Application of the Protruded Structures to Design an UWB Slot Antenna with Band-Notched Characteristic

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Abstract **─** A different method to design a novel ultra-wideband (UWB) slot antenna with band-notch performance is presented. In order to increase the impedance bandwidth of the slot antenna, we use a rectangular slot with a pair of L-shaped strips protruded inside the rectangular slot in the ground plane that with this structure UWB frequency range can be achieved. Additionally, by using square-ring radiating stub with two Γ-shaped strips protruded inside the square-ring stub, a frequency notch band performance has been obtained. The designed antenna has a small size of 20×20 mm^2 while showing the radiation performance in the frequency band of 3.07 GHz to over 14.67 GHz with a band rejection performance in the frequency band of 5.05 GHz to 5.93 GHz. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range.

Index Terms **─** Protruded strips, slot antenna, and UWB Systems.

I. INTRODUCTION

It is a well-known fact that planar microstrip antennas present really appealing physical features, such as simple structure, small size, and low cost [1]. Due to all these interesting characteristics, planar antennas are extremely attractive to be used in emerging ultra-wideband (UWB) applications. [2-5]. In the 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 planar slot antennas with different geometries have been experimentally characterized [6-9].

Despite the advantages of UWB, the frequency range for UWB systems between 3.1 GHz–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 5.15 GHz–5.35 GHz and 5.725 GHz–5.825 GHz bands, so the UWB antenna with a band-notched function is required [10-14].

In this paper, to achieve the above purposes such as the frequency range for UWB systems and single band-notched characteristic (to avoid the interference between UWB and WLAN systems), at the first step of the design algorithm, an extra rectangular slot with a pair of L-shaped strips protruded inside the rectangular slot in the ground plane was used to enhance the bandwidth. Also the modified square-ring radiating stub with two protruded Γ-shaped strips was applied to generate a band-notched performance.

II. ANTENNA DESIGN

The proposed slot antenna fed by a 50-Ohm microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 0.8 mm, and permittivity 4.4. The width 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 with a rectangular slot. The square-ring radiating stub with two Γ-shaped

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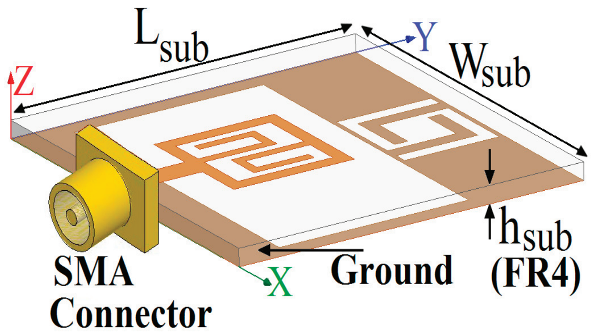
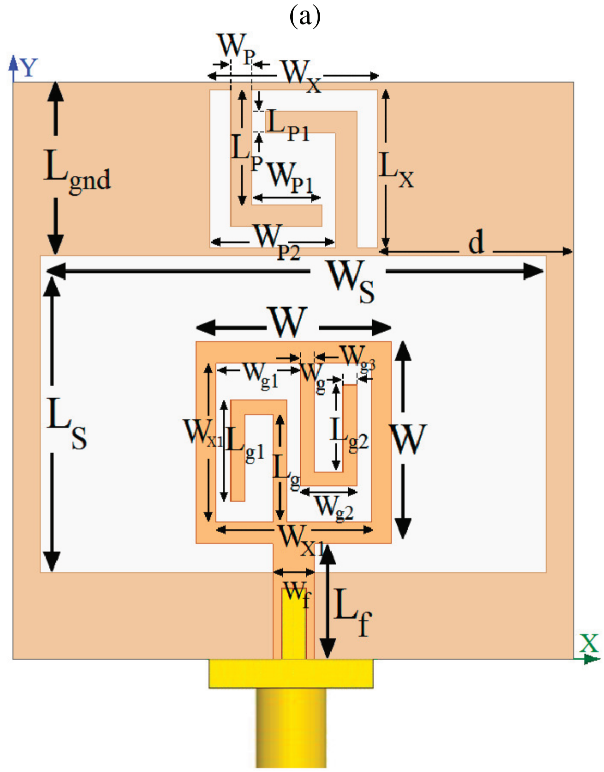
strips protruded inside the square-ring stub is connected to a feed line, as shown in Fig. 1. On the other side of the substrate, a conducting ground plane with a rectangular slot with a pair of L-shaped strips protruded inside the rectangular slot in the ground plane is placed. The proposed antenna is connected to a 50Ω SMA connector for signal transmission.



