UWB Monopole Antenna with Dual Band-Notched Function

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Abstract **─** In this letter, an Ultra-Wideband (UWB) monopole antenna with dual frequency band-stop performance is designed and manufactured. In the proposed structure, by inserting an S-shaped parasitic structure inside a square slot in the ground plane a new resonance at higher frequencies can be achieved, which provides a wide usable fractional bandwidth of more than 125%. In order to generate dual band-notched function, we use four L-shaped strips protruded inside square ring. The measured results reveal that the antenna offers a very wide bandwidth from 2.63 to 14.2 GHz with two notched bands covering all the 5.2/5.8 GHz WLAN, 3.5/5.5 GHz WiMAX and 4 GHz C bands. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest.

Index Terms **─** Dual band-notched function, microstrip-fed antenna, protruded L-shaped strip, ultra-wideband communications.

I. INTRODUCTION

There has been more and more attention in Ultra-Wideband (UWB) antennas ever since the Federal Communications Commission (FCC)'s allocation of the frequency band 3.1-10.6 GHz for commercial use [1]. 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, constant group delay, low profile, easy manufacturing, etc. [2-4]. 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 [5-8].

There are many narrowband communication systems which severely interfere with the UWB communication system, such as the Worldwide Interoperability Microwave Access (WiMAX) operating at 3.3-3.7 GHz and 5.35-5.65 GHz, Wireless Local Area Network (WLAN) operating at 5.15-5.35 and 5.725-5.825 GHz, etc. Therefore, UWB antennas with band-notched characteristics to filter the potential interference are desirable. Nowadays, to mitigate this effect many UWB antennas with various band-notched properties have developed [9-10]. Many techniques are used to introduce notch band for rejecting the interference in the UWB antennas. It is done either by inserting protruded parasitic structures inside slots [11-12], using slots at radiating stub [13], or with reconfigurable split ring resonator [14].

All of the above methods are used for rejecting a single band of frequencies. However, to effectively utilize the UWB spectrum and to improve the performance of the UWB system, it is desirable to design the UWB antenna with dual band rejection. It will help to minimize the interference between the narrow band systems with the UWB system. Some methods are used to obtain the dual band rejection in the literature [15-18].

In this paper, a new and compact microstrip-fed monopole antenna with enhanced bandwidth and dual band-notched characteristics for UWB

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applications has been designed and manufactured. The proposed antenna has a small size of 12×18 mm^2, or about 0.15λ×0.25λ at 4.2 GHz (first resonance frequency), which has a size reduction of 28% with respect to the previous similar antenna [4-6].

II. ANTENNA DESIGN

The presented small square monopole antenna fed by a microstrip line is shown in Fig. 1 and printed on an FR4 substrate of thickness 0.8 mm, permittivity 4.4, and loss tangent 0.018. The basic monopole antenna structure consists of a square radiating patch, a feed line, and a ground plane. The proposed antenna is connected to a 50-Ω SMA connector for signal transmission.

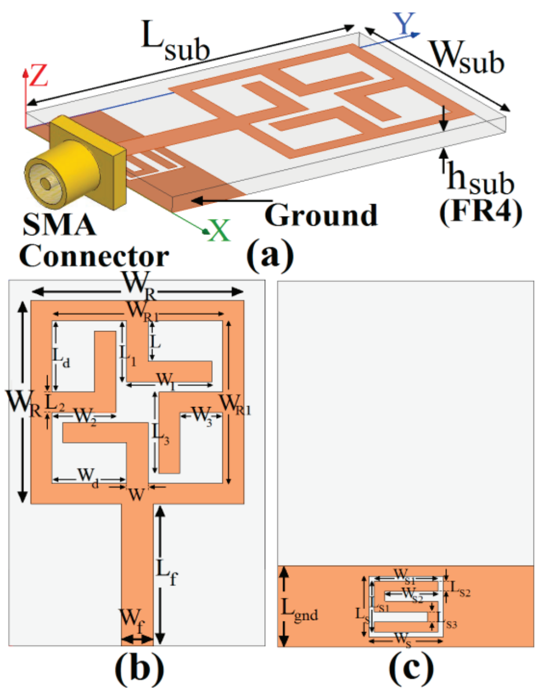

Fig. 1. Geometry of the proposed antenna :(a) side view, (b) top layer, and (c) bottom layer.

