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A modified compact microstrip-fed slot antenna with desired WLAN band-notched characteristic

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Abstract

In this paper, a different method for designing a novel and compact microstrip-fed slot antenna with band-notched characteristic for UWB application is proposed. In the proposed antenna, a pair of protruded T-shaped strips inside an extra rectangular slot in the ground plane is used to create an additional resonance at higher frequencies. By obtaining this resonance (10.7 GHz), the usable upper frequency of the antenna is extended from 10 GHz to 13.2 GHz which provides a wide usable fractional bandwidth of more than 125%. Additionally, by using a square-ring radiating stub with a protruded H-shaped strip inside the ring, a desired frequency band-stop performance has been obtained. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range. The proposed antenna can operate from 2.95 to 13.2 GHz for VSWR < 2 with a rejection band around of 5.1-6 GHz to suppress any interference from wireless local area network (WLAN) systems. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range.

1. Introduction

After allocation of the frequency band from 3.1 to 10.6 GHz for the commercial use of ultra-wideband (UWB) systems by the federal communication commission (FCC) [1], ultra-wideband systems have received phenomenal gravitation in wireless communication. Designing an antenna to operate in the UWB band is quite a challenge because it has to satisfy the requirements such as ultra wide impedance bandwidth, omni-directional radiation pattern, constant gain, high radiation efficiency, constant group delay, low profile, easy manufacturing, etc [2]. In UWB communication systems, one of key issues 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 [3-6].

In [3], a compact hexagonal structure is introduced to enhance the impedance bandwidth. Based on defected ground structure (DGS) and electromagnetic coupling theory (ECT), pairs of L-shaped slots conductor-backed plane structures are used to excite more resonances in [4-5]. A novel CPW-fed E-shaped slot antenna which provides a wide usable fractional bandwidth of more than 115% was reported in [6]. Moreover, other strategies to improve the impedance bandwidth which do not involve a modification of the geometry of the planar antenna have been investigated [7-12].

There are many narrowband communication systems which severely interfere with the UWB communication system, such as the wireless local area network (WLAN) for IEEE

802.11a operating in 5.15–5.35 and 5.725–5.825 GHz bands, Therefore, UWB antennas with band-notched characteristic to filter the potential interference are desirable. Nowadays, to mitigate this effect many UWB antennas with various band-notched properties have developed [13-18].

A new design of micostrip-fed slot antenna with band-stop function for ultra-wideband (UWB) applications is designed and manufactured. By using two rotated T-shaped strips protruded inside the extra rectangular slot in the ground plane, an additional resonance was excited and impedance bandwidth of the antenna is extended. To generate the frequency band-stop function, an H-shaped strip is used inside the square-ring radiating stub. The designed antenna has a small size of 20×20×0.8 mm^3.

2. Antenna Design

The proposed antenna fed by a 50-ohm microstrip line is shown in Fig 1, which is printed on a 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 square radiating stub, feed-line, and slotted ground plane. The proposed antenna is connected to a 50-Ω SMA connector for signal transmission. Final values of the presented antenna design parameters are specified in Table. 1.

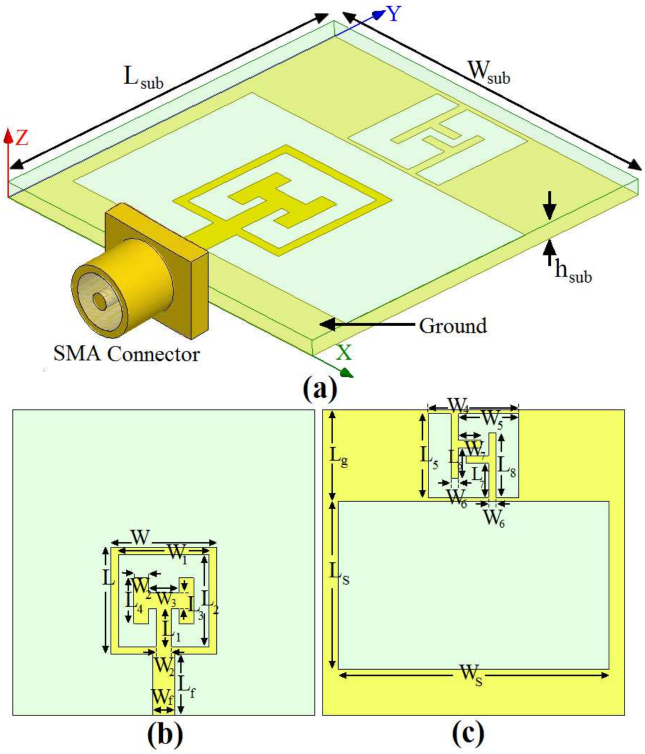

Fig. 1. *Configuration of the proposed antenna (a) side view, (b) top layer, and (c) bottom layer.*

