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A COMPACT MICROSTRIP-LINE-FED SLOT ANTENNA WITH DUAL BAND-NOTCHED CHARACTERISTICS FOR WLAN/WIMAX APPLICATIONS

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Abstract—A compact microstrip-line-fed antenna designed by inserting two pairs of strips into a rectangular slot for achieving triple-band operation is proposed. The antenna, which occupies a small size of only $40 \times 32 \times 1.6\,\mathrm{mm}^3$, utilizes inserted strips to generate dual band-notched characteristics so that three operating bands are able to be achieved, which range from 2.2 to 2.7, 3.07 to 3.86 and 5.13 to 6.23 GHz sufficiently covering both the 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5.5 GHz WiMAX bands. In addition, the measured results show good monopole-like radiation patterns and stable antenna gains across the three operating bands.

1. INTRODUCTION

Modern wireless communication systems have been developed rapidly and dramatically during the last decade, which promotes designs of antennas in the systems to a new era. To satisfy the complicated and diverse environments, a modern antenna not only requires compact size, simple structure, but also should have an ability to support more than one communication standard in a single system. This indicates that the antenna should provide stable multi-band or broadband operations to meet the demand in wireless communication systems. Nowadays, the popular designs suitable for wireless local area network (WLAN: 2.4–2.484, 5.15–5.35, and 5.725–5.85 GHz) operation have been discussed in [1–8], such as a dual-band monopole antenna with L-shaped strips [1], a CPW-fed monopole antenna with two parasitic

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spirals resonators [2], a CPW-fed monopole antenna with two band-rejected slots for triple-band operation [3], and a compact dual-band antenna with a square slot and a circular slot [4]. However, most of the designs mentioned above are not able to provide a multi-band operation with sufficiently wide bandwidth to support the 2.5/3.5.5.5 GHz WiMAX standard (2.5–2.69, 3.4–3.69, and 5.25–5.85 GHz). To adequately cover both the WLAN and WiMAX bands, some designs have also been proposed in [9–11]. Although these antennas can cover required bands, some are too large in size to be integrated into portable devices, which limit their practical applications. While others have wide bandwidths, which may bring about other electromagnetic interferences.

In this article, we demonstrate a simple and compact triple-band antenna suited for WLAN and WiMAX operations. The proposed antenna consists of a rectangular slot and an inverted T-shaped slot, which are able to achieve a broadband operation. By inserting two pairs of symmetric strips, which are designed equal to a quarter of the wavelength at the central rejected frequencies, the unnecessary frequency bands can be restricted without influencing the radiation performance of the antenna. Therefore, through this method, dual band-rejected characteristics can be obtained, and the antenna can provide triple-band operation to achieve WLAN and WiMAX applications. The effects of the inserted strips on the resonance have been studied, and an experimental prototype of the proposed antenna has been fabricated and measured to verify the design concept. Details of the antenna design are presented.

2. ANTENNA DESIGN

The configuration of the proposed triple-band antenna is exhibited in Fig. 1. The proposed antenna, with an overall dimension of only $40 \times 32\,\text{mm}^2$, is fabricated on a FR4 substrate with a relative permittivity of 4.4 and a thickness of 1.6 mm. A $50\,\Omega$ microstrip feed line with a width of 3 mm is adopted for centrally feeding the antenna at one side of the substrate. Moreover, at the end of the feed line, a rectangular conducting plate is applied to create good impedance matching for the proposed antenna. The main structure is a rectangular slot and an inverted T-shaped slot which is connected to the bottom of the wide rectangular one. Since the inverted T-shaped slot affects the higher frequency mode, while the rectangular slot influences the lower frequency mode, the proposed antenna without band-rejected strips is able to operate at a wide frequency band. To avoid the undesired interferences through the wide frequency band,

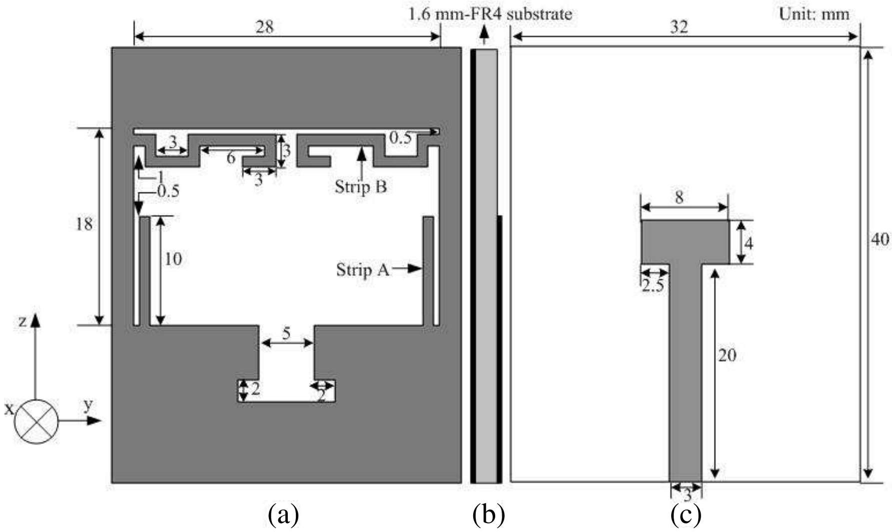


Figure 1. Geometry of the proposed triple-band antenna: (a) top view, (b) side view, and (c) bottom view.

