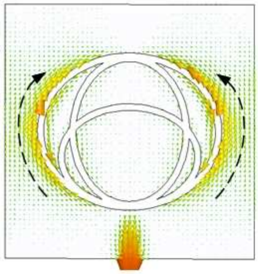
**Table 1.** Simulated and measured center frequencies and bandwidths.

| | $F_1$ (GHz) | $F_2$ (GHz) | $F_3$ (GHz) | $BW1$ (%) | $BW2$ (%) | $BW3$ (%) |
|---|---|---|---|---|---|---|
| Simulated | 2.47 | 3.42 | 5.53 | 46.7 | 22.0 | 15.9 |
| Measured | 2.43 | 3.46 | 5.56 | 34.6 | 19.4 | 16.9 |

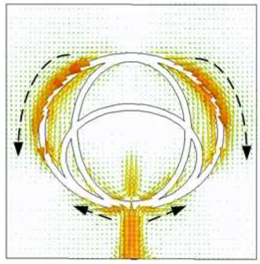
resonant modes are excited and that the achieved bandwidths can cover the WLAN/WiMAX standards.

Table 1 shows the simulated and measured center frequencies and bandwidths of the three operating bands. The measured return losses above 10 dB bandwidths range are from 2.01–2.85 GHz, 3.12–3.79 GHz and 5.09–6.03 GHz, which show agreement with the simulated results, and three wide bandwidths are obtained.

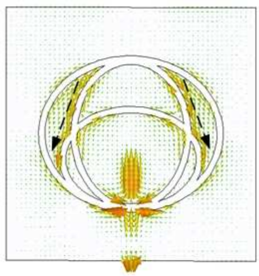
Figure 3 shows the simulated surface current distributions of the proposed triple-band crossed oval-ring slot antenna operating at 2.5, 3.5 and 5.5 GHz for wireless communication. As shown in Figure 3(a), at the frequency of 2.5 GHz, the current is concentrated around the edge of the outer slot and is oppositely directed between the interior and exterior of the outer slot. For the second resonant mode at 3.5 GHz, as shown in Figure 3(b), four half-wavelength current routes are exist, among which the two routes passing the feeding position have the shortest lengths. On the other hand, the current for the third resonant mode is mainly distributed around the two inner crossed slots, as shown in Figure 3(c).



(a) $f = 2.5$ GHz



(b) $f = 3.5$ GHz



(c) $f = 5.5$ GHz

**Figure 3.** Simulated surface current distributions of the proposed antenna operating at 2.5, 3.5 and 5.5 GHz.

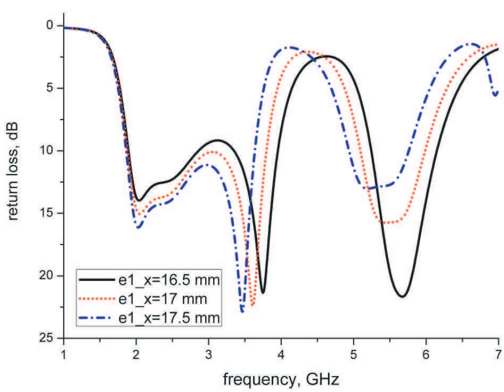



**Figure 4.** Return losses of the proposed antenna with various lengths of the outer oval-slot semi-minor axis $e1\_x$; other antenna parameters are given in Figure 2.

Figure 4 shows the return losses of the proposed slot antenna with various lengths of the outer oval-slot semi-minor axis ($e1\_x$). It is easily found that with the length of $e1\_x$ increasing, the center frequencies of the three resonant modes move to the lower frequencies, especially the second and third modes. The $e1\_x$ increases equals to the lengths of the whole outer-slot and part of the inner-slot increases, and then the surface current paths change.

The return losses for the proposed slot antenna with various lengths of the outer oval-slot semi-major axis ($e1\_y$) are shown in Figure 5. It is easily found that with the length of $e1\_y$ increasing,

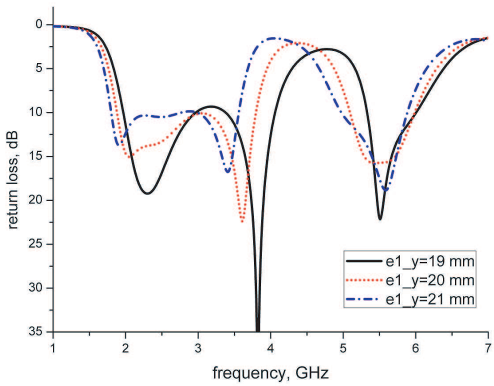



**Figure 5.** Return losses of the proposed antenna with various lengths of the outer oval-slot semi-major axis $e1\_y$; other antenna parameters are given in Figure 2.