(a)



(b)

Fig. 1. Geometry of the proposed slot antenna, (a) side view and (b) top view.

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 approximately, where is the slot wavelength that 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. This parameter is approximately, where is the guided wavelength in the microstrip line [3].

In this study, to design a novel antenna, the modified protruded L-shaped and Γ-shaped strips are placed inside rectangular slot in the ground plane and square-ring stub, respectively. Regarding defected ground structures (DGS) theory, the creating 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 change the bandwidth [4-6]. Therefore, by cutting an extra rectangular slot with a pair of L-shaped strips in the ground plane, much enhanced impedance bandwidth may be achieved.

In addition, to create a desired frequency band-stop characteristic, a pair of Γ-shaped strips is protruded inside square-ring radiating stub. At the notched frequency, the current flows are more dominant around the Γ-shaped strips, and they are oppositely directed between the parasitic element and the radiating stub. As a result, the desired high attenuation near the notch frequency can be produced [10-12]. Final values of the presented antenna design parameters are specified in Table. I.

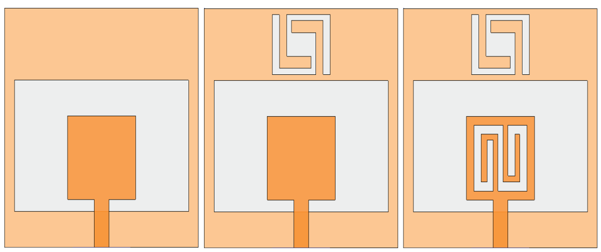
Table. I. Final dimensions of the antenna.

Parameter	W_{sub}	L_{sub}	h_{sub}	W_f	L_f	W
(mm)	20	20	0.8	1.5	4	7
Parameter	W_S	L_S	W_X	L_X	W_{X1}	W_P
(mm)	18	11	6	5.5	5	1
Parameter	L_P	W_{P1}	L_{P1}	W_{P2}	W_g	L_g
(mm)	3.25	2.5	1.5	4.5	0.5	4
Parameter	W_{g1}	L_{g1}	W_{g2}	W_{g3}	d	L_{gnd}
(mm)	3.25	3	1.25	0.5	7	6

III. RESULTS AND DISCUSSIONS

The proposed microstrip-fed 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 analysis and performance of the proposed antenna is explored by using Ansoft simulation software high-frequency structure simulator (HFSS) [15], for better impedance matching.

The configuration of the presented slot antenna was shown in Fig. 1. Geometry for the ordinary square slot antenna (Fig. 2 (a)), with a rectangular slot with a pair of L-shaped strips protruded inside the rectangular slot in the ground plane (Fig. 2 (b)), and the proposed antenna (Fig. 2 (c)) structures are shown in Fig. 2. Return loss characteristics for structures that shown in Fig. 2 are compared in Fig. 3.



(a) (b) (c)

Fig. 2. (a) Ordinary square antenna with two L-shaped slits, (b) with four L-shaped slits, and (c) the proposed antenna structure.

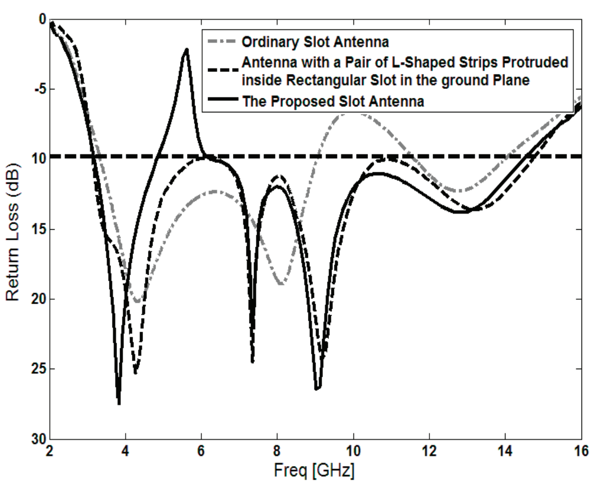
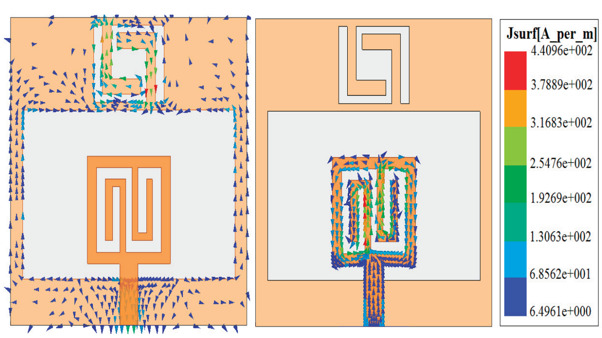


