A Simple Design of UWB Small Microstrip Slot Antenna with Band-Notched Performance by using a T-Shaped Slit and a Pair of U-Shaped Conductor-Backed Plane

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Abstract **─** In this paper, a simple and compact ultra wideband printed slot antenna with band-notch performance is designed and manufactured. In order to increase the impedance bandwidth of the square slot antenna, we use two U-shaped parasitic structures inside the rectangular slot on the ground plane that with this structure UWB frequency range can be achieved. Additionally, by using a T-shaped slit on the ground plane, a frequency notched band performance has been obtained. The designed antenna has a small size of 20×20 mm while showing the radiation performance in the frequency band of 3.05 GHz to over 12 GHz with a band rejection performance in the frequency band of 5.1 GHz to 6.05 GHz.

Index Terms **─** Square slot antenna, T-shaped slit, U-shaped parasitic structure, and ultra-wideband (UWB).

I. INTRODUCTION

In UWB communication systems, one of the key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Consequently, a number of printed microstrip antennas with different geometries have been experimentally characterized [1, 2]. Moreover, other strategies to improve the impedance bandwidth have been investigated [3-5]. The Federal Communication Commission (FCC)'s allocation of the frequency range 3.1 GHz – 10.6 GHz for UWB systems and it will cause interference to the existing wireless communication systems, such as, the wireless local area network (WLAN) for operating in 5.15 GHz – 5.35 GHz and 5.725 GHz – 5.825 GHz bands), so the UWB antenna with a single band-stop performance is required [6, 7].

In this paper, we present a new design of compact wideband slot antenna with band rejection characteristics for UWB applications. In this antenna, two U-shaped parasitic structures inside the rectangular slot on the ground plane were used to enhance the bandwidth and a modified T-shaped slit in the square ground plane was applied to generate a band notch performance. In the slot antenna design, by reducing the antenna size, the impedance matching at lower frequencies becomes poor and the bandwidth is degraded [3, 4]. The distinctive point of the proposed antenna is that although it has small size respect to the antennas introduced in [2-5], (43 % smaller than the antenna in [1]), it has wider impedance bandwidth in the frequency band of 3.05 GHz to 12.06 GHz with a rejection bands around 5.1 GHz – 6.05 GHz, which has a frequency bandwidth increment of 13 % with respect to the previous similar antenna [7-9], and also, the impedance matching at lower frequencies is very well obtained. In [10], by using two parasitic structure in the ground plane and in [11], by using a V-shaped sleeve in the ground plane to achieve the

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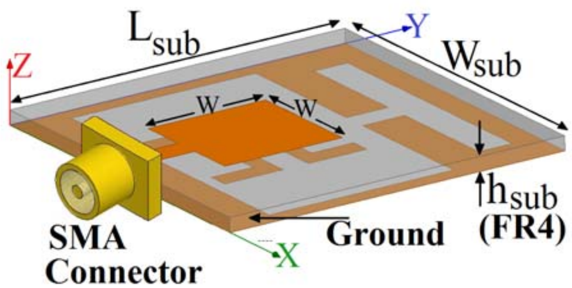
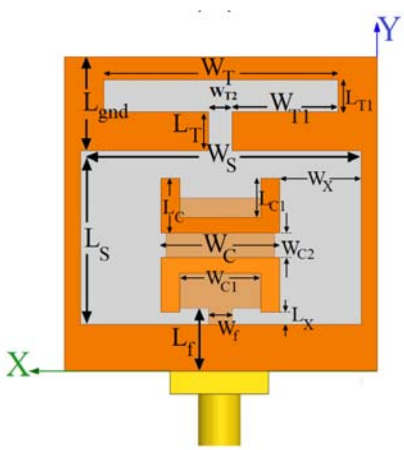
band. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest.

II. ANTENNA DESIGN

The proposed square slot antenna fed by a 50 Ω microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 0.8 mm, and permittivity 4.4. In this proposed antenna, the U-shaped parasitic structures inside the rectangular slot on the ground plane are playing an important role in the broadband characteristics of this antenna. These parasitic structures improve the impedance bandwidth without any cost of size or expense [4]. In addition, using T-shaped slit with variable size generates the frequency band-notch function [3].



(a)



(b)

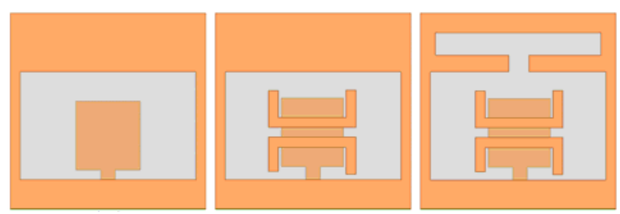
Fig. 1. Geometry of the proposed square slot antenna; (a) bottom view and (b) side view.

