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A COMPACT MICROSTRIP-LINE-FED SLOT ANTENNA WITH DUAL-BAND NOTCHED FOR WIMAX OPERATION

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Abstract—A compact wide-slot antenna fed by microstrip-line for wideband operation is proposed and studied. The proposed antenna consists of a microstrip-fed line and a wide rectangular slot with a reverse L-shaped slot. The proposed antenna resonates the 10-dB bandwidth from 2.17 GHz to 6.25 GHz, and these frequency bands cover the standard IEEE 802.11b/g (2.4–2.485 GHz) and IEEE 802.11a (5.15–5.35 GHz, 5.725–5.875 GHz) for WLAN applications and 2.5 GHz (2.5–2.69 GHz), 3.5 GHz (3.3–3.8 GHz) and 5 GHz (5.25–5.85 GHz) for WiMAX applications. In order to remove unwanted bands, we used two methods to reject the bands. By inserting a strip in the slot of the broadband antenna, a reject frequency band from 4.13 to 4.95 GHz can be obtained; by etching a U-slot on the the broadband antenna, a reject frequency band from 2.96 to 3.17 GHz can be achieved. The slot antenna with dual band-notched for WiMAX operation has been obtained. Detailed design and experimental results are shown and discussed in this paper.

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1. INTRODUCTION

Recently, due to the fast development of wireless technology, many novel wireless products have been introduced to the consumers. The design trend of these wireless products is to integrate many functions into a signal product; therefore, the antenna used in the wireless communication applications must have wideband or multiband. The printed slot antennas [1] are arresting because they usually have a wide impedance bandwidth and can be applied to various wireless communication systems such as WiMAX (Worldwide Interoperability for Microwave Access) and WLAN (Wireless Local Area Networks). Furthermore, they also have the advantages of easy fabrication, simple structure, low cost, low profile and ease to be integrated in active component or MMIC (monolithic microwave integrated circuit MMIC).

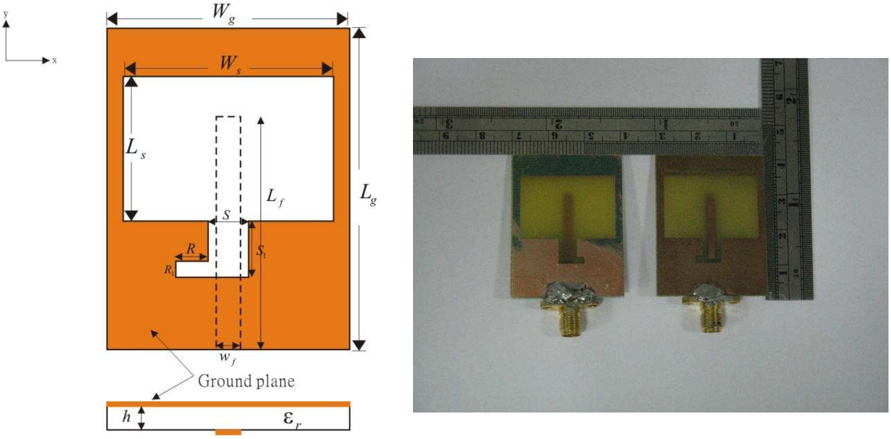
Many previous studies of the CPW-fed (coplanar waveguide-fed) printed slot antennas [2–5] and microstrip-line fed printed slot antennas [6–11] have been presented in the literatures. In particular, printed wide-slot antennas are adopted because their characteristic is conductive to enhance its bandwidth. The antenna proposed in [1] is a CPW-fed square slot antenna, which uses a widened tuning stub to enhance the bandwidth and can obtain 60% impedance bandwidth (1.56–2.88 GHz), but its size is large, and the bandwidth is not wide enough to support most wireless applications. A CPW-fed strip-loaded square slot antenna [2] adds four strips in the slot to excite the square slot and can obtain 62.9% bandwidth, but its size is still large. A polygonal slot antenna [6] fed by microstrip-line has been proposed. The antenna uses a rectangular slot with a triangular slot on the bottom to achieve broadband and can obtained 104% impedance bandwidth (1.85–5.83 GHz). The bandwidth is good enough but the size is very large (100 mm × 80 mm). In [7, 8], these antennas are wide-slot antenna with a rotated rectangle slot (rhombus-like slot) fed by microstrip-line; however, they still have narrow bandwidth and large size. In addition, these antennas proposed in [9, 12, 13] used different shapes strips and inserting the slot, the strips can reject the frequency bands of unwanted. This rejected method is applied extensively in various broadband antennas.