Table 1. *Final parameter values of the antenna.*

Parameter	$\mathbf{W_{sub}}$	$\mathbf{L_{sub}}$	$\mathbf{L_g}$
Value (mm)	20	20	6
Parameter	L_f	W_1	L_1
Value (mm)	4	6	2.5
Parameter	L_3	W_4	L_4
Value (mm)	1	6	4
Parameter	L_6	W_7	L_7
Value (mm)	2	1.5	2.25
Parameter	W	L	W_f
Value (mm)	7	7	1.5
Parameter	W_2	L_2	W_3
Value (mm)	1	6	2
Parameter	W_5	L_5	W_6
Value (mm)	4	5.5	0.5
Parameter	L_8	W_S	L_S
Value (mm)	4.25	18	11

In this work, the antenna design is started by choosing the aperture length L_S. There is 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, determination of the aperture width W_s is required. 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 length of the radiating patch *W*. This parameter is approximately, where is the guided wavelength in the microstrip line [3]. The last and final step in the design is choosing the length of the resonator and the band-stop filter elements. In this design, the optimized length $L_{resonance}$ is set to resonate at $0.25\lambda_{resonance}$ and the optimized length L_{notch} is set to band-stop resonate at $0.5\lambda_{notch}$,

$$f_{resonance\ /\ filter} = \frac{c}{4L\sqrt{(\varepsilon_r + 1)/2}} \tag{1}$$

Where $L_{resonance}=W_6+0.5(W_7+L_8+)+0.25L_5$ which corresponds to extra resonance frequency (5.5 GHz). Also $L_{notch}=W_4+0.5(W_2+W_3+L_1+L_4)$ corresponds to band-notched frequency (10.7 GHz).

In this study, to design a novel antenna, the protruded T-shaped and H-shaped strips are placed inside rectangular slot in the ground plane and square-ring stub, respectively. Regarding 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 [7-8]. Therefore, by cutting an extra rectangular slot with a pair of rotated T-shaped strips in the ground plane, much enhanced impedance bandwidth may be achieved. In addition, to create a desired band-stop characteristic, an H-shaped strip is protruded inside the square-ring radiating stub. At the notched frequency, the current flows are more dominant around the H-shaped strip, and they are oppositely directed between the parasitic element and the radiating stub. As a result, the desired high attenuation near the notched frequency can be produced [14-15].

3. Results and Discussions

In this section, the presented antenna with various design parameters was constructed. The numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [19].

The configuration of the presented antenna was shown in Fig .1. Geometry for the ordinary slot antenna (Fig. 2(a)), the antenna with a pair of rotated T-shaped strips (Fig. 2(b)), and the proposed antenna (Fig. 2(c)) structures are compared in Fig 3.

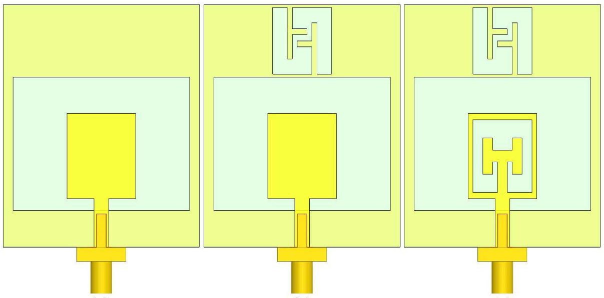

Fig. 2. *(a) Ordinary slot antenna, (b) antenna with a pair of rotated T-shaped strips protruded inside the extra slot in the ground plane, and (c) the proposed slot antenna.*