The final dimensions of the designed antenna are as follows: W_{sub} = 20 mm, L_{sub} = 20 mm, h_{sub} = 0.8 mm, W_f = 1.5 mm, L_f = 4 mm, W = 7 mm, W_s = 18 mm, L_s = 11 mm, W_c = 10 mm, L_c = 3 mm, W_{c1} = 8 mm, L_{c1} = 2 mm, W_{c2} = 1 mm, W_x = 4 mm, L_x = 1 mm, W_T = 18 mm, L_T = 1.5 mm, W_{T1} = 8.5 mm, L_{T1} = 2.5 mm, W_{T2} = 1 mm, and L_{gnd} = 6 mm.

III. RESULTS AND DISCUSSIONS

The proposed slot antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The Ansoft simulation software high-frequency structure simulator (HFSS) [12] is used to optimize the design.

The configuration of the presented slot antenna was shown in Fig. 1. Geometry for the ordinary square slot antenna (Fig. 2 (a)), with two U-shaped parasitic structures inside the rectangular slot on the ground plane (Fig. 2 (b)), and the proposed antenna (Fig. 2 (c)) structures are shown in Fig. 2. The return loss characteristics for the structures that are shown in Fig. 2 are compared in Fig. 3. As shown in Fig. 3, it is observed that the upper frequency bandwidth is affected by using the U-shaped parasitic structures inside the rectangular slot on the ground plane and the notch frequency bandwidth is sensitive to the T-shaped slit cut in the upper edge of the ground plane.



(a) (b) (c)

Fig. 2. (a) The ordinary square slot antenna, (b) antenna with a pair of U-shaped parasitic structures in the ground plane, and (c) the proposed square slot antenna.

Also the input impedance of the proposed slot antenna structure that was studied in Fig. 1, on a Smith chart is shown in Fig. 4. To understand the phenomenon behind this additional resonance performance, the simulated current distribution on the ground plane for the slot antenna with two U-shaped parasitic structures inside the rectangular slot on the ground plane at the new resonance frequency of 11.15 GHz is presented in Fig. 5 (a). It can be observed from Fig. 5 (a), that the current is concentrated on the edges of the interior and exterior of U-shaped parasitic structure inside the rectangular at 11.15 GHz. Therefore, the antenna impedance changes at this frequency due to the resonance properties of the proposed structure. Also, to understand the phenomenon behind this band-notch performance, the simulated current distribution on the ground plane for the proposed antenna at the notch frequency (5.5 GHz) is presented in Fig. 5 (b). It can be observed from Fig. 5 (b) that the current is concentrated on the edges of the interior and exterior of the T-shaped slit at 5.5 GHz. Therefore, the antenna impedance changes at this frequency due to the band-notch properties of the proposed structure.

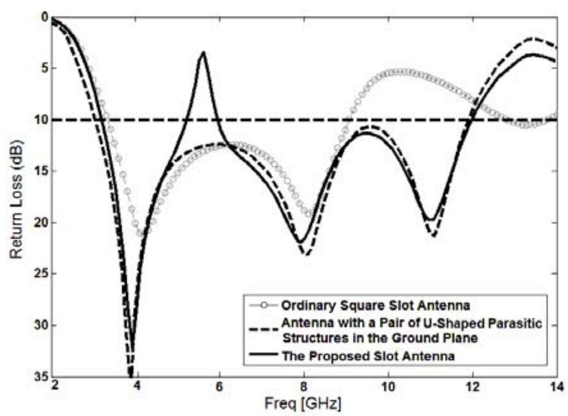


Fig. 3. Simulated VSWR characteristics for the various square slot antenna structures shown in Fig. 2.

The simulated VSWR curves with different values of W_{T2} are plotted in Fig. 6. As shown in Fig. 6, when the interior gap distance between the T-shaped slit edges increase from 0.25 mm to 4 mm, the center frequency of the notched band varies from 6.48 GHz to 4.85 GHz. From these results, we can conclude that the notch frequency is controllable by changing the gap distance between the T-shaped slit edges.

