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A New Design of Monopole Antenna with 3.5/5.5 GHz Dual Band-Stop Function Using Protruded Strip Resonators

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Abstract

In this paper, a different method for designing an ultra-wideband (UWB) microstrip monopole antenna with dual band-notched characteristic has been presented. The main novelty of the proposed structure is the using of protruded strips as resonators to design an UWB antenna with dual band-stop property. In the proposed design, by cutting the rectangular slot with a pair of protruded T-shaped strips in the ground plane, additional resonance is excited and much wider impedance bandwidth can be produced. To generate a single band-notched function, we convert the square radiating patch to the square-ring structure with a pair of protruded step-shaped strips. By cutting a rectangular slot with the protruded Γ-shaped strip at the feed line, a dual band-notched function is achieved. The measured results reveal that the presented dual band-notched antenna offers a very wide bandwidth from 2.8 to 11.6 GHz, with two notched bands, around of 3.3-3.7 GHz and 5-6 GHz covering all WiMAX and WLAN bands.

Keywords: Dual band-notched antenna, protruded strip, WiMAX, WLAN, UWB system.

I. INTRODUCTION

UWB Communication systems usually require smaller antenna size in order to meet the miniaturization requirements of the radio-frequency (RF) units [1]. It is a well-known fact that planar antennas present really appealing physical features, such as simple structure, small size, and low cost. Due to all these interesting characteristics, planar antennas are extremely attractive to be used in emerging UWB applications, and growing research activity is being focused on them. Consequently, a number of planar microstrip antennas with different geometries have been experimentally characterized [2-4].

The frequency range for UWB systems between 3.1–10.6 GHz [5] will cause interference to the existing wireless communication systems for example the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15–5.35 GHz and 5.725–5.825 GHz bands, the worldwide interoperability microwave access (WiMAX) operating in 3.3–3.7 GHz and 5.35-5.65 GHz, so the UWB antenna with a band-notched function is required. Lately to generate the frequency band-notched function, several band-notched microstrip antennas have been reported [6-9].

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 [10-14].

In this paper a novel method for designing a compact microstrip-fed monopole antenna with dual band-notched characteristic for UWB applications has been proposed. The proposed antenna consists of a square-ring radiating stub with a pair of protruded step-shaped strips, a feed-line with an inverted Γ-shaped strip protruded inside the rectangular slot, and a ground plane with a pair of protruded T-shaped strips inside the rectangular slot. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest. In this paper, the antenna structure was described in Section II. Section III discusses the simulation and measurement results. Finally, the conclusion is provided in Section IV.

II. ANTENNA DESIGN

The presented small monopole antenna fed by a microstrip line as shown in Fig. 1 is printed on an FR4 substrate of thickness 1.6 mm, permittivity 4.4, and loss tangent 0.018. The basic monopole antenna structure consists of a square patch, a feed line, and a ground plane. The square patch has a width W. The patch is connected to a feed line of width W_f and length L_f. On the other side of the substrate, a conducting ground plane is placed. The proposed antenna is connected to a 50Ω- SMA connector for signal transmission.

