Design of UWB CPW-Fed Slot Antenna with a Band-Stop Notch Using a Parasitic Strip on the Substrate Backside

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Abstract **─** This paper presents a new design of 5.5 GHz band-notched slot antenna fed by a Coplanar Waveguide (CPW) for Ultra-Wideband (UWB) application. By converting a square radiating stub to the stepped structure, a good impedance bandwidth can be achieved, which covers an UWB frequency range. The band-notched characteristic of this antenna is realized by adding an inverted U-shaped parasitic strip on the other side of antenna substrate. The proposed antenna can operate from 2.85 to 11.93 GHz with a rejection band around 5.02 to 6.13 GHz, to avoid any interference form the Wireless Local Area Network (WLAN) systems. The proposed antenna displays good omni-directional radiation patterns. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications. The designed antenna has a small dimension of 30×30×0.8 mm^3.

Index Terms **─** Band-notched function, CPW-fed antenna, parasitic strip, stepped radiating stub and UWB application.

I. 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. [2-3]. 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 [4-8].

There are many narrowband communication systems which severely interfere with the UWB communication system, such as Wireless Local Area Network (WLAN) operating in 5.15-5.35 GHz and 5.725-5.825 GHz bands. Therefore, UWB antennas with band-notched characteristics to filter the potential interference are desirable [9]. Nowadays, to mitigate this effect, many UWB antennas with various band-notched properties have developed [10-11]. Many techniques are also used to introduce notch band for rejecting the interference in the UWB antennas. It is done either by using on-ground slits [12], protruded strip resonators [13], or reconfigurable structures [14].

In this paper, we propose a new CPW-fed microstrip slot antenna with WLAN band-notched function for UWB applications. The designed antenna has a small size. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range. The proposed

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antenna configuration is simple, easy to fabricate and can be integrated into any UWB system. The designed antenna has a simple configuration with small size.

II. ANTENNA DESIGN

The presented slot antenna fed by a CPW; a CPW is a one type of strip transmission line defined as a planar transmission structure for transmitting microwave signals. It comprises of at least one flat conductive strip of small thickness and conductive ground plates. A CPW structure consists of a median metallic strip of deposited on the surface of a dielectric substrate slab, with two narrow slits ground electrodes running adjacent and parallel to the strip on the same surface, as shown in Fig. 1. Beside the microstrip line, the CPW is the most frequent use as planar transmission line in RF/microwave integrated circuits. It can be regarded as two coupled slot lines. Therefore, similar properties of a slot line may be expected. The CPW consists of three conductors, with the exterior ones used as ground plates. These need not necessarily have same potential. As illustrated in Fig. 1, the conductors placed together with distance of d=0.135 mm.

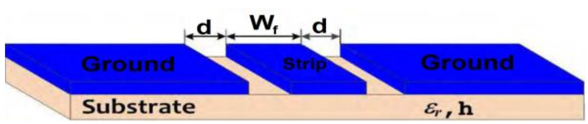

Fig. 1. Coplanar Waveguide structure (CPW).

The antenna was fabricated on an h=0.8 mm FR4 epoxy substrate with the dielectric constant ε_r=4.4 and loss tangent δ=0.02. Basic antenna structure consists of a rectangular radiating stub, a feed-line and a ground plane with a rectangular slot. The radiating stub is connected to a feed line. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission. The proposed antenna configuration is shown in Fig. 2. Final values of the antenna design parameters are specified in Table 1.

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.

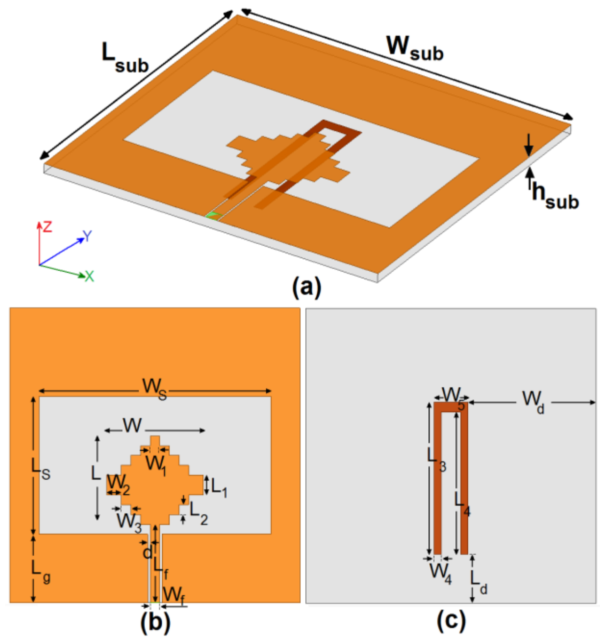

Fig. 2. Geometry of proposed antenna: (a) side view, (b) top layer and (c) bottom layer.

