A Novel Design of Dual Band-Notched Slot Antenna Using a Pair of Γ-Shaped Protruded Strips for UWB Applications

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Abstract **─**In this paper, we present a novel design of dual band-notch printed slot antenna for UWB applications. The antenna consists of a square radiating stub and a ground plane structure with an H-shaped slot and a pair of Γ-shaped strips protruded inside rectangular slot, which provides a wide usable fractional bandwidth of more than 145% (2.49 GHz – 15.73 GHz). In order to increase the impedance bandwidth of the ordinary slot antenna, we use an H-shaped slot in the ground plane, through which an UWB frequency range can be achieved. Additionally, by using a protruded Γ-shaped strip in the top edge of the rectangular slot a single frequency band-stop performance can be achieved, also in order to create the second notch frequency, we insert the second protruded Γ-shaped strip in the bottom edge of the rectangular slot. Simulated and measured results obtained for this antenna show that the proposed slot antenna offers two notched bands, covering all the 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX and 4 GHz C-band range. The antenna has a small dimension of 20×20 mm^2.

Index Terms **─** H-shaped slot, microstrip-fed slot antenna, protruded Γ-shaped strip, and ultra-wideband (UWB) applications.

I. INTRODUCTION

Communication systems usually require smaller antenna size in order to meet the miniaturization requirements of radio-frequency (RF) units [1]. In UWB systems, the improvement of the impedance bandwidth, which does not involve a modification of the geometry of the planar antenna, has been investigated, and growing research activity is being focused on them. As important compact UWB antennas, printed slot antennas have attracted more and more attention. Consequently, a number of planar slots with different geometries have been experimentally characterized [2-6].

In this paper, a new dual band-notched microstrip-fed slot antenna is presented. In the presented antenna, an H-shaped slot was used for bandwidth enhancement and two Γ-shaped strip protruded inside the rectangular slot on the ground plane were applied in order to generate dual bad-notch function. The size of the designed antenna is smaller than the UWB antennas with band-notched function reported recently [4-7]. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications.

II. ANTENNA DESIGN

The presented small slot antenna fed by a 50Ω microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 0.8 mm, permittivity 4.4, and loss tangent 0.018. The basic slot antenna structure consists of a square stub, a feed line, and a ground plane. The square stub is connected to a 50Ω microstrip feed line. On the

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other side of the substrate, a conducting ground plane is placed. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission. The final dimensions of the proposed designed antenna are shown in Table 1.

In this design, to achieve a new additional resonance frequency and give a bandwidth enhancement performance, we use an H-shaped slot on the ground plane. Based on defected ground structure (DGS), the modified H-shaped slot acts as an impedance matching element that controls the impedance bandwidth of the proposed antenna. This is because it can create additional surface current paths in the antenna; therefore additional resonance is excited and hence much wider impedance bandwidth can be produced, especially at higher bands [8].

Additionally, in this study, the proruded Γ-shaped strips in the ground plane perturb the resonant response and act as half-wave filtering element to generate a new notch frequency, because it can creates additional surface current path in the feed line. At the notch frequency, the current flows are more dominant around the proruded Γ-shaped strips, and they are oppositely directed between the protruded strips and the ground plane [9]. As a result, the desired high attenuation near the notch frequencies can be produced.

Table 1: The final dimensions of the designed antenna.

Param.	mm	Param.	mm	Param.	mm
W_{Sub}	20	L_{Sub}	20	h_{sub}	0.8
L_f	4	W_f	1.5	W	7
L_S	11	W_S	18	W_1	1.5
L_1	6	W_2	0.5	L_2	5
W_3	0.4	L_3	5.5	W_4	0.5
L_4	8	L_5	8.6	L_6	8.5
W_H	2	L_H	4	W_{H1}	1
L_{H1}	1.5	L_{gnd}	4		