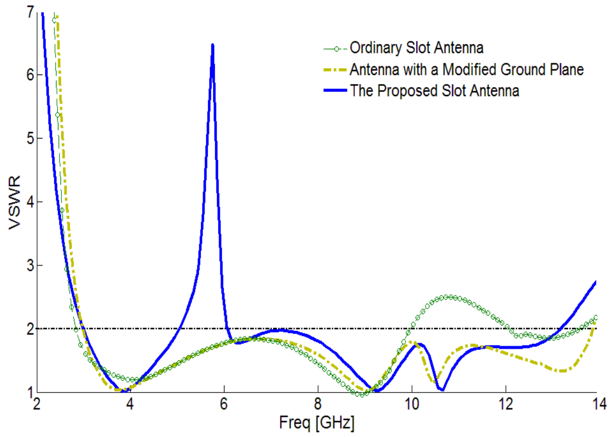

Fig. 3. *Simulated VSWR characteristics for the various antennas shown in Fig. 2.*

As shown in Fig.3, by using a pair of protruded T-shaped strips inside the extra rectangular slot in the ground plane, a new resonance at 10.7 GHz is generated and the usable upper frequency of the antenna is extended from 10 GHz to 13.2 GHz. Also, the protruded H-shaped strip at the square-ring radiating stub is used to obtain the WLAN frequency band-stop performance [20].

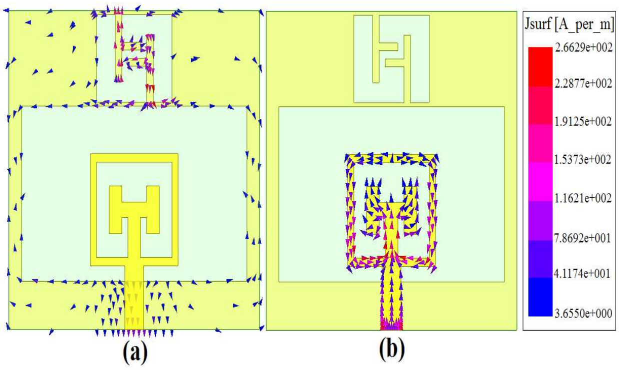

Fig. 4. *Simulated surface current distributions for the proposed antenna (a) in the ground plane at 10.7 GHz and (b) in the radiating stub at 5.5 GHz.*

To understand the phenomenon behind the bandwidth enhancement and band-notched performances, simulated current distributions for the proposed slot antenna in the ground plane at 10.7 GHz (new resonance frequency) and in the radiating stub at 5.5 GHz (notched frequency) are presented in Fig. 4. It can be observed in Fig. 4 (a), at 10.7 GHz, the current concentrated on the edges of the interior and exterior of the protruded T-shaped strips. Therefore, the antenna impedance changes at this frequency due to the resonant properties of the embedded structures in the ground plane. As illustrated in Fig. 4 (b), at the notched frequency the current flows are more dominant around of the H-shaped strip inside the square-ring radiating stub. As a result, the desired high attenuation near the notched frequency can be produced [21-22].

Fig. 5 illustrates the measured and simulated VSWR characteristics for the proposed. The fabricated antenna has the frequency band of 2.92 to over 13.2 GHz with a rejection band around of 5-6 GHz.

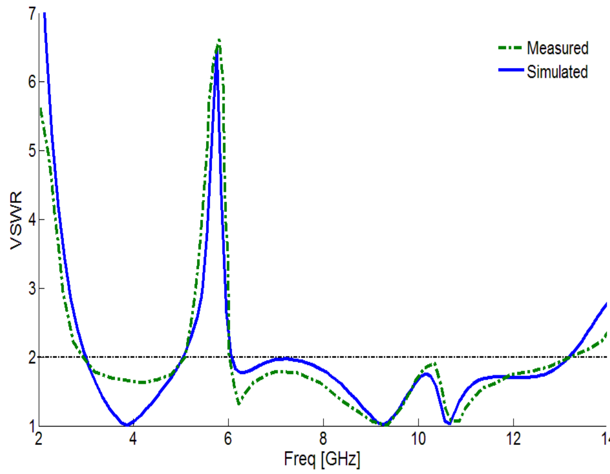

Fig. 5. *Measured and simulated VSWR characteristics for the proposed antenna.*

However, as shown in Fig. 5, 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, 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 return loss 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.