The proposed antenna with final design parameters, was built and tested. The measured and simulated VSWR characteristics of the proposed antenna is shown in Fig. 7. The fabricated antenna has the frequency band of 3.05 GHz to over 12 GHz with a rejection band around 5.1 GHz to 6.05 GHz. As shown in Fig. 7, there is a good agreement between the measured data and the simulated results. This discrepancy could be due to the effect of the SMA port, and also the accuracy of the simulation due to the wide range of simulation frequencies. To confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

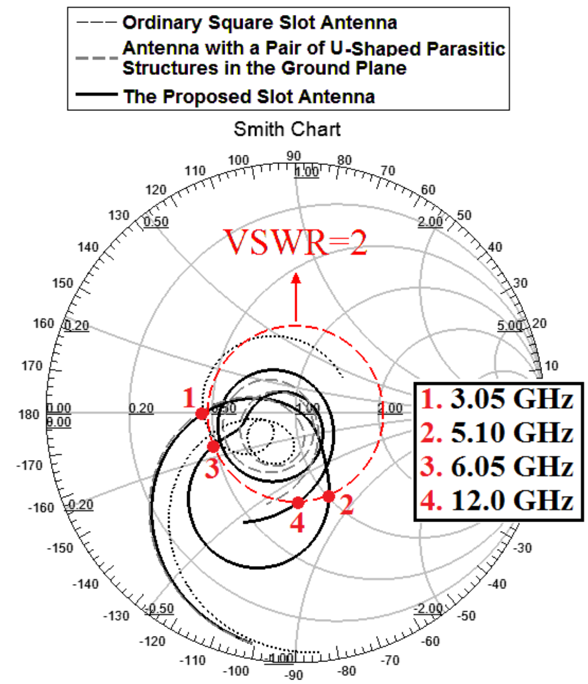
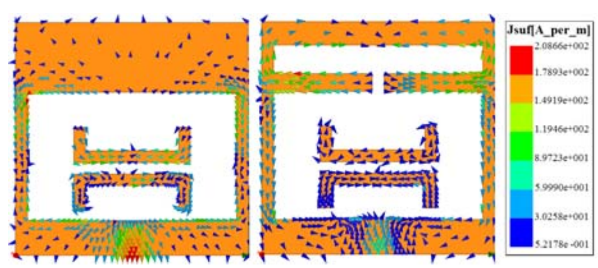


Fig. 4. The simulated input impedance on a Smith chart for the various slot antenna structures shown in Fig. 2.



(a) (b)

Fig. 5. Simulated surface current distributions on the ground plane for (a) the square antenna with a pair of U-shaped parasitic structures in the ground plane at third resonance frequency (11.15 GHz) and (b) for the proposed antenna at the notch frequency (5.5 GHz).

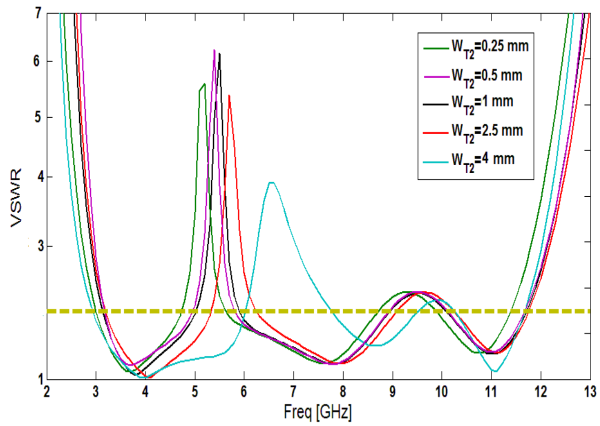


Fig. 6. Simulated VSWR characteristic for various values of W_{T2}.

Figure 8 shows the simulated and measured radiation patterns including the co-polarization and cross-polarization in the H-plane (x-z plane) and E-plane (y-z plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. Reasonable agreement between simulations and measurements is demonstrated at 4 GHz, 7 GHz, and 10 GHz. It can be seen that the radiation patterns in x-z plane are nearly omni-directional for the 4 GHz and 7 GHz.

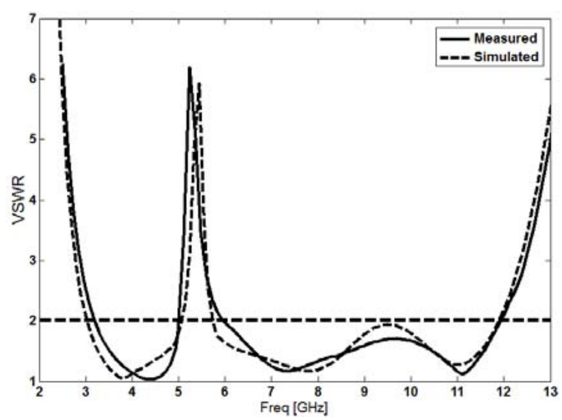


Fig. 7. Measured and simulated VSWR for the proposed antenna.