In this work, we start by choosing the dimensions of the designed antenna. These parameters including the substrate is W_{sub}×L_{sub}=12×18 mm^2 or about 0.15λ×0.25λ at 4.4 GHz (the first resonance frequency of the ordinary monopole antenna). We have a lot of flexibility in choosing the width of the radiating patch. This parameter mostly affects the antenna bandwidth. As W_R decreases, so does the antenna bandwidth, and vice versa. Next step, we have to determine the length of the radiating patch. This parameter is approximately $\lambda_{lower}/4$, where λ_{lower} is the lower bandwidth frequency wavelength. λ_{lower} depends on a number of parameters such as the monopole width as well as the thickness and dielectric constant of the substrate on which the antenna is fabricated.

The last and final step in the design is to choose the length of the resonator and the band-stop filter elements. In this design, the optimized length $L_{resonance}$ is set to resonate at $0.25\lambda_{resonance}$, where $L_{resonance}=W_{S2}+L_{S2}+0.5W_{S2}$. Also, the optimized length L_{notch} is set to band-stop resonate at $0.5\lambda_{notch}$, where $L_{notch1}=L_2+W_2+L_3+L_d$, and $L_{notch2}=L_1+W_1+2W$. λ_{notch1} and λ_{notch2} corresponds to first band-notch frequency (3.9 GHz) and second band-notch frequency (5.5 GHz), respectively.

In this study, the square slot with S-shaped parasitic structure inside slot in the ground plane is used to perturb an additional resonance at higher frequencies [19], and the L-shaped strips protruded inside square-ring radiating patch are used to give a dual frequency band-notch operation.

III. RESULTS AND DISCUSSIONS

The planar monopole 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 analysis and performance of the proposed antenna is explored by using Ansoft simulation software High-Frequency Structure Simulator (HFSS) [20], for better impedance matching. The final dimensions of the antenna parameters are specified in Table 1.

Table 1: Final dimensions of proposed antenna

Parameter	W_{sub}	L_{sub}	h_{sub}	W_R	L_{gnd}
Value (mm)	12	18	1.6	10	4
Parameter	W_{R1}	L_f	W_f	W	L
Value (mm)	8	7	1.5	0.5	2.5
Parameter	W_1	L_1	W_2	L_2	W_3
Value (mm)	4	3	3	0.5	0.5
Parameter	L_3	W_S	L_S	W_{S1}	L_{S1}
Value (mm)	4	3	3	2.5	2.5
Parameter	W_{S2}	L_{S2}	L_{S3}	L_d	W_d
Value (mm)	2	0.5	0.5	3.75	3.75

Geometry for the ordinary square monopole antenna [Fig. 2 (a)], with S-shaped parasitic structure inside square slot in the ground plane [Fig. 2 (b)], with S-shaped parasitic structure inside square slot in the ground plane and square ring radiating patch with a pair of L-shaped strips protruded inside square ring [Fig. 2 (c)], and the proposed antenna structure [Fig. 2 (d)] are shown in Fig. 2.

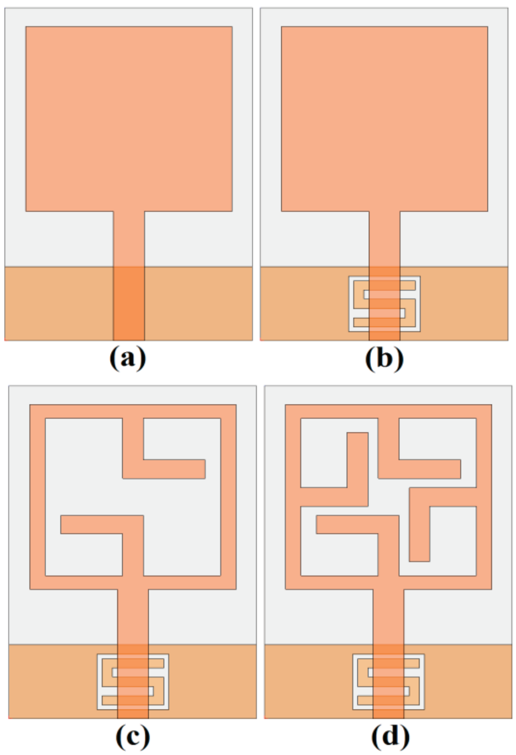

Fig. 2. Various structures for the proposed antenna: (a) ordinary square antenna, (b) with S-shaped parasitic structure inside square slot in the ground plane, (c) with S-shaped parasitic structure inside square slot and square ring radiating patch with a pair of L-shaped strips protruded inside the square ring, and (d) the proposed antenna.

