UWB Microstrip-Fed Slot Antenna with Band-Rejection Performance Using an SRR Conductor-Backed Plane

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Abstract **─** In this article, a novel and compact ultra-wideband (UWB) slot antenna with band-notched function is presented. This antenna consist of a square radiating stub, a 50Ω microstrip feed-line, a ground plane with a pair of rotated T-shaped strips protruded inside square slots and a Split Ring Resonator (SRR) conductor-backed plane. In this design, by cutting a pair of modified square slots with rotated T-shaped strips protruded inside slots, additional resonance is excited and hence much wider impedance bandwidth can be produced. In order to achieve a band-notched function, an SRR parasitic structure was inserted in the ground plane. The measured results show that the proposed antenna can achieve the Voltage Standing Wave Ratio (VSWR) requirement of less than 2.0 in frequency range from 3.1 GHz to 13.15 GHz, with band-rejection performance of 5.08 GHz to 6 GHz, to avoid interference from WLAN communications. The presented microstrip-fed slot antenna exhibits good radiation behavior. The antenna has a small size.

Index Terms **─** Band-notched function, protruded T-shaped strips, SRR conductor-backed plane and UWB microstrip-fed antenna.

I. INTRODUCTION

One of key issues in UWB communication systems is the design of a compact antenna, while providing wideband characteristic over the whole operating band. Consequently, a number of microstrip antennas with different geometries have been experimentally characterized [1-2]. Moreover, other strategies to improve the impedance bandwidth have been investigated [3-4].

The frequency range for UWB systems between 3.1-10.6 GHz will cause interference to the existing wireless communication systems. For example, the Wireless Local Area Network (WLAN) for IEEE 802.11a operating in 5.2/5.8 GHz; therefore, the UWB antenna with a band-notched function is required. In this paper, a compact microstrip-fed slot antenna with band-notched characteristic for UWB applications has been presented. In the proposed antenna, by using a pair of rotated T-shaped strips protruded inside square slots in the ground plane, an additional resonance was excited. By obtaining this resonance, the usable upper frequency of the antenna is extended from 9.3 GHz to 13.15 GHz. To generate a frequency notch band function, we used an SSR conductor-backed plane. The designed antenna has a small size and the impedance bandwidth of the designed antenna is higher than the UWB antennas reported recently [5-8].

II. ANTENNA DESIGN

The presented slot antenna fed by a microstrip line is shown in Fig. 1, which is printed on a FR4 substrate of thickness of 0.8 mm, permittivity of 4.4 and loss tangent of 0.018. The width W_f of the microstrip feed line is fixed at 1.5 mm. The basic antenna structure consists of a square radiating stub, a feed line and a ground plane. The

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proposed antenna is connected to a 50Ω SMA connector for signal transmission.

In this work, we start by choosing the aperture length, L_S. We have a lot of flexibility in choosing this parameter. The length of the aperture mostly affects the antenna bandwidth. As L_S decreases, so does the antenna BW and vice versa. In the next step, we have to determine the aperture width, W_S. The aperture width is approximate, whereas the slot wavelength depends on a number of parameters; such as the slot width as well as the thickness and dielectric constant of the substrate on which the slot is fabricated. The last and final step in the design is to choose the width of the radiating patch, W_R. This parameter is approximate, whereas the guided wavelength is the microstrip line [2].