This paper proposes two compact slot antennas. The first antenna is a broadband antenna with frequency bands from 2.17 to 6.25 GHz for WLAN and WiMAX applications. The second antenna having two notched bands for rejecting two unwanted bands is an extended antenna from the first antenna. The two proposed antennas have equal size of 30 mm × 40 mm. Besides the advantage of compact size, the proposed antennas also have simple structure, low cost, and low profile.

The mechanism of antenna design and band notch are presented and discussed in this paper.

2. ANTENNA DESIGN

The proposed antenna as shown in Figure 1(a), consists of a wide rectangular slot with a reverse L-shaped slot and a microstrip fed line. Figure 1(b) shows the picture of manufactured antenna. The wide-slot antenna is fabricated on a FR4 substrate with a thickness of 1.6 mm (h), a relative permittivity of 4.4 (ε_r) and an overall dimensions of $30 \times 40\,\text{mm}^2$ ($W_g \times L_g$). The microstrip fed line having a width $W_f = 3\,\text{mm}$ and a length $L_f = 29\,\text{mm}$ is connected to a $50\,\Omega$ standard miniature adapter (SMA). The main structure of the proposed slot antenna is a wide rectangular slot with size of $L_s \times W_s$ ($18 \times 26\,\text{mm}^2$) and a reverse L-shaped slot, which is connected from the bottom of wide rectangular slot. The reverse L-shaped slot has the dimensions of $S \times S_1$ ($5 \times 7\,\text{mm}^2$) and $R \times R_1$ ($2 \times 2\,\text{mm}^2$). By combining the wide rectangular slot and the reverse L-shaped slot, the proposed antenna can achieve a wide frequency band because the reverse L-shaped slot operates the high frequency mode and the wide rectangular slot operates the low frequency mode. Therefore, the parameters of these slots are important for available bandwidth. The proposed antenna structure is smaller than [6] and the impedance bandwidth is 97%, which is close to the bandwidth of [6].



(a) (b)

Figure 1. (a) The geometry of the slot antenna for broadband application, (b) picture of the proposed antennas with and without band notch.

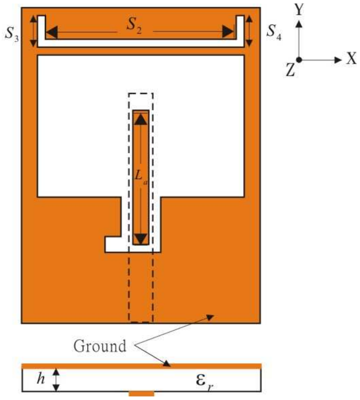


Figure 2. The geometry of the dual band notched slot antenna for WiMAX application.