VSWR characteristics for the structures that were shown in Fig. 2 are compared in Fig. 3. As shown in Fig. 3, it is observed by inserting an S-shaped parasitic structure inside the square slot in the ground plane the impedance bandwidth is effectively improved at the upper frequency; also, by creating a square-ring radiating patch with four L-shaped strips protruded inside ring, dual band-notch characteristic is generated.

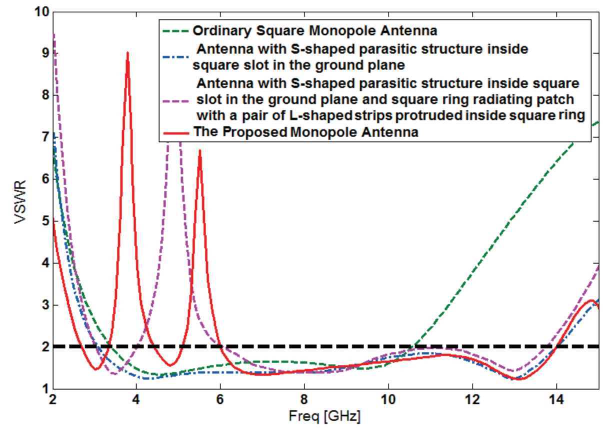

Fig. 3. Simulated VSWR characteristics for the various antennas shown in Fig. 2.

To understand the phenomenon behind this additional resonance performance, simulated current distributions in the ground plane for the proposed antenna at 13.1 GHz are presented in Fig. 4 (a). It is found that by using an S-shaped parasitic structure inside the square slot, third resonance at 13.1 GHz can be achieved. Another important parameter of this structure is the square-ring radiating patch with four L-shaped strips protruded inside the ring. Figures 4 (b) and (c) present the simulated current distributions on this radiating patch at the notched frequencies (3.8 & 5.5 GHz). As shown in Figs. 4 (b) and (c), at the notched frequencies the current flows are more dominant on the L-shaped strips inside the square-ring radiating patch [21-25].

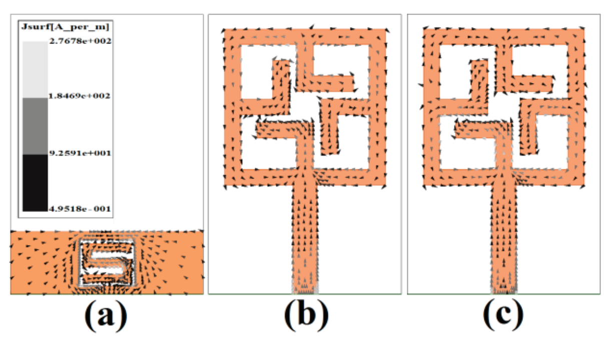

Fig. 4. Simulated surface current distributions on radiating patch for the proposed antenna: (a) in the ground plane at 10.95 GHz (new resonance frequency), (b) at radiating patch at 3.8 GHz (first notched frequency), and (c) at 5.5 GHz (second notched frequency).

The proposed microstrip monopole antenna with final design as shown in Fig. 5 was built and tested, and the VSWR characteristic was measured using a 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, a two-antenna technique using a 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).

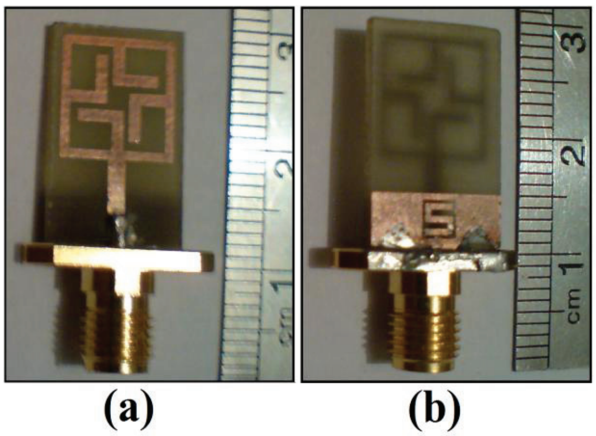

Fig. 5. Photograph of the realized printed monopole antenna: (a) top view, and (b) bottom view.

Figure 6 shows the measured and simulated VSWR characteristics of the proposed antenna. As shown, the fabricated antenna has the frequency band of 2.63 to 14.20 GHz with two rejection bands around 3.32-4.23 and 5.08-5.94 GHz. Figure 7 illustrates the measured radiation patterns, including the co-polarization, in H-plane (E_φ in x-y) and E-plane (E_θ in y-z). It can be seen that quasi-omnidirectional radiation pattern can be observed on x-z plane over the whole UWB frequency range for the three frequencies [26-27].