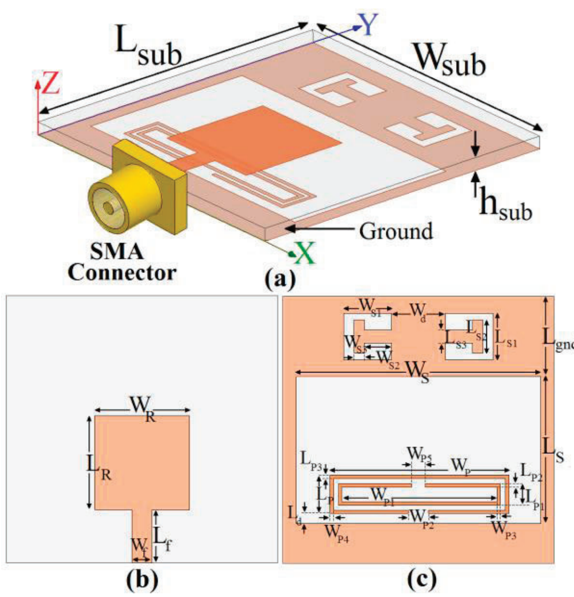

Fig. 1. Geometry of the proposed microstrip slot antenna: (a) side view, (b) top layer and (c) bottom layer.

In this design, the pair of protruded T-shaped strips inside the square slots in the ground plane are playing important roles in the broadband characteristics of the proposed antenna. Regarding Defected Ground Structures (DGS) theory, the created slots in the ground plane provide additional current paths. Moreover, these structures change the inductance and capacitance of the input impedance, which in turn leads to changing the bandwidth. Therefore, by cutting a pair of square slots in the ground plane, much enhanced impedance bandwidth may be achieved

In order to generate a band-notched property, an SRR conductor-backed plane was used. At the notched frequency, the current flows are more dominant around the SRR structure and they are directed oppositely between the parasitic element and the radiating stub. As a result, the desired high attenuation near the notch frequency can be produced [6].

The optimized values of the proposed antenna design are specified in Table 1.

Table 1: The values of the proposed antenna design parameters

$W_{sub} = 20mm$	$L_{sub} = 20mm$	$h_{sub} = 0.8mm$
$W_f = 1.5mm$	$L_f = 4mm$	$W_R = 7mm$
$L_R = 7mm$	$W_S = 18mm$	$L_S = 11mm$
$W_{S1} = 3.5mm$	$L_{S1} = 3.5mm$	$W_{S2} = 2mm$
$L_{S2} = 2.5mm$	$W_{S3} = 0.75mm$	$L_{S3} = 1mm$
$W_d = 4mm$	$L_d = 0.75mm$	$W_P = 14mm$
$L_P = 2.5mm$	$W_{P1} = 12.5mm$	$L_{P1} = 1.5mm$
$W_{P2} = 1.5mm$	$L_{P2} = 0.25mm$	$W_{P3} = 0.25mm$
$L_{P3} = 0.25mm$	$W_{P4} = 0.25mm$	$W_{P5} = 1mm$
$L_{gnd} = 6mm$		

III. RESULTS AND DISCUSSIONS

In this Section, the microstrip slot antenna with various design parameters was constructed and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. Ansoft simulation software High-Frequency Structure Simulator (HFSS) [9] is used to optimize the design and agreement between the simulation and measurement is obtained.

The configuration of the various antenna structures were shown in Fig. 2. VSWR characteristics for the ordinary slot antenna (Fig. 2 (a)), ordinary antenna with a pair of rotated T-shaped strips protruded inside square slots in the ground plane (Fig. 2 (b)) and the proposed slot antenna (Fig. 2 (c)) are compared in Fig. 3. As shown in Fig. 3, it is observed that the upper frequency bandwidth is affected by using the pair of rotated T-shaped strips protruded inside square slots. To generate a band notch function, we use an SRR parasitic structure in the ground plane.

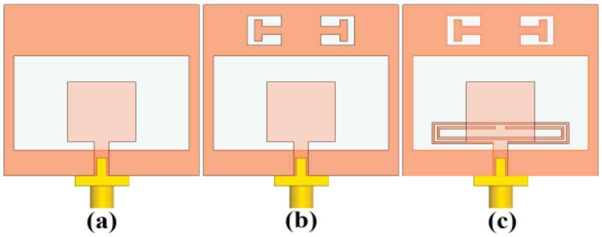

Fig. 2. (a) Ordinary slot antenna, (b) ordinary antenna with a pair of rotated T-shaped strips protruded inside square slots in the ground plane and (c) the proposed slot antenna.