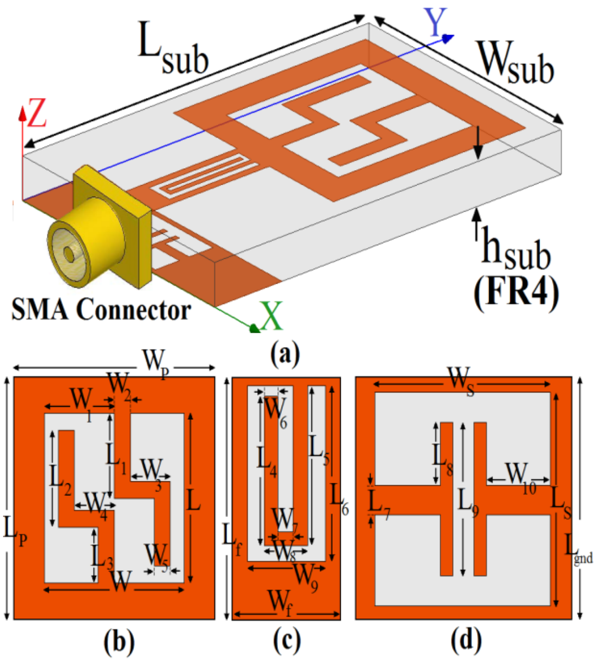

Fig. 1 Geometry of proposed antenna (a) side view, (b) radiating patch, (c) feed-line, (d) modified ground plane

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 final dimensions of the designed antenna are specified in Table I.

Table. 1. Final dimensions of the antenna.

Parameter	W_{sub}	L_{sub}	L_{gnd}	L_f	W_f
(mm)	12	18	3.5	7	2
Parameter	W_P	L_P	W_S	L_S	W
(mm)	10	10	4	3	8
Parameter	L	W_1	L_1	W_2	L_2
(mm)	8	4	4	1	3.85

Parameter	W_3	L_3	W_4	L_4	W_5
(mm)	2	3	2	4.5	1
Parameter	L_5	W_6	L_6	W_7	L_7
(mm)	4.65	0.25	4.8	0.5	0.5
Parameter	W_8	L_8	W_9	L_9	W_{10}
(mm)	1	0.75	1.5	2	1.5

II. 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.

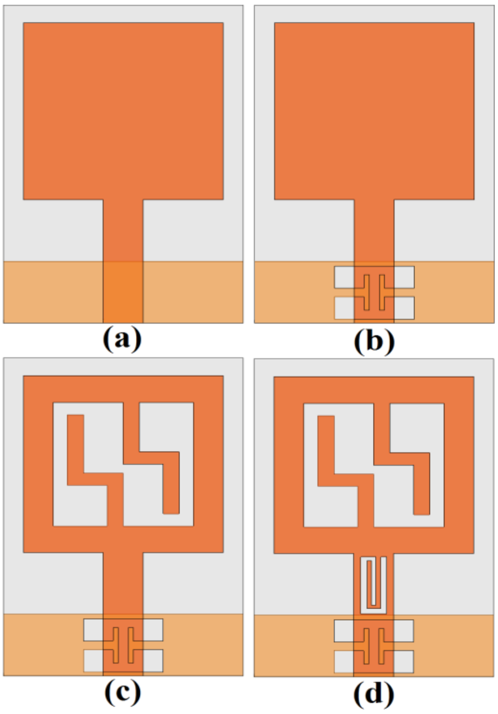

Fig. 2 (a) Ordinary monopole antenna, (b) the antenna with a pair of T-shaped strips protruded inside the slot in the ground plane, (c) the square-ring antenna with pairs of protruded step-shaped and T-shaped strips, and (d) the proposed antenna structure

VSWR characteristics for the ordinary monopole antenna (Fig. 2(a)), the antenna with a pair of T-shaped strips protruded inside the slot at ground plane (Fig. 2(b), the square-ring antenna with a pair of protruded step-shaped strips and a pair of T-shaped strips protruded inside the slot at ground plane (fig. 2(c), and the proposed antenna structure (Fig. 2(d) are compared in Fig. 3.

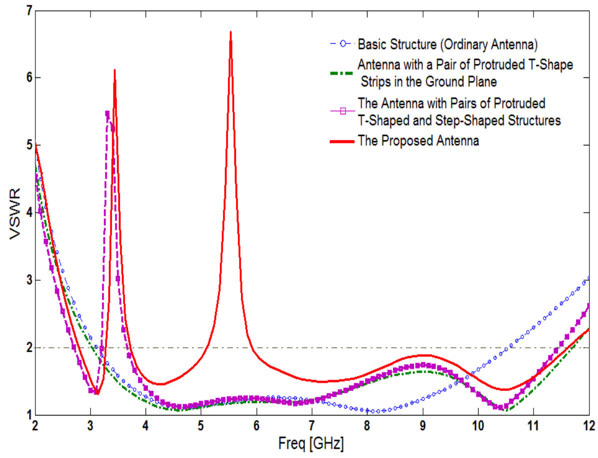

Fig. 3 Simulated VSWR characteristics of the various structures of the presented antenna.