Table 1: Final dimensions of the antenna

Parameter	(mm)	Parameter	(mm)
W_{sub}	30	L_2	1
L_{sub}	30	W_2	1.5
h_{sub}	0.8	L_3	16.5
W_f	1	W_3	1
L_f	8	L_4	16
W_S	14	W_4	0.5
L_S	24	L_g	7
L	9	W_5	2
W	10	L_d	3
L_1	2	W_d	14
W_1	1	d	0.135

III. RESULTS AND DISCUSSIONS

The proposed CPW-fed 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 configuration of the presented antenna was shown in Fig. 1. Geometry for the ordinary slot antenna [Fig. 3 (a)], the antenna with stepped radiating stub (Fig. 3 (b)] and the proposed antenna [Fig. 3 (c)] structures are shown in Fig. 3.

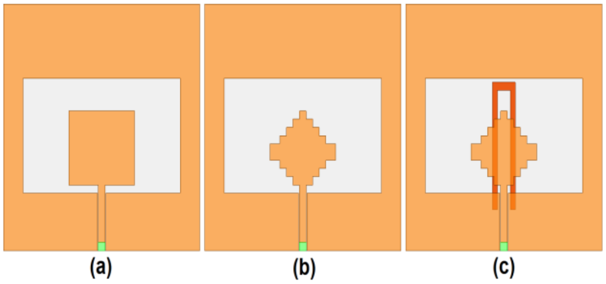

Fig. 3. (a) Ordinary slot antenna, (b) antenna with a stepped radiating stub and (c) the proposed slot antenna.

Figure 4 shows the effects of the stepped radiating stub and inverted U-shaped parasitic strip on the impedance matching, in comparison to the same antenna without them. It is found that by converting the square radiating patch to the stepped structure, the antenna can achieve good impedance bandwidth from resonant 2 GHz to 12 GHz. Also, in the proposed design, to generate a band-stop performance, an inverted U-shaped strip was embedded at the substrate backside [16]. The input impedance of the proposed antenna on a Smith Chart is shown in Fig. 5.

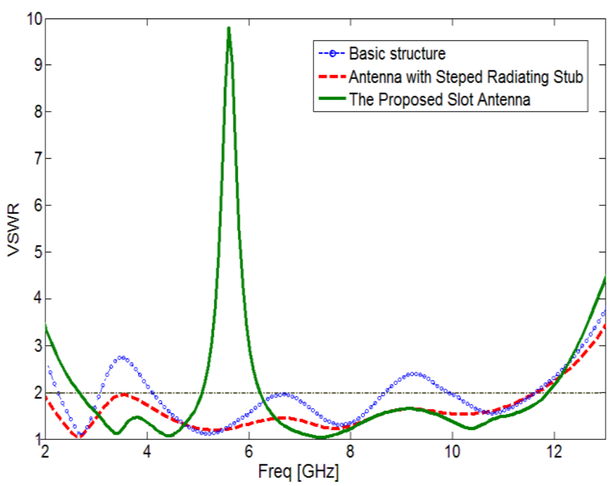

Fig. 4. Simulated VSWR characteristics for the various structures shown in Fig. 2.

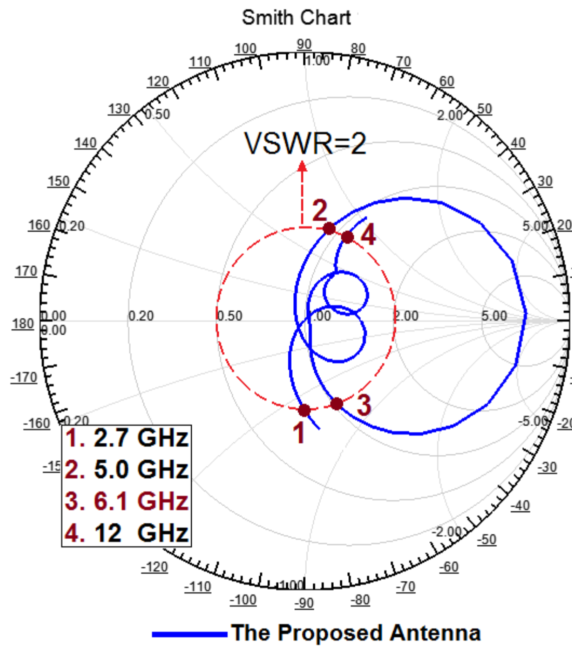

Fig. 5. Simulated input impedance on a Smith Chart for the proposed antenna.