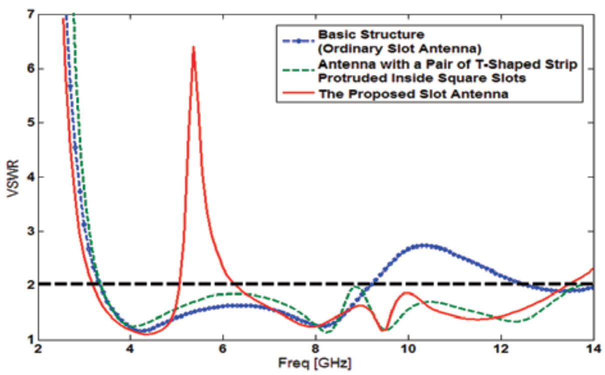

Fig. 3. Simulated VSWR characteristics for the various antennas shown in Fig. 2.

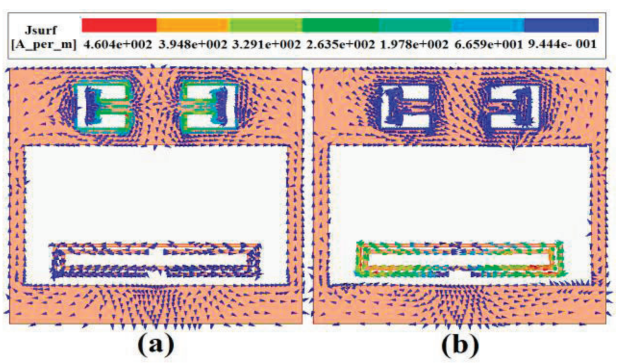

Fig. 4. Simulated surface current distributions on the ground plane: (a) at the extra resonance frequency in 9.5 GHz and (b) at the notched frequency in 5.5 GHz.

In order to know the phenomenon behind this multi-resonance and band-stop performance, simulated current distributions for the proposed antenna in the ground plane at 9.5 GHz and 5.5 GHz are shown in Fig. 4. It can be observed in Fig. 4 (a), that the current concentrated on the edges of the interior and exterior of the rotated T-shaped strips. Therefore, the antenna impedance changes at these frequencies due to the resonant properties of these structures [2]. Another important design parameter of this structure is the SRR conductor-backed plane. Figure 4 (b) presents the simulated current distributions at the notched frequency (5.5 GHz). As shown in Fig. 4 (b), in the notched frequency the current flows are more dominant around of the SRR conductor-backed plane [10].