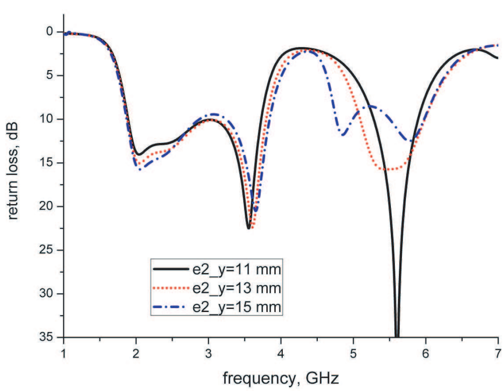



**Figure 6.** Return losses of the proposed antenna with various lengths of the inner oval-slot semi-minor axis $e2\_y$; other antenna parameters are given in Figure 2.

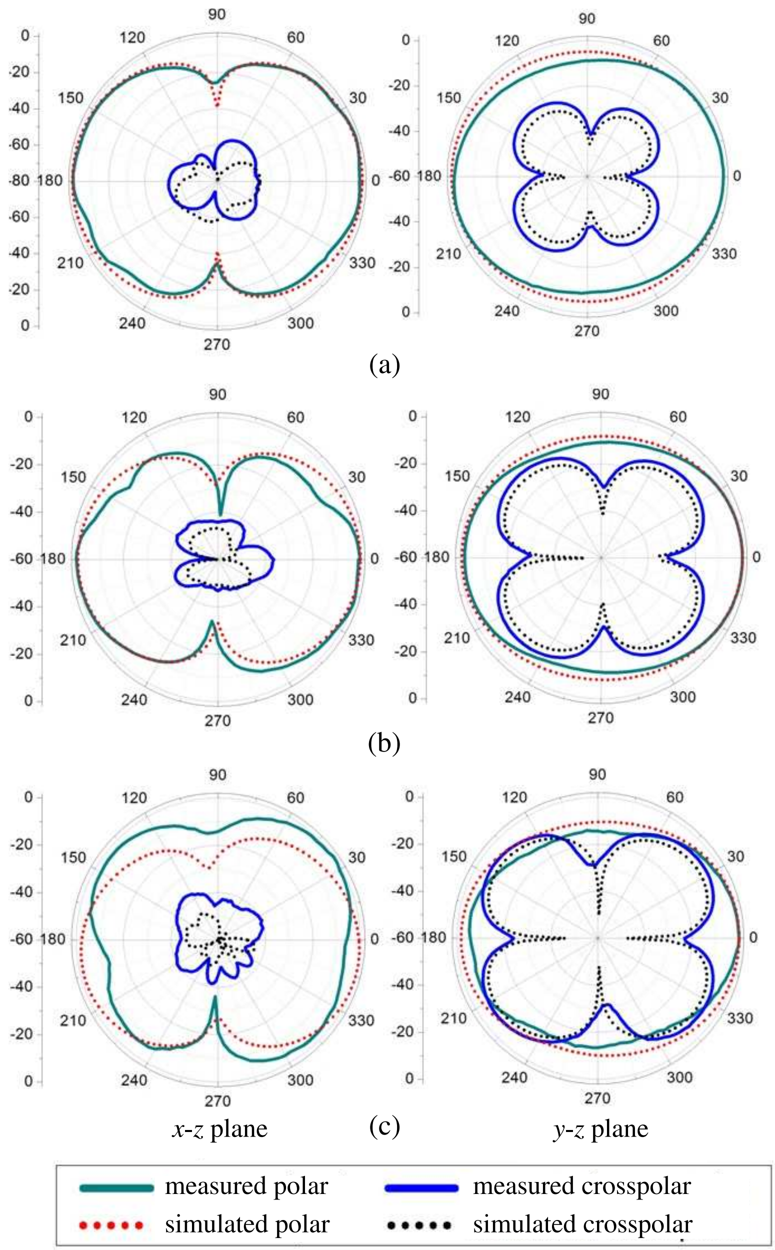



**Figure 7.** Radiation patterns of the proposed antenna. (a) 2.5 GHz. (b) 3.5 GHz. (c) 5.5 GHz.

so the circumference length of the outer oval-slot increasing, the center frequencies of the first and the second resonant modes move to lower frequencies. However, the highest center frequency of the third mode, which excited by the inner crossed slots, changes little.