To understand the phenomenon behind the bandwidth enhancement and band-notched properties, the simulated current distributions for the proposed antenna at 3.4, 10.3 GHz (new resonances frequencies) and 5.5 GHz (notched frequency) are presented in Fig. 6. It can be observed in Figs. 6 (a) and (b) at the 3.4 GHz and 10.3 GHz, the current concentrated on the edges of the interior and exterior of the stepped radiating stub. Therefore, the antenna impedance changes at these frequencies, due to the resonant properties of the stepped structure [17-19]. Figure 6 (c) presents the simulated current distributions for the proposed antenna on the substrate backside at the notched frequency (5.5 GHz). As shown in Fig. 6 (c), at the notched frequency, the current flows are more dominant around of the inverted U-shaped parasitic strip. As a result, the desired high attenuation near the notched frequency can be produced [20-21].

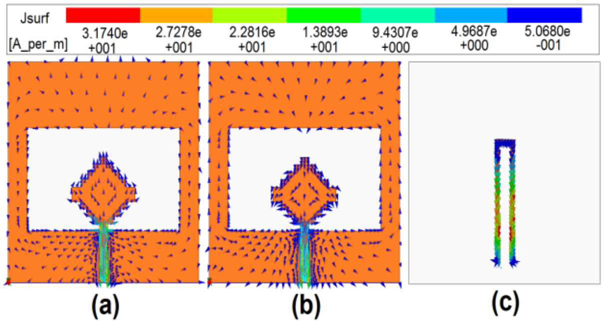

Fig. 6. Simulated surface current distributions for the proposed antenna at: (a) 3.4 GHz, (b) 10.3 GHz and (c) 5.5 GHz.

The proposed antenna with final design was built and tested. The VSWR characteristic of the antenna was measured using the 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. Also, two-antenna technique using an Agilent E4440A spectrum analyzer and a double-ridged horn antenna as a reference antenna placed at a distance of 2 m, is used to measure the radiation gain in the z axis direction (x-z plane). Measurement set-up of the proposed antenna for the VSWR, antenna gain and radiation pattern characteristics are shown in Fig. 7.

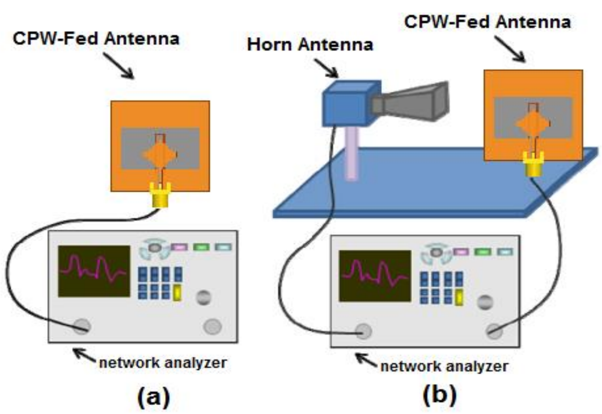

Fig. 7. Measurement set-up of the proposed antenna: (a) VSWR and (b) antenna gain and radiation patterns.

Figure 8 illustrates the measured and simulated VSWR characteristics for the proposed. The fabricated antenna has the frequency band of 2.85 to over 11.9 GHz, with a rejection band around of 5-6 GHz.

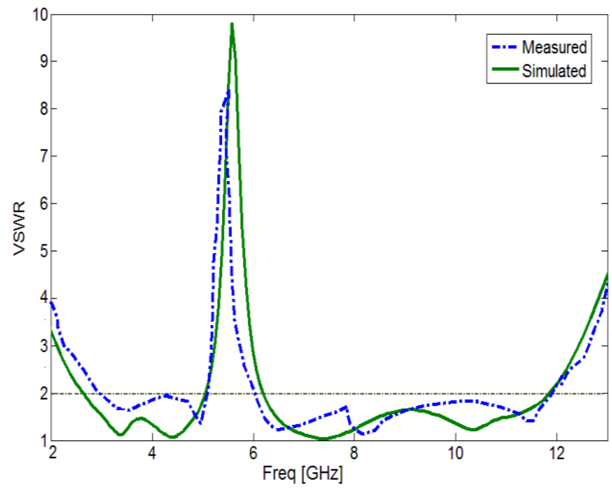

Fig. 8. Measured and simulated VSWR characteristics for the proposed antenna.