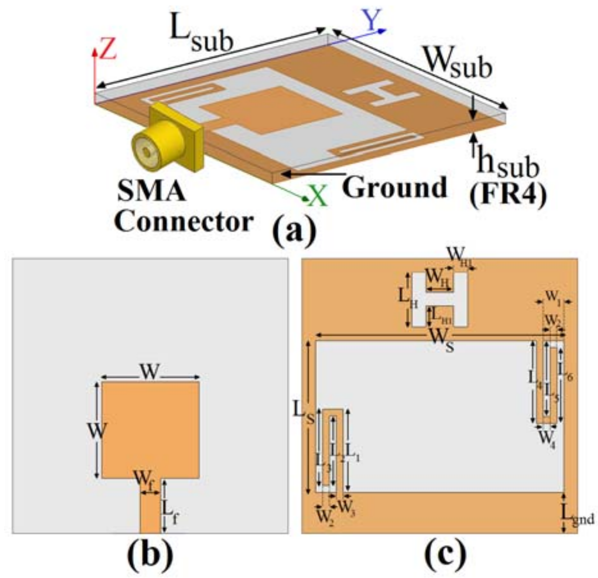

Fig. 1. Geometry of the proposed microstrip-fed slot antenna, (a) side view, (b) top layer, and (c) bottom layer.

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. The parameters of this proposed antenna are studied by changing one parameter at a time and fixing the others. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [10].

Various antenna structures used for simulation studies are shown in Fig. 2. The VSWR characteristics of the ordinary slot antenna (Fig. 2 (a)), ordinary slot antenna with an H-shaped slot in the ground plane (Fig. 2 (b)), and the proposed antenna structure (Fig. 2 (c)) are compared in Fig. 3. As shown in Fig. 3, in the proposed antenna configuration, the ordinary slot can provide the fundamental and next higher resonant radiation band at 4.1 GHz and 8.5 GHz, respectively. To design a novel antenna, also in order increase the upper frequency bandwidth, an H-shaped slot is inserted in the ground plane as displayed in Fig. 2 (b). As shown in Fig. 3, the upper frequency bandwidth is significantly affected by using the H-shaped slot. It is found that the H-shaped slot itself is radiating at higher frequencies (10.3 GHz). Therefore by using this slot, the third resonance occurs at 10.3 GHz in the simulation. This behaviour is mainly due to the change of surface current path by the dimensions of a pair of H-shaped slots in the ground plane [2]. Also by using two proruded Γ-shaped strips in the ground plane, the dual band-notch function can be achieved, which cover all the 5.2/5.8GHz WLAN, 3.5/5.5 GHz WiMAX, and 4 GHz C-band [11].

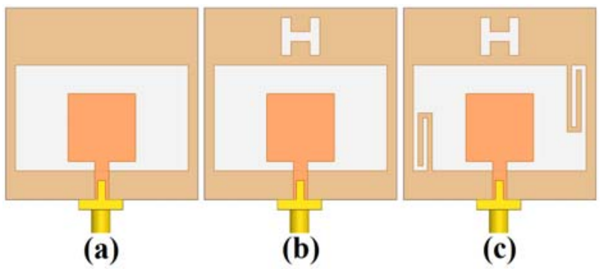

Fig. 2. (a) The basic structure (ordinary slot antenna), (b) antenna with an H-shaped slot in the ground plane, and (c) the proposed antenna.

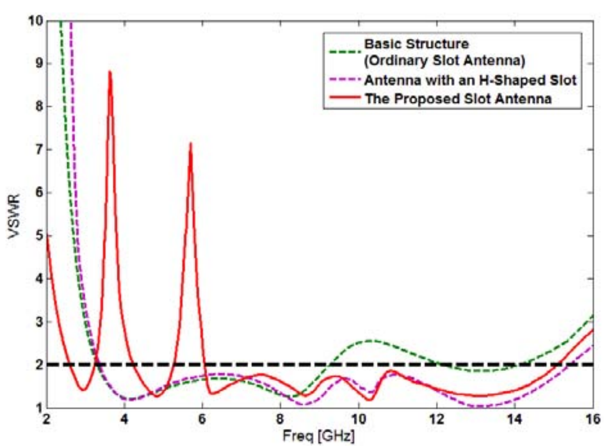

Fig. 3. Simulated VSWR characteristics for the antennas shown in Fig. 2.

