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DESIGN OF TRIPLE-FREQUENCY FOLDED SLOT ANTENNA FOR 2.4/3.5/5.2/5.8-GHz WLAN APPLICATIONS

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Abstract—In this article, a novel coplanar waveguide (CPW)-fed miniaturization folded slot antenna for wireless local area network (WLAN) application is proposed and investigated. The multi-operating bands are achieved by folded slot antenna with slot loading. The parametric analysis of the antenna is done by the available electromagnetic solver HFSS11. The designed antenna has a small overall size of 28 mm × 30 mm, and operates over the frequency ranges, 90 MHz (2.40 GHz–2.49 GHz), 400 MHz (3.4 GHz–3.8 GHz) and 870 MHz (5.17–6.04 GHz) suitable for WLAN 2.4/5.2/5.8 GHz and WiMAX 3.5/5.5 GHz applications. The proposed antenna is developed, and its measured characteristics are in good agreement with the simulated results. The experimental results show that the antenna gives dipole-like radiation patterns and good antenna gains over the operating bands. In addition, effects of main parameters of the triple-frequency for the design on the electromagnetic performance are examined and discussed in detail.

1. INTRODUCTION

The demand for the design of antenna with triple- or multi-band operation has increased since such antenna is vital for integrating more than one communication standards in a single compact system to effectively promote the portability of a modern personal communication system. The developed antenna must not only have a triple/multi-band operation, but also have a simple structure, compact size, and easy integration with the circuit. Coplanar waveguide (CPW)-fed slots are one of the most popular kinds of antennas

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as they can be easily integrated into circuits [1]. Also, CPW transmission lines have lower radiation losses and less dispersion than microstrip. Among the known triple/multi-band antenna prototypes, a survey of the literature indicates that the printed slot antenna is a promising candidate for implementing the wideband or multi-band standards with a small area [2–7]. There are different types of slot antennas such as tapered slot antennas which are wideband or ultra wideband [8, 9]. Several design approaches and implementations have been demonstrated to achieve the desired triple-frequency requirements. However, the aforementioned techniques supporting triple/multi-band operations still suffer from large size. To solve this problem, Chiang et al. [10] proposed the slot antenna with strip-loaded approach to realize the miniaturization. Ghosh et al. [11] described a miniaturization slot antenna using slit loading.

Therefore, a slot loading CPW-fed folded slot antenna with triple-frequency operation for WLAN applications is proposed in this article. With pairs of different slots loaded in the folded slot, the proposed antenna is able to generate three operating bands 2.4/3.5/5.5, which satisfy the required bandwidth for WLAN and WiMAX applications very well. Good radiation performance suitable for WLAN and WIMAX systems is realized. Detail of the antenna design and experimental results are presented and discussed.

2. ANTENNA DESIGN AND SIMULATION

The schematic configuration of the proposed CPW-fed slot antenna with slot loading for triple-frequency operation is shown in Figure 1. For the design studied here, the antenna is printed on FR-4 structure with thickness of 1 mm (h) and relative permittivity of 4.3 (ε_r) with overall dimensions of 28 mm × 30 mm.

The optimized parameters of the proposed antenna are shown in Figure 1, and the computed reflection coefficient of the different shaped antennas using HFSS11 software is shown in Figure 2. In order to realize the miniaturization of the slot antenna, the antenna I configuration is the basic prototype with a folded slot loading for the proposed design. Furthermore, based on I, one improved prototype II has been proposed for achieving the second resonant mode. And antenna III is the final design of the proposed. As shown in Figure 2, antenna I produces low operating band, and antenna II can achieve a high resonant frequency based on the first resonant frequency. Triple-frequency operating bands can be achieved based on antenna III. A 50 Ω CPW impedance transformation feed line is used for feeding the antenna. The proposed antenna has a good impedance