Fig. 3. Simulated return loss characteristics for the various structures of the antenna shown in Fig. 2.

As shown in Fig. 3, it is observed that the upper frequency bandwidth is affected by using the rectangular slot with a pair of L-shaped strips protruded inside the rectangular slot in the ground plane. In the proposed design, by using the modified DGS consist of the extra rectangular slot with a pair of L-shaped strips in the ground plane, an additional resonance at 9 GHz is excited and hence, much wider impedance bandwidth can be produced, especially at the higher frequencies. By using this modified structure in the ground plane, the usable upper frequency of the antenna is extended from 8.7 GHz to 14.67 GHz. Also, the WLAN band-notched property is sensitive to the square-ring radiating stub with two Γ-shaped strips protruded inside the square-ring stub.

In the proposed antenna configuration, the ordinary rectangular slot can provide the fundamental and next higher resonant radiation band at 4.1 GHz and 8 GHz, respectively, in the absence of the modified protruded strips. The upper frequency bandwidth is significantly affected using the pair of protruded L-shaped strips inside the extra rectangular slot in the ground plane. This behavior is mainly due to the change of surface current path by the dimensions of L-shaped strips as shown in Fig. 4 (a). In addition, by using these modified DGS on the other side of substrate, the impedance bandwidth is effectively improved at the upper frequency. As shown in Fig. 4 (b), the current is concentrated on the edges of the interior and exterior of the protruded Γ-shaped strips inside the square-ring radiating stub at the notched frequency (5.5 GHz). This figure shows that the electrical current for the notched frequency (Fig. 4 (b)) does change direction along the bottom and top edge of the radiating stub [16-17].



(a) (b)

Fig. 4. Simulated surface current distributions for the proposed antenna at, (a) 9 GHz (resonance frequency) and (b) 5.5 GHz (notched frequency).

Figure 5 shows the simulated VSWR curves with different values of L_g. As shown in Fig. 5, when the length of the protruded Γ-shaped strips strip increases from 3.25 mm to 4.50 mm, the centre of notch frequency is decreases from 5.86 GHz to 5.11 GHz. From these results, we can conclude that the notch frequency is controllable by changing the length of the protruded Γ-shaped strips [18-19].

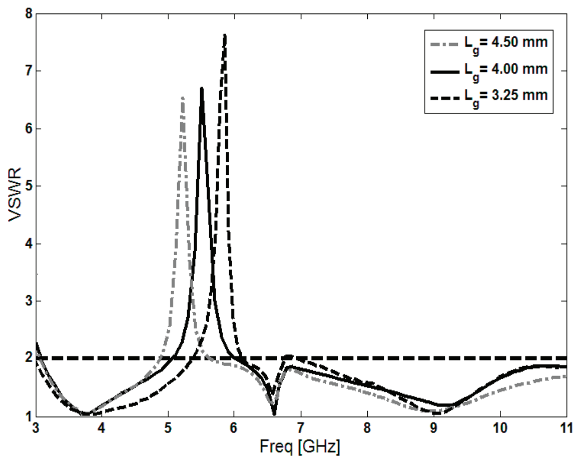
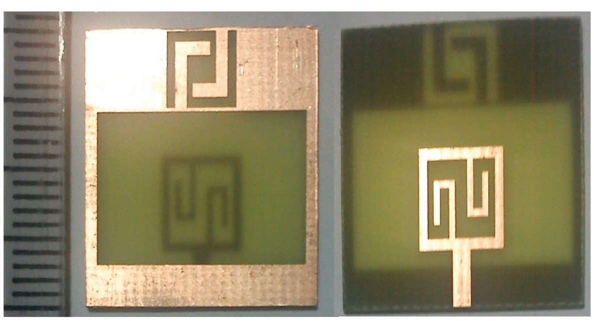


Fig. 5. Simulated VSWR for the proposed antenna with different values of L_g .