The radiation patterns on the y-z plane displays 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.

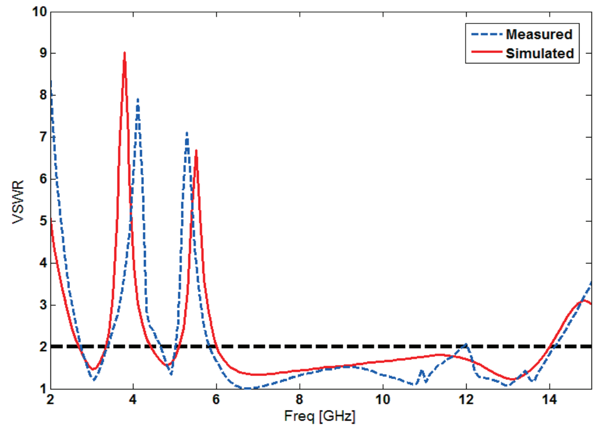

Fig. 6. Measured and simulated VSWR characteristics for the proposed antenna.

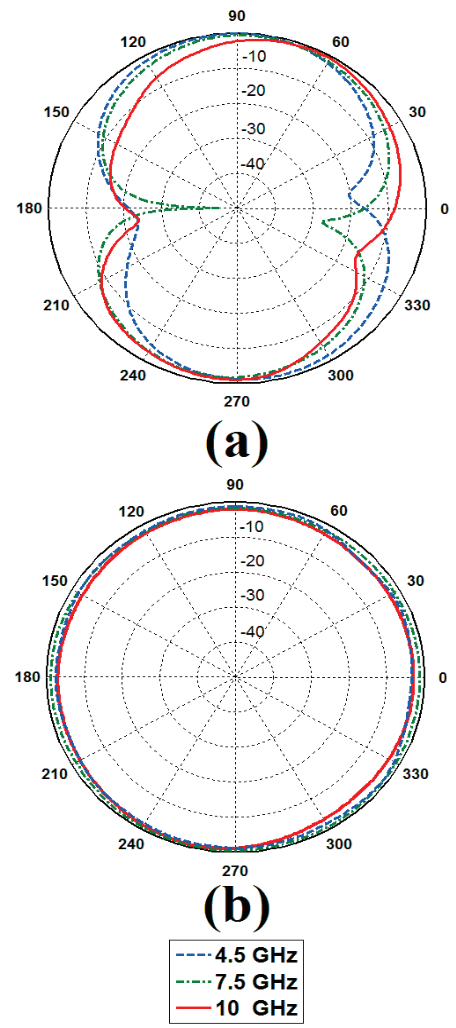

Fig. 7. Measured radiation patterns of the proposed antenna: (a) E_θ in y-z plane, and (b) E_φ in x-y plane.

Figure 8 shows the measured maximum gain for the proposed monopole antenna. Two sharp decreases of maximum gain in the notched frequencies band at 4 and 5.5 GHz are noticed [28-30].

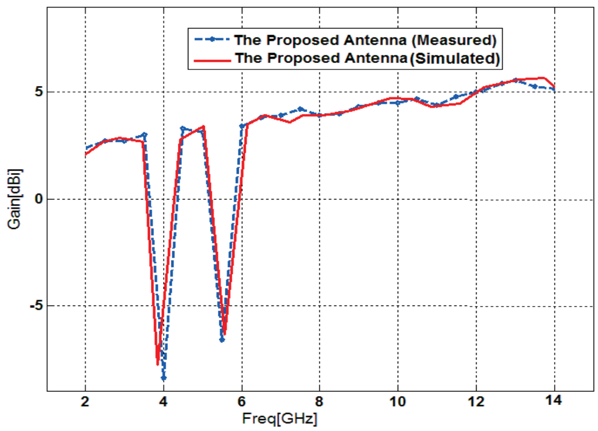

Fig. 8. Measured and simulated maximum gain for the proposed monopole antenna.

IV. CONCLUSION

In this paper, a novel small square monopole antenna with single and dual band-notched characteristics and wide bandwidth capability for UWB applications is analyzed. Proposed dual band-notched antenna can operate from 2.63 to 14.20 GHz with two rejection bands around 3.32-4.23 and 5.08-5.94 GHz. The designed antenna has small size. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest.

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