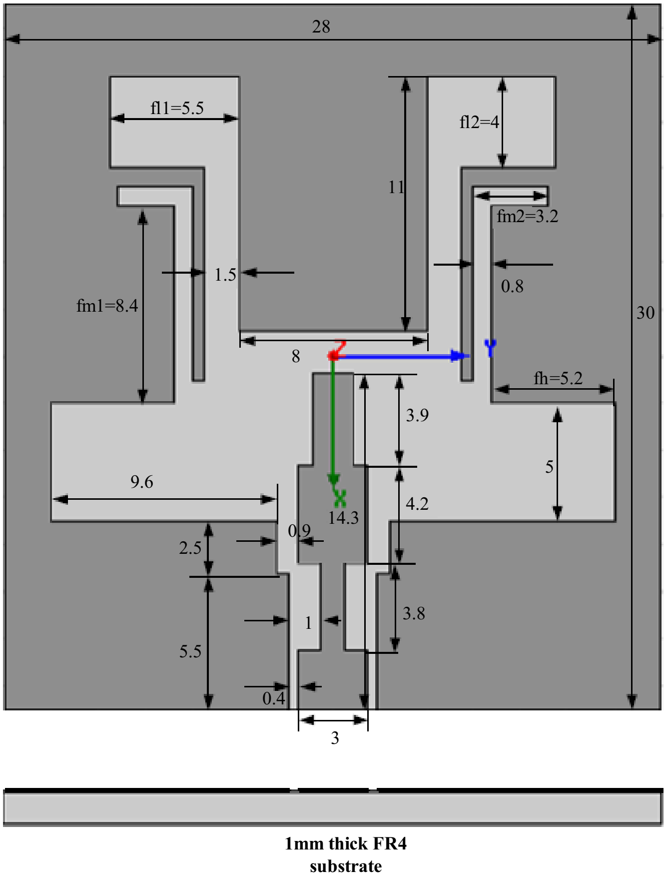

Figure 1. Schematic configurations of proposed CPW-fed antenna (unit: mm).

matching condition at the three operating bands 90 MHz (2.40 GHz–2.49 GHz), 400 MHz (3.4 GHz–3.8 GHz) and 870 MHz (5.17–6.04 GHz), respectively, corresponding to an impedance bandwidth of 3.7%, 11.1% and 15.5% with respect to the appropriate resonant frequencies over the three operating bands. Apparently, the above obtained bandwidths simultaneously cover the WLAN standards in the 2.4/5.2/5.8 GHz bands and the WiMAX standards in the 3.5/5.5 GHz bands.

To further examine the above excitation mechanism of the proposed antenna, the excited surface current distributions and the ground for the optimally design antenna, as presented, were studied. Figure 3 shows the results for the three resonant frequencies at 2.4,

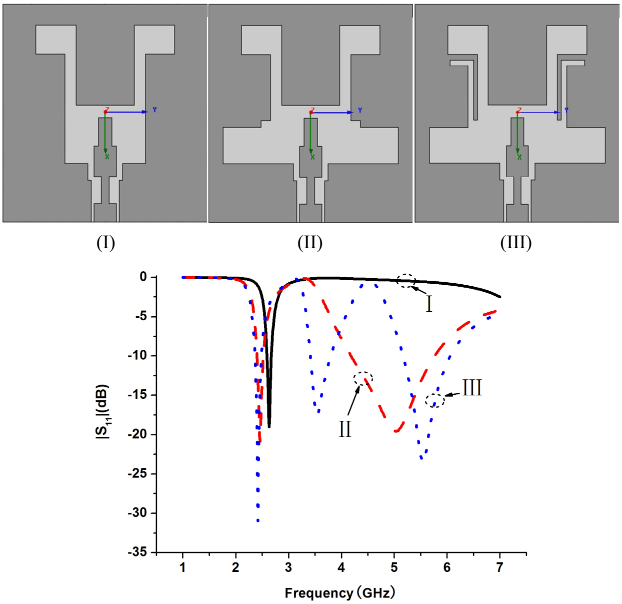

Figure 2. Configuration of the three antennas and simulated results against frequency for the proposed antenna with/without second slot, third slot loading.

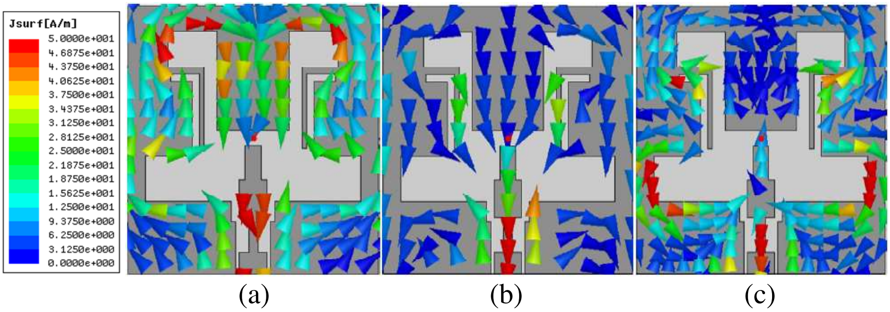

Figure 3. Simulated results of the surface current distributions for the proposed triple-frequency slot antenna studied in Figure 2 at (a) 2.4 GHz, (b) 3.6 GHz, (c) 5.5 GHz.