The return losses for the proposed slot antenna with various lengths of the inner oval-slot semi-minor axis ($e2\_y$) are shown in Figure 6. It is easily found that with the length of $e2\_y$ increasing, the center frequencies of the first and the second resonant modes varied little. However, as the current routes around the inner upper slots increasing, the center frequency of the third mode and the bandwidth changes obviously.

The radiation characteristics have also been investigated, and the simulated and measured far-field radiation patterns of the proposed antenna at the three resonant frequencies of 2.5, 3.5 and 5.5 GHz are shown in Figure 7. Nearly omni-directional radiation patterns in the $y$-$z$ plane and dipole-like radiation patterns in the $x$-$z$ plane are obtained at these frequencies. These three resonant modes are seen to be of same polarization planes and similar radiation characteristics. Good agreement is obtained between the simulated and measured results. Figure 8 shows the simulated and measured peak gains of the proposed antenna for frequencies across the three operating bands. The obtained average gains are 4.03 dBi (3.94–4.12 dBi), 4.75 dBi (4.63–4.87 dBi) and 6.21 dBi (5.91–6.51 dBi) respectively, within the operating bands of 2.4–2.7 GHz, 3.3–3.7 GHz and 5.1–5.9 GHz and the gain variations for triple bands are within 0.6 dB. The simulated radiation efficiency

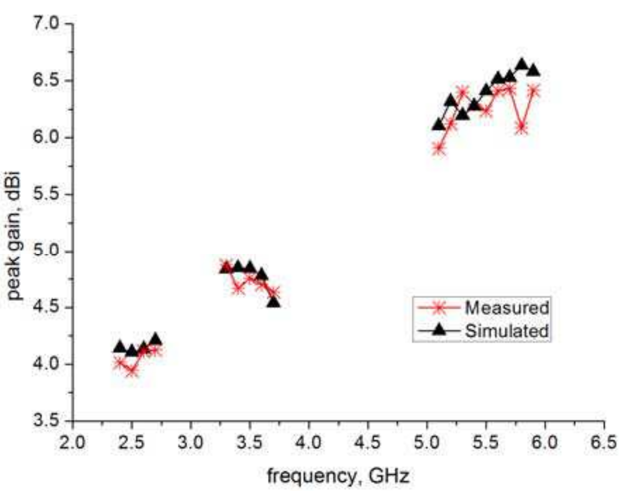



**Figure 8.** Peak gains of the proposed antenna for frequencies across 2.5, 3.5 and 5.5 GHz operating bands.

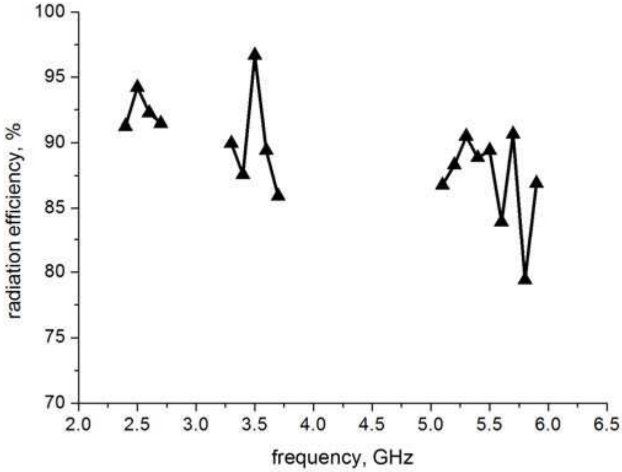



**Figure 9.** Simulated radiation efficiency for frequencies across 2.5, 3.5 and 5.5 GHz operating bands.

curves are plotted in Figure 9, which are obtained by using HFSS software.

## 4. CONCLUSION

A novel crossed oval-ring slot antenna with triple-band operation for WLAN/WiMAX applications is proposed. The antenna achieves multiband characteristic through etching oval-ring slots on the ground plane, which is simple in structure and much easy to fabricate. The measured results show that the obtained impedance bandwidths are good enough for WLAN/WiMAX applications. Moreover, the proposed antenna has good radiation characteristics and gains over the three operating bands, which make it an excellent candidate for the WLAN and WiMAX applications.

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