In order to know the phenomenon behind this additional resonance performance, the simulated current distributions on the ground plane for the ordinary slot antenna with an H-shaped slot at 10.3 GHz (new additional resonance) are presented in Fig. 4 (a). It can be observed in Fig. 4 (a), that the current is concentrated on the edges of the interior and exterior of the H-shaped slot at the 10.3 GHz. Other important design parameters of this structure are two proruded Γ-shaped strips, used in the rectangular slot. Figures 4 (b) and 4 (c) present the simulated current distributions on the ground plane for the proposed antenna structure at the first notched frequency (3.8 GHz) and the second notched frequency (5.5 GHz), respectively. As shown in Figs. 4 (b) and 4 (c), at these notch frequencies the current flows are more dominant around of the two proruded Γ-shaped strips. As a result, the desired high attenuation near the notched frequencies can be produced [12-13].

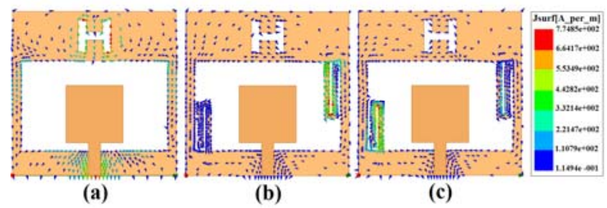

Fig. 4. Simulated surface current distributions on the ground plane for (a) ordinary slot antenna with an H-shaped slot in the ground plane at 10.3 GHz (new additional resonance frequency), (b) for the proposed antenna structure at 3.85 GHz (first notch frequency), and (c) at 5.5 GHz (second notch frequency).

The simulated radiation efficiencies and maximum gains of the proposed antenna are shown in Fig. 5. Results of the calculations using the HFSS software indicated that the proposed antenna features a good efficiency, being greater than 82 % across the entire radiating band except in two notched bands. On the other hand, the simulated radiation efficiencies of the proposed dual band-notched antenna, at 3.85 GHz and 5.5 GHz, are only about 34 % and 27 %, respectively. Also, the simulated maximum gains of the proposed antenna are presented in Fig. 5. It can be observed from Fig. 5 that by using a square radiating patch with proposed slots, two sharp decrease of maximum gain in the notched frequencies band at 3.85 GHz and 5.5 GHz are shown. As shown in Fig. 5, the radiation efficiency has a slight drop at higher frequencies. This drop between low and high frequency patterns' results is mostly due to FR4 substrate loss at high frequencies [14].

Figure 6 shows the measured and simulated VSWR characteristics of the proposed antenna. The fabricated antenna has the frequency band of 2.49 GHz to over 15.73 GHz with two rejection bands around 3.67 GHz – 4.15 GHz and 5.01 GHz

– 5.98 GHz. As shown in Fig. 6, there exists a discrepancy between measured data and simulated results; this could be due to the effect of the SMA port, and also the accuracy of the simulation is due to the wide range of simulation frequencies. In order to confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

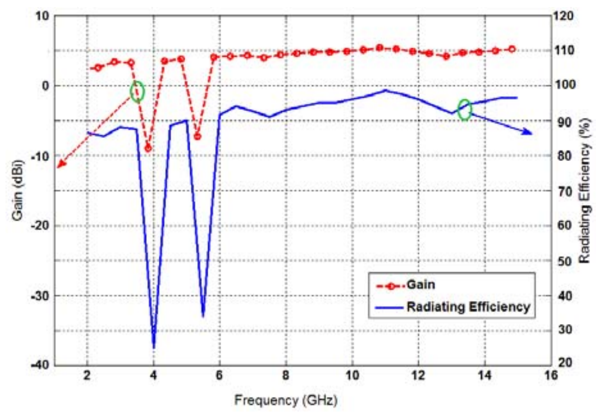

Fig. 5. Simulated radiation efficiency and maximum gain values of the proposed slot antenna.