Figure 9 shows the effects of the T-shaped slit at the ground plane, on the maximum gain in comparison to the same antenna without it. As shown in Fig. 9, the basic structure (ordinary slot antenna) has a gain that is low at 2 GHz and increases with frequency [8]. It is found that the gain of the basic structure decreases with the use of the T-shaped slit in the ground plane. It can be observed in Fig. 9 that by using the T-shaped slit at the ground plane, a sharp decrease of maximum gain in the notched frequency band at 5.5 GHz is shown. For other frequencies outside the notched frequency band, the antenna gain with the filter is similar to those without it.

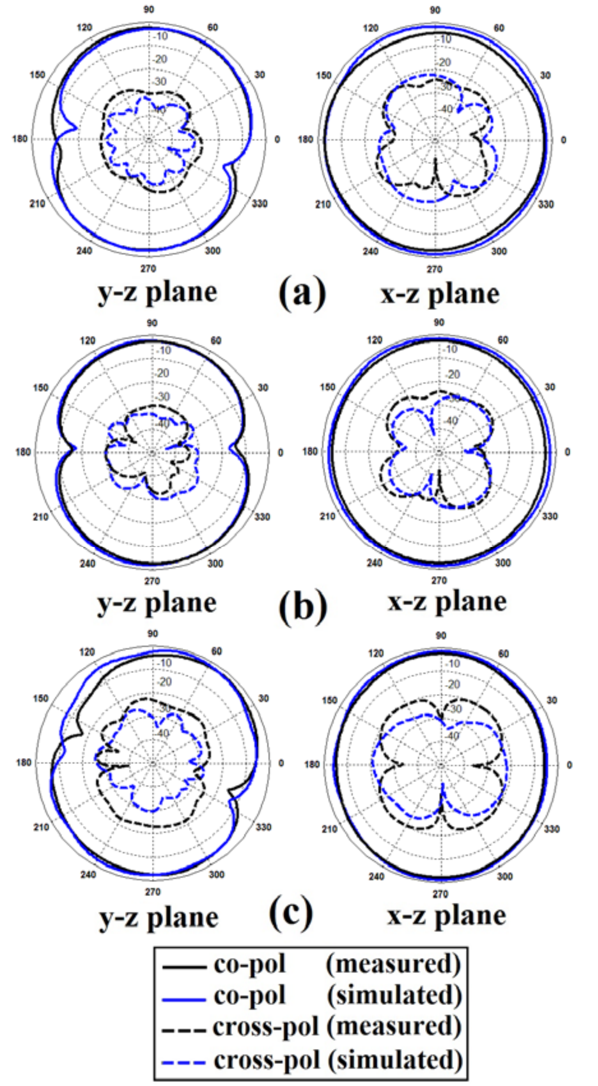


Fig. 8. Measured and simulated radiation patterns of the proposed antenna at (a) 4 GHz, (b) 7 GHz, and (c) 10 GHz.

IV. CONCLUSION

In this paper, a novel design of ultra wide band slot antenna with variable band notch function is proposed. The presented slot antenna can operate from 3.05 GHz to 12 GHz with VSWR < 2, and with a rejection band around 5.1

GHz to 6.05 GHz. By using two U-shaped parasitic structures inside the rectangular slot on the ground plane additional resonance at higher frequency range is excited and much wider impedance bandwidth can be produced. In order to generate a frequency band-stop performance we use a T-shaped slit in the ground plane. The designed antenna has a small size. The measured results show good agreement with the simulated and measured results.

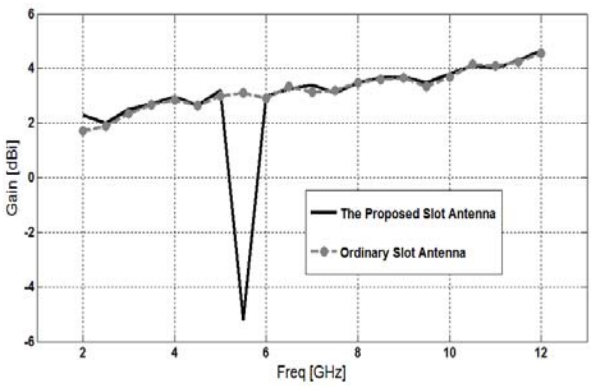


Fig. 9. Maximum gain comparisons for the ordinary slot antenna (simulated), and the proposed antenna (measured) in the z-direction (x-z plane).

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