3.6, and 5.5 GHz. Obviously for the lowest band excitation (2.4 GHz band). A large surface current density is observed along the folded slot, whereas for the highest- (5.5 GHz) and the third-band (3.6 GHz band) excitations, the current distribution becomes more concentrated along the second slot and the third folded slot, respectively. According to the observed phenomenon of current distribution on the proposed antenna when operating at the three bands, we investigated the influence of the related geometrical dimensions on the impedance matching condition of the three resonant modes. Figure 4 presents simulated return loss against frequency for the proposed triple-frequency slot antenna with

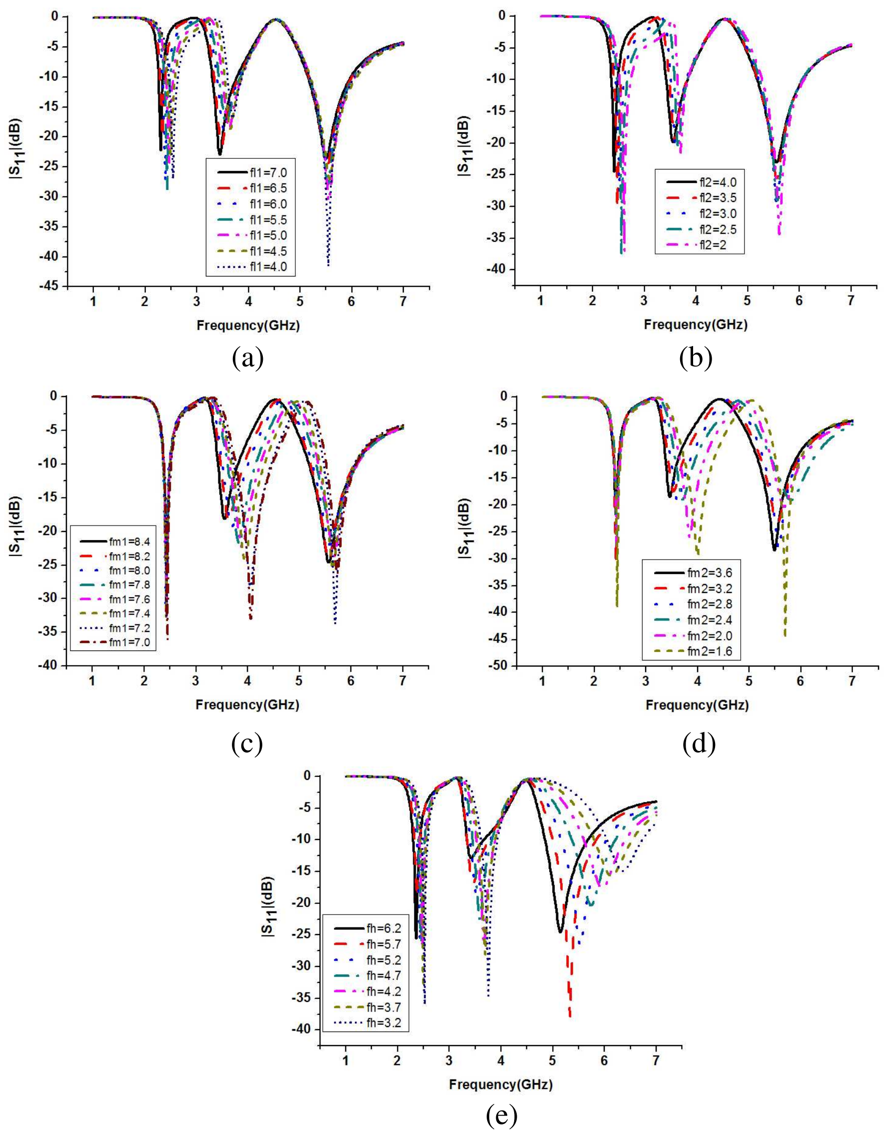

Figure 4. Simulated return loss against frequency for the proposed triple-frequency slot antenna with various (a) f_{l1}, (b) f_{l2}, (c) f_{m1}, (d) f_{m2} and (e) f_h, other parameters are the same as shown in Figure 1.