two pairs of symmetric strips inserted into the rectangular slot are introduced to generate two notched bands. These strips act as quarter wavelength resonators to reject the useless bands. The central notched frequency can be assumed as:

$$f_{notch} = \frac{c}{4L \cdot \sqrt{\varepsilon_{eff}}} \quad \varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2} \tag{1}$$

where L is the length of the strip. ε_{eff} is the effective dielectric constant, and c is the speed of light in free space. We can take (1) [12] into account to obtain the total length of the strip at the beginning of the design and then adjust the geometry for the final design. The lengths of strips A and B are assumed as LA and LB, respectively. According to the formulas, through calculation and parameters study, the optimal lengths: $LA = 10\,\text{mm}$, $LB = 20\,\text{mm}$ are obtained in terms of the center-rejected frequencies at 2.9 and 4.5 GHz, respectively. The electromagnetic simulation software Ansoft HFSS 11 is employed to perform the design and optimization process. Through careful study and adjustment of configuration, the width of the band-rejected strips is 1 mm, and other parameters are also obtained as described in Fig. 1.

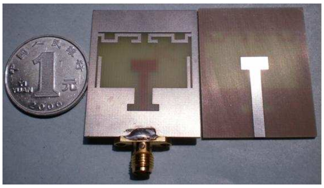


Figure 2. Photograph of the fabricated prototype.

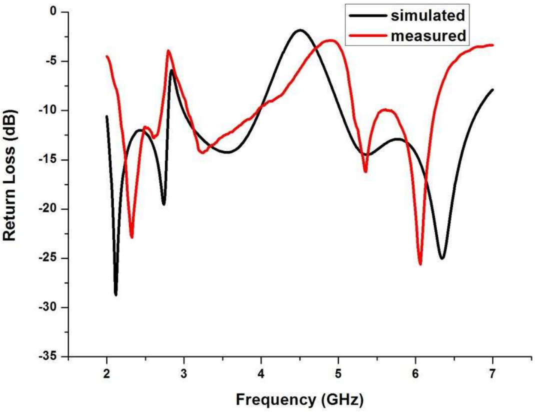
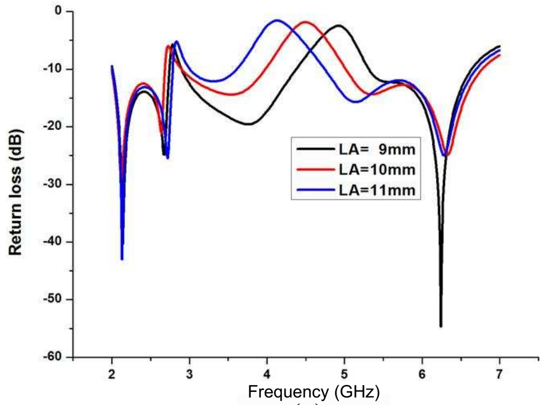


Figure 3. Simulated and measured return loss curves of the proposed antenna.

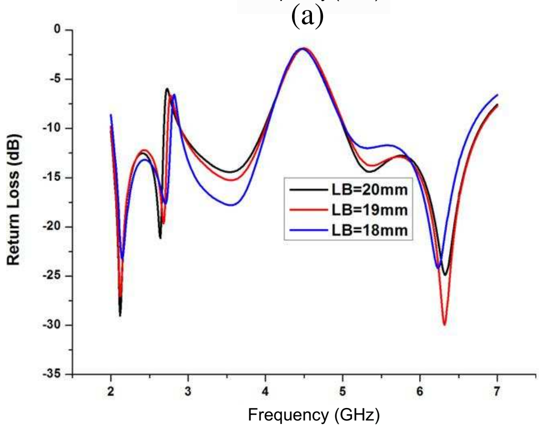
3. RESULTS AND DISCUSSIONS

To verify the advanced performance of the design, a prototype of the proposed antenna has been fabricated and shown in Fig. 2. The simulation and experimental studies are accomplished utilizing Ansoft HFSS 11 and WILTRON 37269A vector network analyzer, respectively. Fig. 3 shows the simulated and measured return loss characteristics of the proposed antenna. Obviously, two band-rejected features are formed from 2.71 to 3.06 GHz and 3.87 to 5.12 GHz thus, three independent operating bands are achieved for WLAN and WiMAX applications. The measured return losses below −10 dB bandwidths range from 2.2 to 2.7, 3.07 to 3.86 and 5.13 to 6.23 GHz with the relative bandwidth of 20%, 23% and 19%, respectively, which show approximate agreement with the simulated results. The differences may be due to the effect of the coaxial cable connector.