For three-band WiMAX systems, a dual-band rejected characteristic should be added to the broadband wide-slot antenna. To reach the requirement, we added the strip L_a to produce a rejected band at the higher frequency and etched the U-shaped slot to produce a reject band at the lower frequency as shown in Figure 2. The length of strip L_a is 17 mm and that of U-shaped slot is 32 mm ($S_2 + S_3 + S_4$). The broadband wide-slot antenna is with a dual band rejected function at 3 and 4.5 GHz to form a three-band operation for WiMAX application.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The return loss of proposed wide-slot antenna is successfully measured by Vector network analyzer and simulated by Ansoft HFSS (High-Frequency Structure Simulator). Figure 3 shows the measured and simulated return loss of the compact wide-slot antenna. The bandwidth based on 10-dB return loss from 2.17 to 6.25 GHz covers WLAN and WiMAX spectrum, and the broad bandwidth is about 4.08 GHz or 97% with respect to the center frequency at 4.21 GHz. In this case, the microstrip-line length L_f is an important parameter. By tuning the microstrip-line length, the lower resonant frequency shift and the higher frequency impedance matching is affected, so we choose the parameters of $L_f = 29$ mm. Then, a good impedance matching and a wide impedance bandwidth can be obtained.

In the following paragraph, we will show the influence of important parameters of the proposed antenna. W_s is the width of wide rectangular slot, which controls the resonant frequency bands and impedance matching of the proposed antenna. From the return loss shown in Figure 4, when the parameter W_s is 18 mm, the resonance mode shifts to higher frequency bands and the impedance bandwidth is not enough for broadband application. When W_s is chosen as 26 mm, the longer current path generates lower resonant frequency bands and the total resonant length of the rectangular slot is about 0.5λ of 2.17 GHz. Beside the impedance bandwidth covers the broad bandwidth.

The parameter R on the reverse-L-shaped slot also influences impedance matching of the proposed antenna. Figure 5 shows the measured return loss of different length of R. When R changes from 0 to 5 mm, the 10-dB impedance bandwidth at low frequency band does not change but that of high frequency band has significant changes. These changes might due to the prominent slot produce inductive coupling. The optimal length of R is 2 mm that obtains the best performance at higher bands.

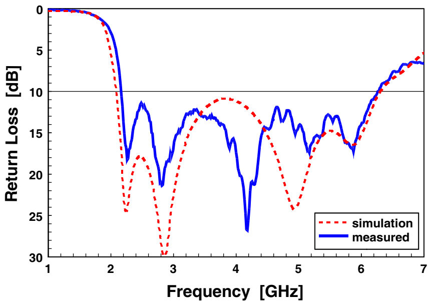


Figure 3. Measured and simulated return loss of the broadband antenna.

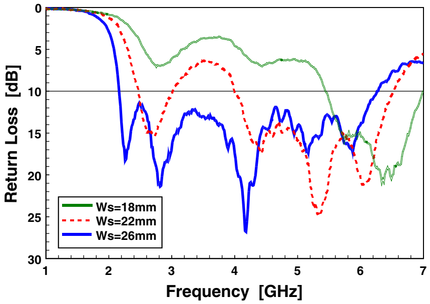


Figure 4. Measured return loss for various lengths (W_s) of the broadband antenna.

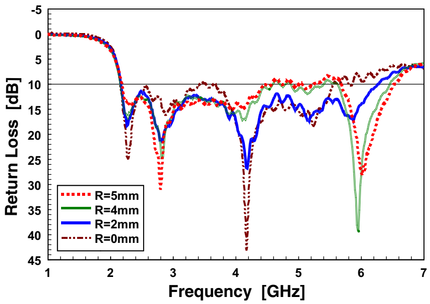


Figure 5. Measured return loss for various lengths (R) of the broadband antenna.

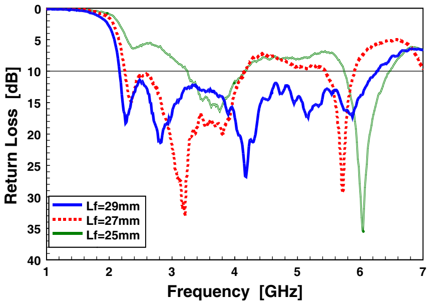


Figure 6. Measured return loss for various lengths (L_f) of the broadband antenna.