Figure 9 shows the measured and simulated vertically (linearly) polarized 2D radiation patterns, including the co-polarization on XZ plane (E-plane) and XY plane (H-plane). The main purpose of the radiating patterns is to demonstrate that the antenna actually radiates over a wide frequency band. It can be seen that the radiation patterns on XZ plane are nearly omni-directional for the three frequencies, due to leakage of radiation by using of partial ground technique. The omni-directional radiation pattern provides freedom in transmitter and receiver location. The performance of linearly polarized antennas is often described in terms of *E* & *H* planes. The radiation patterns on the y-z plane are like a small electric dipole leading to bidirectional patterns in a very wide frequency band. With the increase of frequency, the radiation patterns become worse because of the increasing effects of the cross polarization [22-25]. It is found that the measured results are in good agreement with the simulated results.

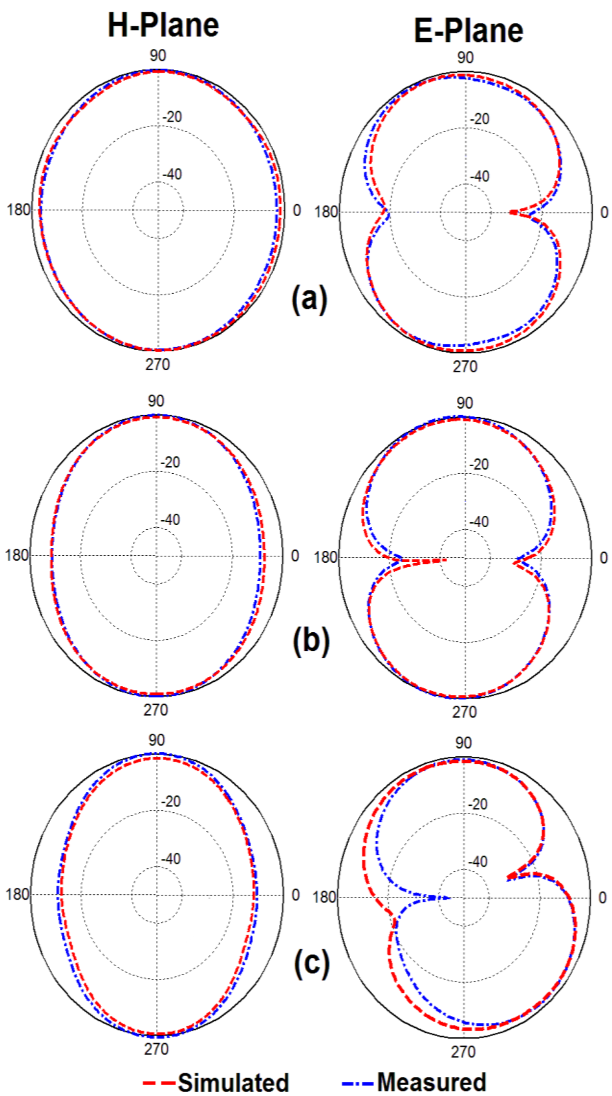

Fig. 9. Measured and simulated radiation patterns of the proposed antenna: (a) 4 GHz, (b) 7.5 GHz and (b) 11 GHz.

Measured and simulated maximum gain characteristics of the proposed antenna with and without band-notched function were shown in Fig. 10. As illustrated, a sharp decrease of maximum gain in the notched frequency band at 5.5 GHz is shown in Fig. 9. 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 level in the operation bands [26-30].

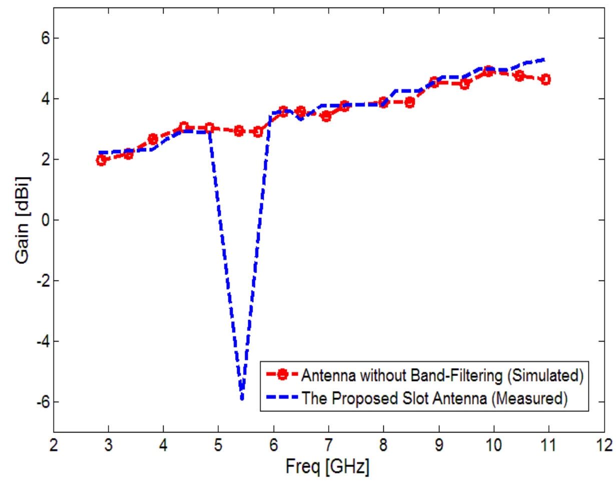

Fig. 10. Measured maximum gain characteristics of the proposed antenna.

IV. CONCLUSION

A novel small CPW-fed slot antenna with WLAN band-stop characteristics for UWB applications has been proposed. In this design, the proposed antenna bandwidth is from 2.85 to 11.93 GHz with a rejection band around 5.02 to 6.13 GHz. The proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. 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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