The inserted strips play as filters to suppress the undesired frequency bands. The length of the strip is about $1/4\lambda_{sub}$, where λ_{sub} is the wavelength of the central rejected frequency in the FR4 substrate. To obtain the optimal dimension of these strips, the effects of the strips length on the impedance matching of the proposed antenna have been studied. Fig. 4(a) depicts the simulated return loss curves with different LA. As shown in Fig. 4(a), small effects on the lower rejected band can be seen. On the contrary, the upper rejected band is greatly influenced by the variations of LA and shifted to higher frequency with a decrease of LA. By fixing LA to 10 mm, effects of the variation of LB are studied in Fig. 4(b). Obviously, the upper



(a)



(b)

Figure 4. Simulated return loss curves against various lengths of band-rejected strips: (a) strip A and (b) strip B.

central rejected frequency changes slightly, while the lower central rejected frequency moves to much lower frequency when increasing LB. Because of increasing the length of strip, the current path will also be lengthened, which affects the central rejected frequency.

To further investigate the band-rejected characteristics of the proposed design, the simulated surface current distributions at different notched frequencies have been studied, and the results are shown in Figs. 5(a) and (b) for 2.9 and 4.5 GHz, respectively. As can been seen from Fig. 5, the surface current distributions mainly flow along strips A and B for 2.9 and 4.5 GHz respectively, which indicate that strip A generates the 2.9 GHz rejected band, and strip B achieves 4.5 GHz band-notched performance. In this case, the concentrated

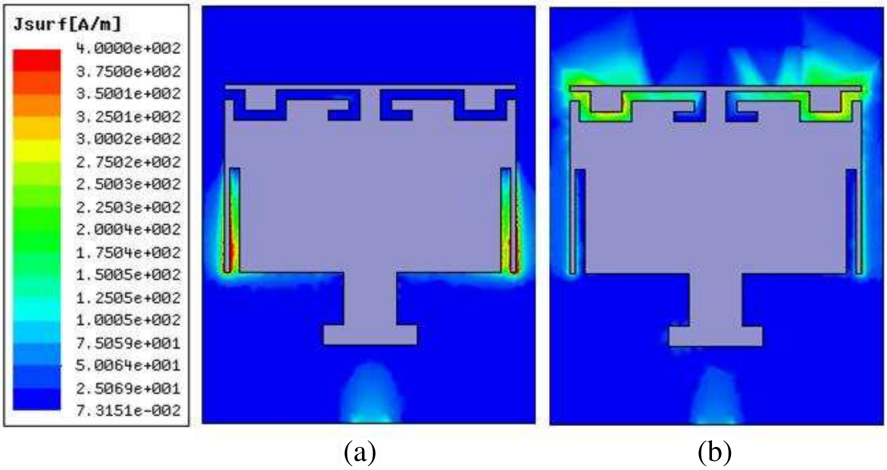


Figure 5. Simulated surface current distributions of the proposed antenna: (a) 2.9 GHz and (b) 4.5 GHz.

surface current distributions on the strips destructively interfere the original surface current distributions on the antenna, which make the impedance near the feed point change and bring about strong power reflection at the required rejected frequencies. Therefore, owing to the unmatched input impedance at some unnecessary frequencies, the band-rejected behaviors are obtained. However, for other frequencies, the introduction of the two stripfilters has few effects.

The measured far-field radiation patterns of the fabricated prototype at 2.45, 3.5 and 5.5 GHz are plotted in Fig. 6. Both co- and cross-polarizations are presented, which show nearly omnidirectional patterns in H-plane (xy plane) and almost bidirectional patterns in E-plane (xz plane) over the operating bands. Finally, Fig. 7 shows the peak antenna gains through simulation and measurement in the maximum directions of each required frequency point. Gain decreases occur both at 2.7–3.1 and 3.9–5.1 GHz bands. Since the return losses in the rejected frequencies are not very high, just about -5 dB and -3 dB, respectively, the gains do not drop dramatically in the notched bands. However, this gain performance has already satisfied the demand for WLAN and WIMAX applications. We have obtained average gains of 2.55 (2.5–2.6 dBi), 2.8 (2.6–3 dBi) and 3 dBi (2.7–3.3 dBi) for the lower, middle and upper required WLAN and WiMAX bands, respectively.