The length of microstrip feed-line influences the coupling between the microstrip feed line and the top side of the patch. Figure 6 shows the measured return loss of various lengths of the microstrip feed-line (L_f). When the microstrip feed-line decreases, the bandwidth and impedance matching at low bands become worse because the coupling becomes worse. The optimal length of microstrip feed-line is 29 mm and the 10-dB impedance matching covers from 2.17 to 6.25 GHz.

From the studied in above subsection, a wide-band antenna by combining the wide rectangular slot and the reverse L-shaped slot on the slot antenna was proved. In this paragraph, we will study the board frequency band with dual band notch for WiMAX application. Figure 7 shows the measured return losses of broadband with and without dual band notch. By inserted the strip L_a and etched the U-shaped slot, two rejected bands from 2.96 to 3.17 GHz and from 4.13

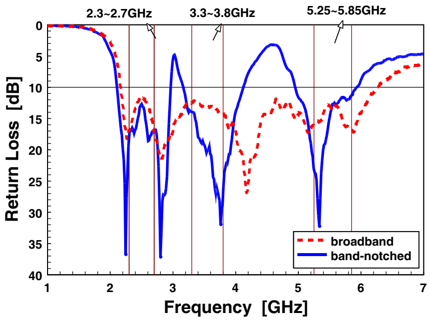


Figure 7. Measured return loss of the proposed antenna for WiMAX bands.

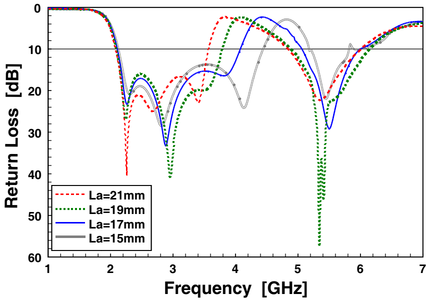


Figure 8. Measured return loss for various lengths (L_a) of the dual-band notched antenna.

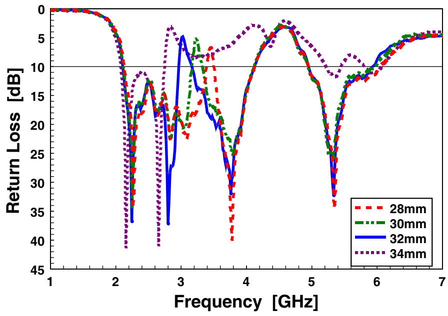
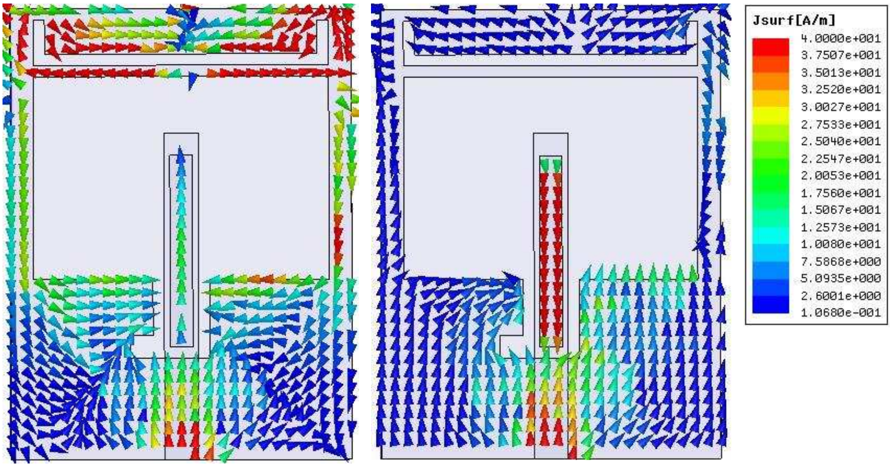


Figure 9. Measured return loss for various lengths (S_2) of the dual-band notched antenna.

to 4.95 GHz are obtained for use in WiMAX system. Figure 8 shows the simulated return losses of various lengthes of strip L_a. The length L_a controls the high reject band. The longer length of L_a, the lower of high reject frequency band. The optimal length of L_a is 17 mm. Figure 9 shows the measured return losses of various lengths of the U-shaped slot. Because the length of U-shaped slot controls the low reject band, the high reject band keeps at 4.5 GHz. From Figure 9, when the total length of U-shaped slot $(S_2 + S_3 + S_4)$ changes from 28 to 34 mm, the center frequency bands of the low reject band move form 3.4 to 2.8 GHz.