(a) f_{l1}, (b) f_{l2}, (c) f_{m1}, (d) f_{m2} and (e) f_h. Other parameters are the same as shown in Figure 1. As for the lowest resonant band, the simulated results were verified by adjusting the length of f_{l1} = (4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0), and f_{l2} = (2.0, 2.5, 3.0, 3.5, 4.0). We found that the lowest resonant band is shifted toward the lower frequency band when f_{l1} and f_{l2} increase, whereas the two higher resonant bands are slightly affected. As for the second resonant frequency, the simulated results were verified by adjusting the length of the third folded slot f_{m1} (7.0, 7.2, 7.4, 7.6, 7.8, 8.0, 8.2, 8.4) and f_{m2} (1.6, 2.0, 2.4, 2.8, 3.2, 3.6). Obviously, for this design varying the length of f_{m1} and f_{m2}, the 3.6 GHz operating band, shifted toward the lower frequency band when f_{m1} and f_{m2} increases, does not significantly change the other two operating bands. Consider the highest resonant frequency from the current distribution on the antenna, as shown in Figure 3. The tuning effect of length f_h (3.2, 3.7, 4.2, 4.7, 5.2, 5.7, 6.2) is examined and shown in Figure 4(e). Obviously, varying the length f_h will seriously affect the highest operating band, whereas less change is seen for the other two operating bands.

3. EXPERIMENTAL RESULTS

Based on the simulation results carried out on a commercial EM simulation software HFSS11, f_{l1} of 5.5 mm, f_{l2} of 4.0 mm, f_{m1} of 8.4 mm, f_{m2} of 3.2 mm and f_h of 5.2 mm are selected, and a fabricated prototype for the proposed antenna is constructed and measured. Figure 5 shows the proposed and fabricated dual-band antenna. Figure 6 shows the simulated and measured return losses against

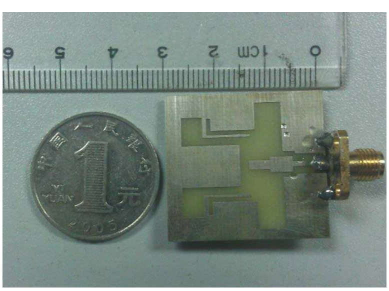

Figure 5. Fabricated dual-band antenna.

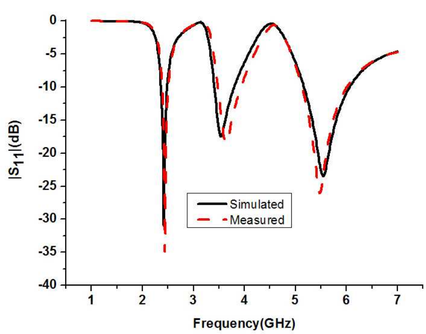

Figure 6. Measured and simulated return loss against frequency for the proposed CPW-fed slot antenna.