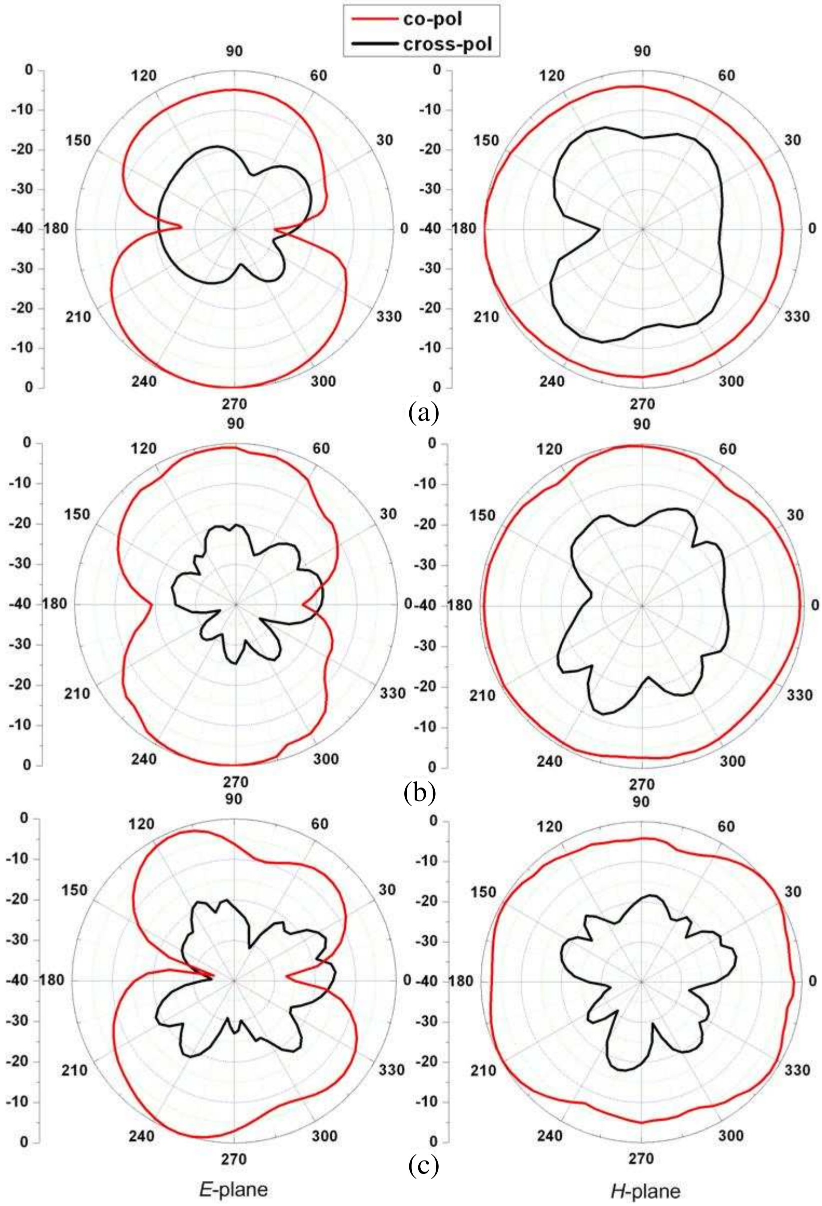


Figure 6. Measured radiation patterns of the proposed antenna: (a) 2.45 GHz, (b) 3.5 GHz and (c) 5.5 GHz.

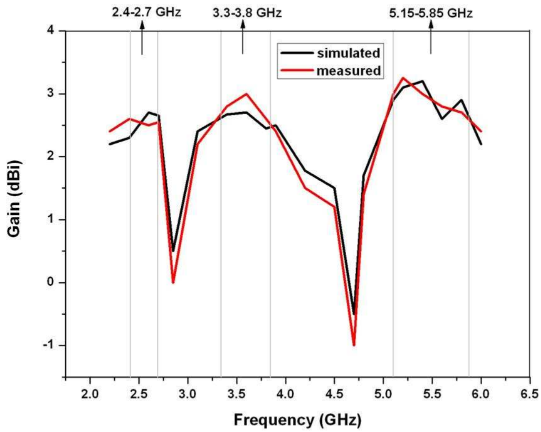


Figure 7. Simulated and measured antenna gains of the proposed antenna.

4. CONCLUSION

A compact microstrip-line-fed slot antenna with two pairs of band-rejected strips for WLAN and WiMAX applications has been presented. The application of strip-filters has successfully generated dual notched frequency bands so that triple operating bands, sufficiently covering both the 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/5.5 GHz WiMAX bands, can be obtained. In addition, the proposed antenna, providing nearly monopole-like radiation characteristics and moderate antenna gains across the operating bands, is suitable for the new generation of wireless communication systems.

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