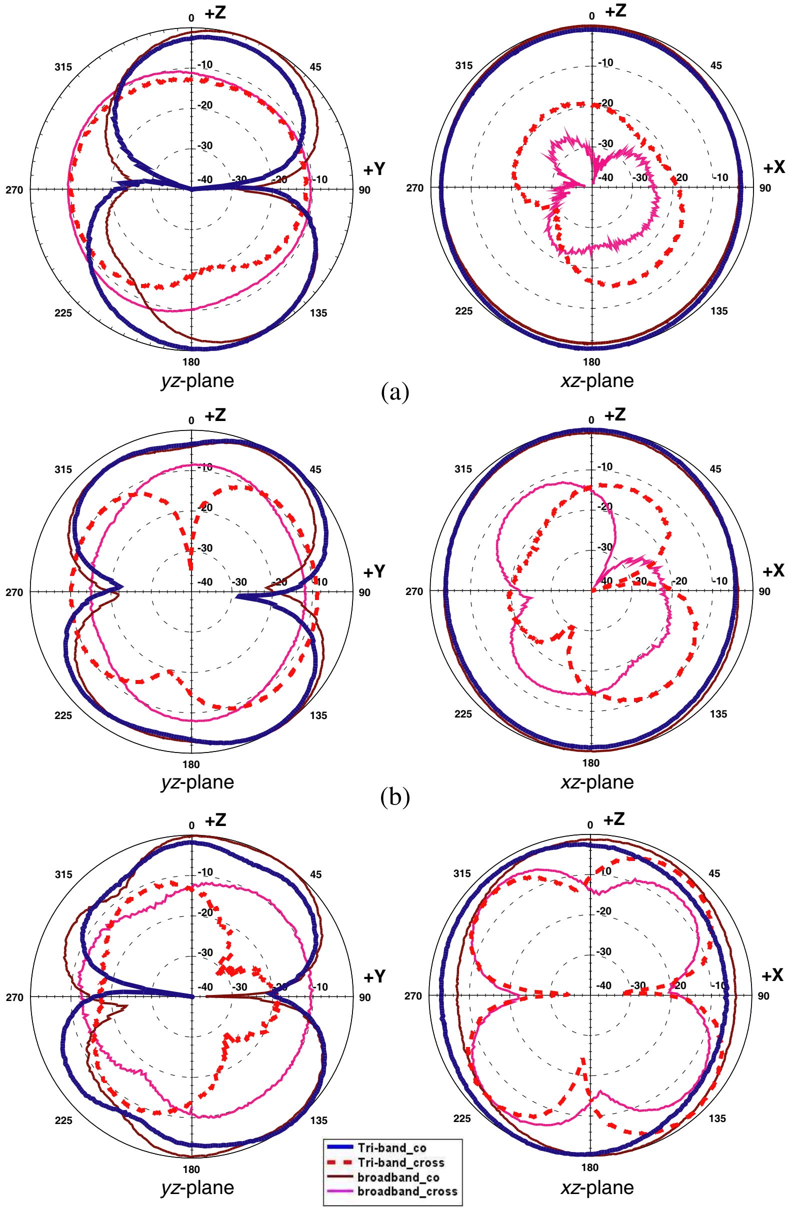
The surface current distributions at the rejected frequencies 3.1 and 4.5 GHz are presented in Figure 10. The surface current distributions for 3.1 GHz are concentrated on the U-shaped slot as shown Figure 10(a), while that for 4.5 GHz are concentrated on the strip L_a as shown Figure 10(b). The resonant length of the U-shaped slot is 32 mm, which is about 0.6λ of 3.06 GHz; the resonant length of L_a is 17 mm, which is about 0.25λ of 4.5 GHz.