The proposed antenna with optimal design as shown in Fig. 6 was built and tested. The VSWR characteristic was measured using a HP 8720ES network analyzer in an anechoic chamber. The radiation patterns have been measured inside an anechoic chamber using a double-ridged horn antenna as a reference antenna placed at a distance of 2 m.



(a) Bottom view (b) Top view

Fig. 6. Prototype of the realized antenna.

The measured and simulated VSWR characteristics of the proposed antenna were shown in Fig .7. The fabricated antenna has the frequency band of 3.07 to over 14.67 GHz with a rejection band around 5.05 to 5.93 GHz.

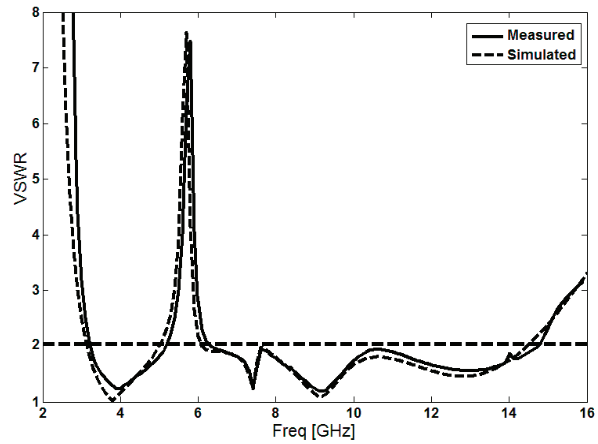


Fig. 7. Measured and simulated VSWR for the proposed antenna.

Figure 8 depicts the measured 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 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 because of 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 [20-23].

IV. CONCLUSION

In this paper, a novel design of UWB slot antenna with variable band-notched function is proposed. The presented slot antenna can operate from 3.07 GHz to 14.67 GHz for VSWR < 2 with a rejection band around 5.05 GHz-5.93 GHz. By using a rectangular slot with a pair of protruded L-shaped strips in the ground plane, an additional resonance at higher frequency range is excited and much wider impedance bandwidth is produced. In order to generate a frequency band-stop performance, we use the square-ring radiating stub with two protruded Γ-shaped strips. The designed antenna has a small size. The measured results showed good agreement with the simulated results. Experimental results show that the presented slot antenna can be a good candidate for UWB applications.

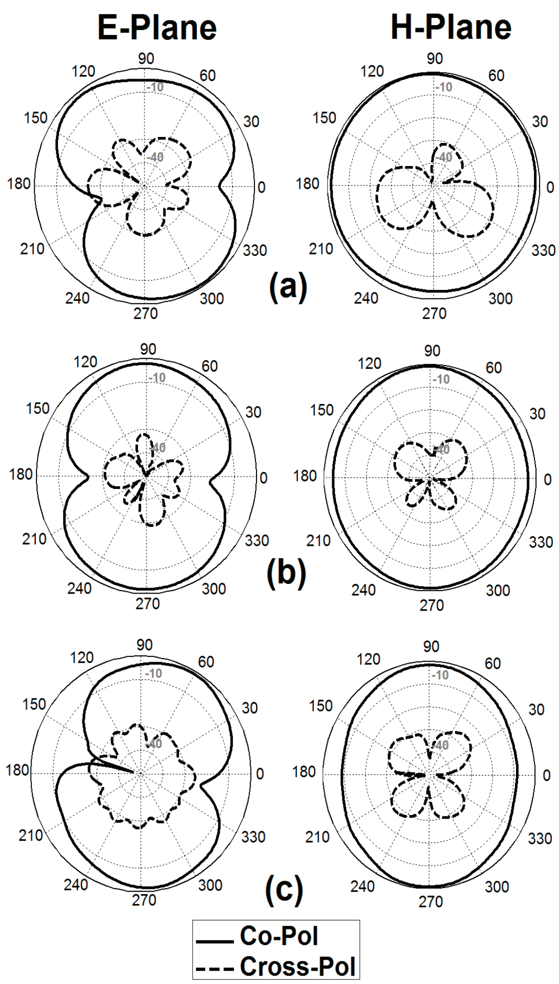


Fig. 8. Measured radiation patterns of the proposed antenna (a) 4 GHz, (b) 7 GHz, and (c) 10 GHz.

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