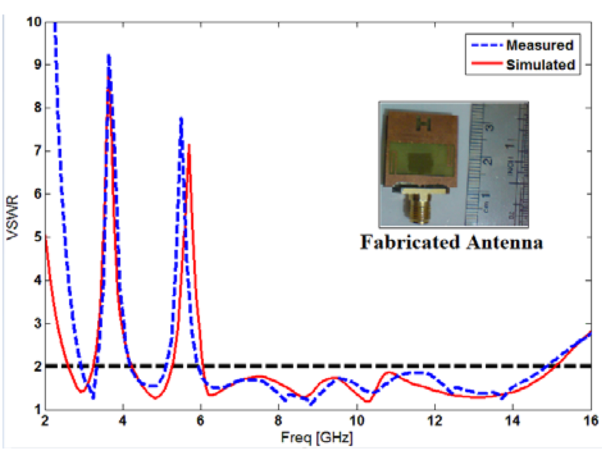

Fig. 6. Measured and simulated VSWR for the proposed antenna with a picture of the fabricated antenna.

Figure 7 shows the measured radiation patterns including the co- and cross-polarizations in the *H*-plane (*x*-*z* plane) and *E*-plane (*y*-*z* plane), respectively. It can be seen that the radiation patterns in *x*-*z* plane are nearly omnidirectional for the three frequencies.

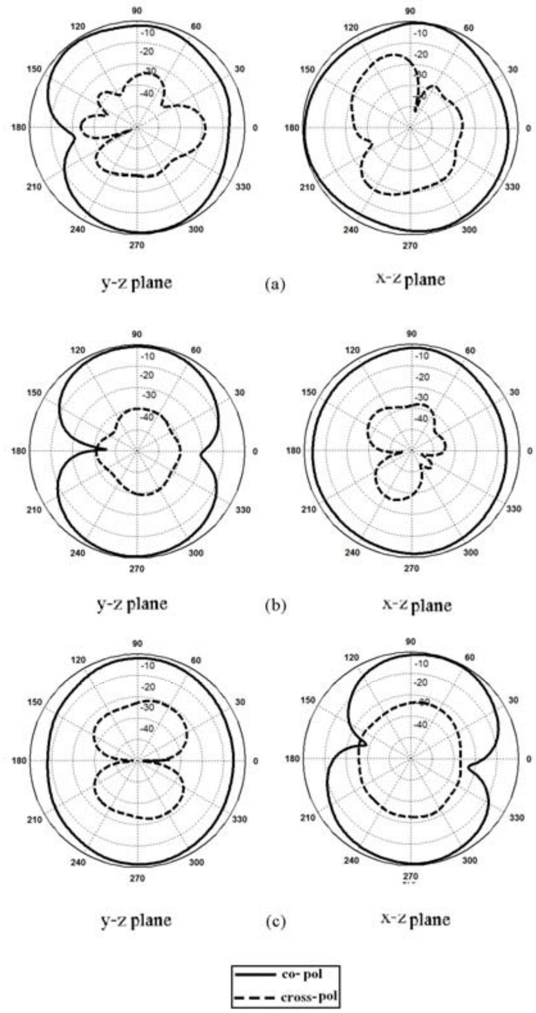

Fig. 7. Measured radiation patterns of the proposed antenna for (a) 4.5 GHz, (b) 7.5 GHz, and (c) 10 GHz.

IV. CONCLUSION

In this paper, a novel compact wideband printed slot antenna (PSA) with single and dual band-notched characteristics has been proposed for various UWB applications. The fabricated antenna has the frequency band of 2.49 GHz to over 15.73 GHz with two rejection bands around 3.67 GHz – 4.15 GHz and 5.01 GHz –5.98 GHz. By cutting an H-shaped slot in the ground plane, additional resonance is excited and hence much wider impedance bandwidth can be produced, especially at the higher band. Moreover, by using two protruded Γ-shaped strips with variable dimensions on the ground plane, dual band notch characteristics are generated. The designed antenna has a small size. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and experimental results show that the proposed antenna could be a good candidate for UWB applications.

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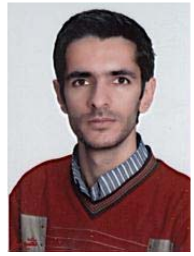

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