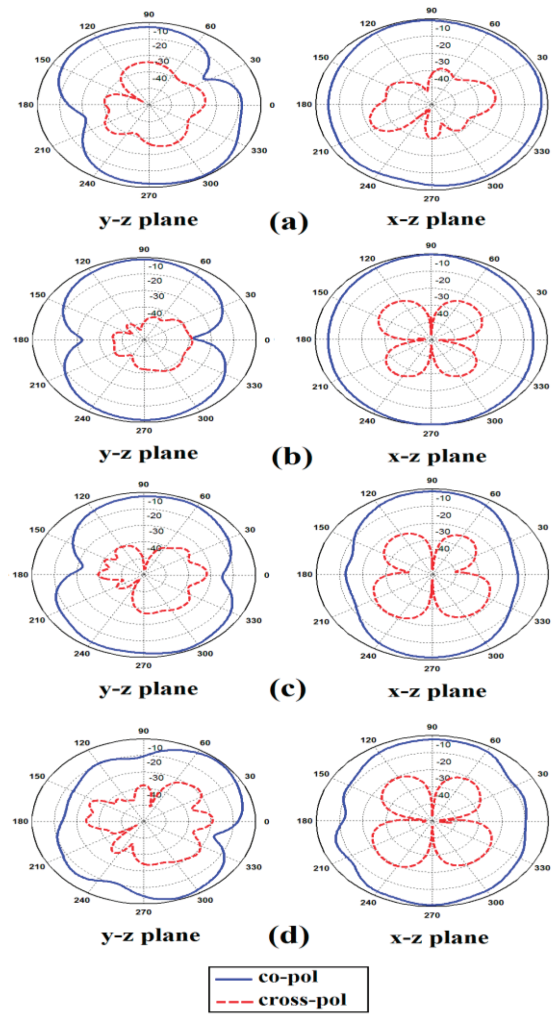

Fig. 5. Measured radiation patterns of the proposed antenna: (a) 4 GHz, (b) 6.5 GHz, (c) 9 GHz and (d) 12 GHz.

Figure 5 depicts the measured and simulated radiation patterns of the proposed antenna, including the co-polarization and cross-polarization in the H-plane (x-z plane) and E-plane (y-z plane). It can be seen that the quasi-omnidirectional radiation pattern can be observed on x-z plane over the whole UWB frequency range, especially at the low frequencies. The radiation patterns on the y-z plane display a typical figure-of-eight, similar to that of a conventional dipole antenna. It should be noticed that the radiation patterns in E-plane become imbalanced as frequency increases, due to the increasing effects of the cross polarization. The patterns indicate at higher frequencies; more ripples can be observed in both E and H-planes, owing to the generation of higher-order modes. The cross-polarization component also increases at higher frequencies, due to the increased horizontal surface currents [11-14].

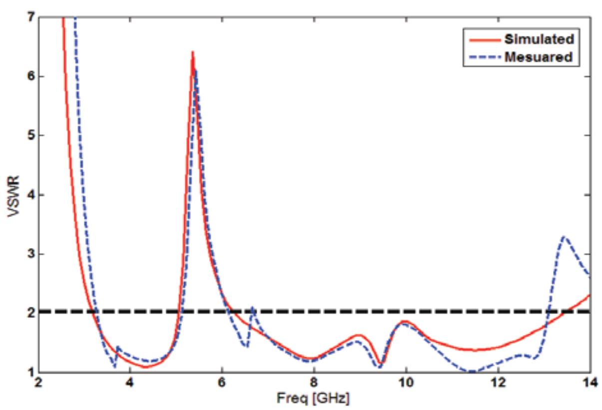

Fig. 6. Measured and simulated VSWR characteristics for the proposed antenna.

Simulated and Measured VSWR for the proposed antenna were shown in Fig. 6. The fabricated antenna has the frequency band of 3.1 GHz to 13.15 GHz, with band-notched function around 5.1-6 GHz.

However, as shown in Fig. 6, there exists a discrepancy between measured data and the simulated results. This discrepancy is mostly due to a number of parameters; such as the fabricated antenna dimensions as well as the thickness and dielectric constant of the substrate on which the antenna is fabricated and the wide range of simulation frequencies. In a physical network analyzer measurement, the feeding mechanism of the proposed antenna is composed of a SMA connector and a microstrip line (the microstrip feed-line is excited by a SMA connector); whereas, the simulated results are obtained using the Ansoft simulation software (HFSS). That in HFSS by default, the antenna is excited by a wave port that it is renormalized to a 50-Ohm full port impedance at all frequencies. In order to confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the manufacturing and measurement processes need to be performed carefully. Moreover, SMA soldering accuracy and FR4 substrate quality need to be taken into consideration.

IV. CONCLUSION

In this paper, we propose a novel design of ultra-wide band slot antenna with band-notched function. The presented antenna can operate from 3.1 GHz to 13.15 GHz, with rejected band in 5-6 GHz. By applying a pair of rotated T-shaped strips protruded inside square slots plane, additional resonances are excited and hence much wider impedance bandwidth can be produced. In order to generate a frequency band-stop performance, we inserted an SRR conductor-backed plane. The designed antenna has a small size. Simulated and experimental results show that the proposed antenna could be a good candidate for UWB applications.

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