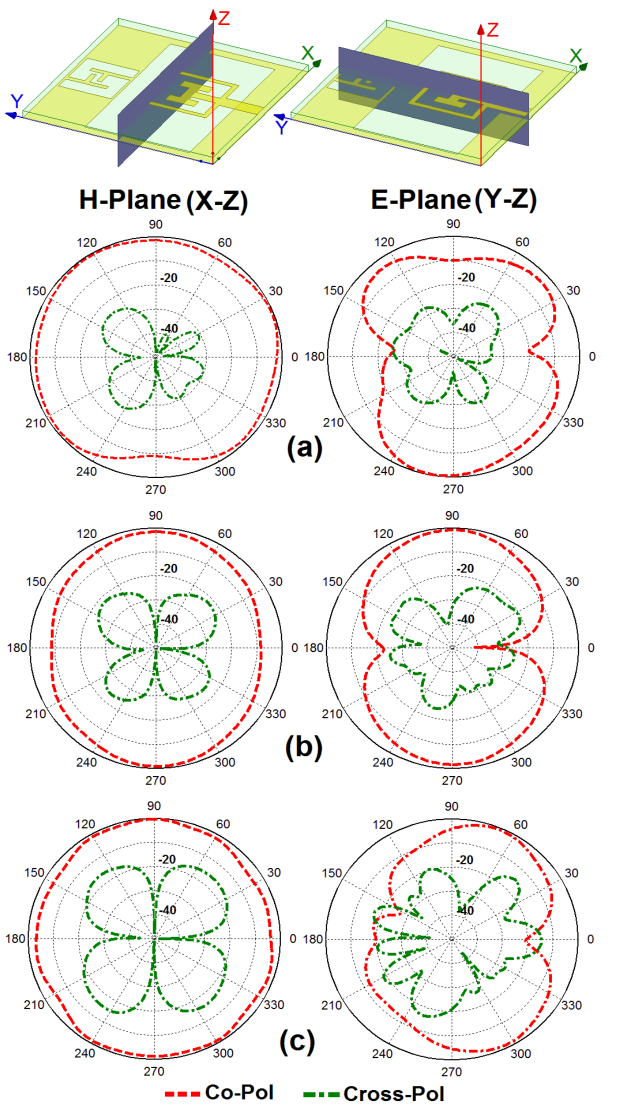

Fig. 6. Measured radiation patterns of the antenna (a) 4 GHz, (b) 8 GHz and (b) 12 GHz.

Fig. 6 depicts the measured radiation patterns of the proposed antenna including 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 higher 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. The cross-polarization component also increases at higher frequencies due to the increased horizontal surface currents [23-25].

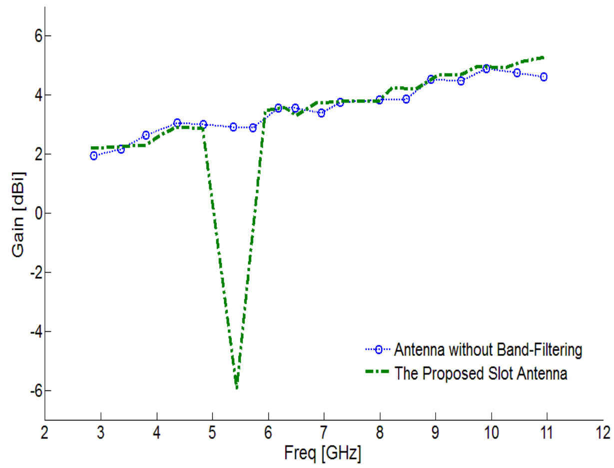

Fig. 7. Measured maximum gain of the proposed antenna.

Measured maximum gain of the proposed antenna was shown in Fig. 7. As illustrated, a sharp decrease of maximum gain in the notched frequency band at 5.5 GHz is shown in Fig. 7. For other frequencies outside the notched frequency band, the antenna gain with the filter is similar to this without it. As seen, the proposed antenna has sufficient and acceptable gain levels in the operation bands [26-30].

4. Conclusion

A novel small microstrip slot antenna with a band-stop property for UWB applications has been proposed. In this design, the proposed antenna bandwidth is from 2.9 to 13.2 GHz with a rejection band around 5.1 to 6 GHz. The antenna structure consists of a square-ring radiating sub with protruded H-shaped strip inside the ring, a feed-line and a slotted ground plane with a pair of protruded T-shaped strips inside the extra rectangular slot. The proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. The designed antenna has a small size. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications. The designed antenna has a compact size of 20×20 m^2.

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