Figure 11 shows the measured radiation patterns at 2.5 GHz, 3.5 GHz and 5.5 GHz in X-Z plane and Y-Z plane, respectively. It is noted that the X-Z plane patterns have the same polarization planes and the similar radiation patterns. The radiation pattern in X-Z plane is nearly omni-directional at 2.5 GHz and 3.5 GHz, but slightly distorted at 5.5 GHz. Moreover, the radiation pattern in Y-Z plane is



(a) (b)

Figure 10. Simulated current distributions of the dual-band notched antenna. (a) $f = 3.1$ GHz and (b) $f = 4.5$ GHz.



(a)

(b)

(c)

Figure 11. Measured radiation patterns of the proposed antenna. (a) $f = 2.5\,\mathrm{GHz}$, (b) $f = 3.5\,\mathrm{GHz}$, (c) $f = 5.5\,\mathrm{GHz}$.

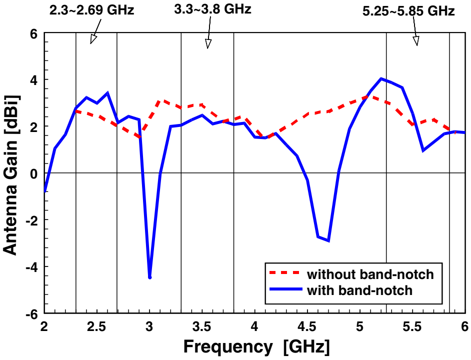
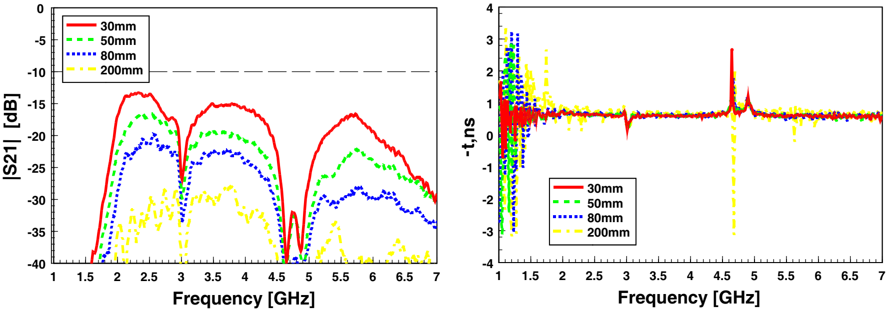


Figure 12. Measured gain of the proposed antenna for WiMAX bands.



(a) (b)

Figure 13. Measured S_{21}. (a) Magnitude, (b) group delay at $D = 30$, 50, 80 and 200 mm.

bi-directional radiation pattern. The measured gain of the proposed antenna is shown in Figure 12. We can clearly observe that the gain significantly drop over the two rejected bands and the peak antenna gain is 4 dBi located at 5.2 GHz. The three operating bands at WiMAX spectrum have suitable gain variations for WiMAX applications.

Figure 13(a) shows the measured $|S_{21}|$ of the proposed antenna with dual band notch at different distances ($D = 30$, 50, 80 and 200 mm). Two notch bands centered at 3 and 4.75 GHz can be seen. Figure 13(b) shows the measured group delay. At around 3, 4.64, and 4.9 GHz, the noise increases due to the weaker $|S_{21}|$.

4. CONCLUSION

The compact design of a dual-band notched slot antenna for WiMAX applications is successfully implemented. In the design, by adding a metal strip and U-shaped slot on the proposed broadband antenna, the unwanted bands are rejected. In the experimental results, the measured gain only change slightly in the operating bands. In addition, the proposed antenna also has simple structure, compact size and good radiation performances.

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