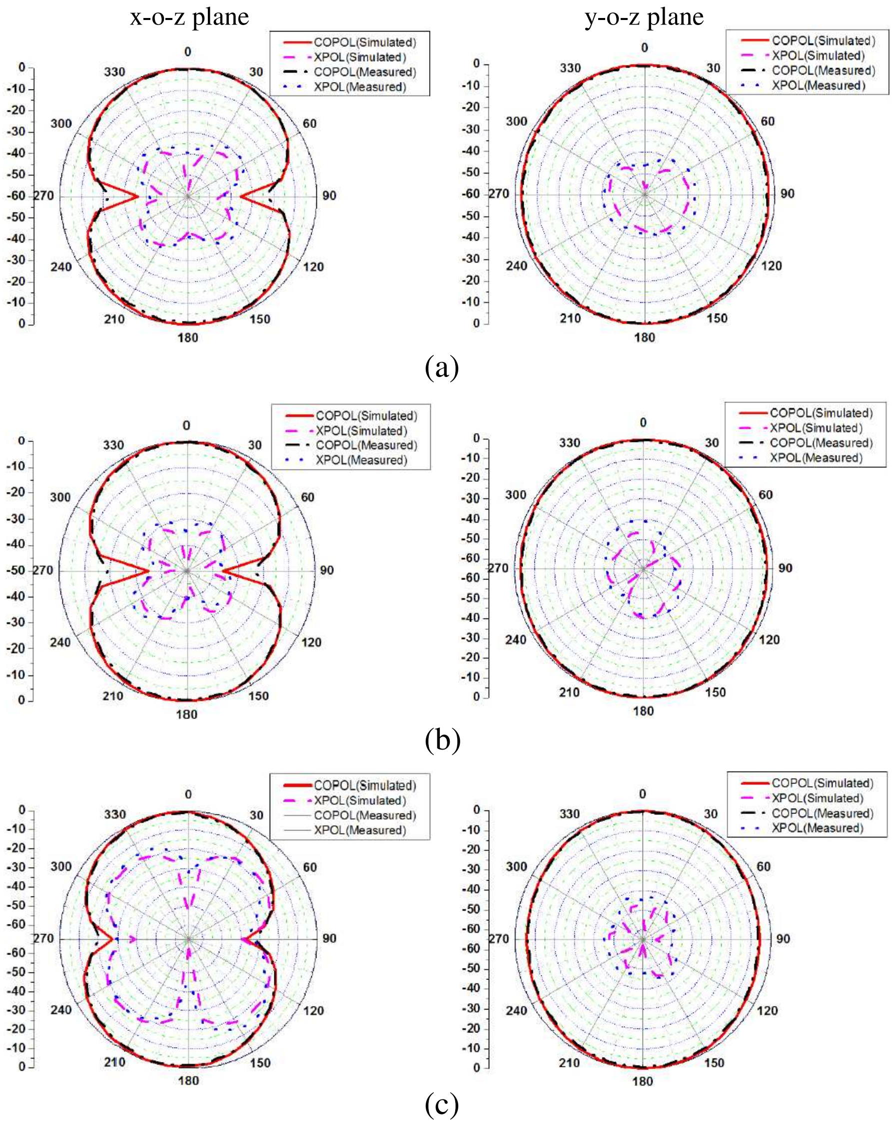

Figure 7. Simulated and measured radiation patterns of the proposed triple-frequency antenna at (a) 2.4 GHz, (b) 3.6 GHz, and (c) 5.5 GHz. E-plane (x-z plane), H-plane (y-z plane).

the frequency for the proposed antenna. Good agreement between them can be observed. The measured impedance bandwidth for 10 dB return loss at 2.4 GHz (2.40 GHz–2.49 GHz), 3.6 GHz (3.4 GHz–3.8 GHz) and 5.5 GHz (5.17–6.04 GHz), respectively. The measured radiation patterns at 2.4 GHz, 3.6 GHz and 5.5 GHz reach 90 MHz (2.40 GHz–2.49 GHz), 400 MHz (3.4 GHz–3.8 GHz) and 870 MHz (5.17–6.04 GHz), respectively. As shown in the figure, the proposed antenna displays almost omnidirectional radiation in H-plane (y-z plane) and bidirectional radiation in E-plane (x-z plane). Finally, the measured peak gains ($+z$) against frequency for the proposed antenna across the two bands are shown in Figure 8. As can be found, stable gain variation across the three operating bands can be achieved.

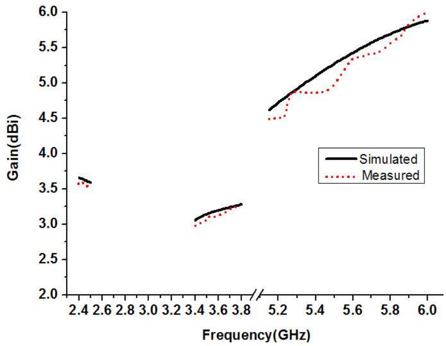

Figure 8. Simulated and measured gains of the proposed antenna for frequencies across the 2.4–2.5 GHz, 3.4–3.8 GHz and 5.15–6.0 GHz bands.

4. CONCLUSIONS

A compact triple-frequency folded slot antenna for WLAN application has been presented and experimentally studied. The antenna has a simple structure and is easy to be printed on FR4 substrate with a small area about 28 mm × 30 mm. In addition, although the antenna has a simple structure and compact size, it can generate three operating bands centered at about 2.4 GHz, 3.6 GHz and 5.5 GHz to cover the 2.4/3.6/5.2/5.8 GHz WLAN bands. The antenna shows good dipole-like radiation characteristics with moderate gain over the operating bands, which are attractive for practical application in the WLAN communication devices.

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