As shown in Fig. 3, by using the pair of T-shaped strips at the ground plane, a new resonance at the higher frequency (10.5 GHz) is generated and the usable upper frequency of the antenna is extended from 10.5 GHz to 11.6 GHz. To generate a single frequency band-notched function, we convert the square radiating patch to the square-ring structure with a pair of protruded step-shaped strips, and also by using an inverted Γ-shaped strip inside the rectangular slot at feed-line, the good dual band-notched function can be achieved which is covering the 3.5/5.5 GHz WiMAX/WLAN bands [11-13].

To understand the phenomenon behind the multi resonance and dual band-notched performances, the simulated current distribution on the ground plane for the proposed antenna at the new resonance frequency (9.5 GHz) and notched frequencies (3.5&5.5 GHz) is presented in Fig. 4. It can be observed on Fig. 4(a), the current concentrated on the edges of the interior and exterior of the T-shaped strips protruded inside the slot at 10.5 GHz. Therefore the antenna impedance changes at these frequencies due to the resonance properties of the proposed structure. As shown in Fig. 4 (b), the current direction on the reject structures is opposite to that on the nearby antenna structure, so the far fields produced by the currents on the reject structures and nearby antenna structure cancel out each other in the reject band. Fig. 4 (c) presents the simulated current distributions on the feed line at the second notched frequency (5.5 GHz). As seen, at the second notched frequency, the current flows are more dominant around of the rotated Γ-shaped strip. As a result, the desired high attenuation near the second notched frequency can be produced [16-17].

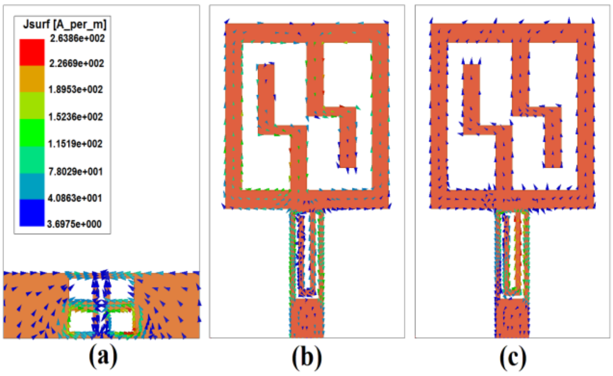

Fig.4. Simulated surface current distributions for the proposed antenna (a) at the extra resonance frequency (10.5 GHz), (b) at the first notched frequency (3.5 GHz), and (c) at the second notched frequency (5.5 GHz)

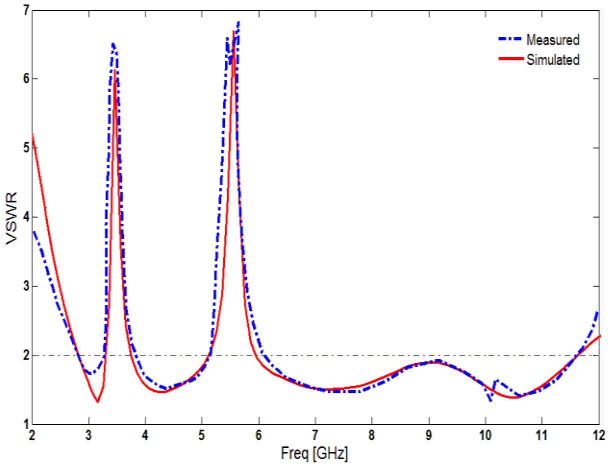

Fig. 5 Measured and simulated VSWR characteristics of the proposed antenna

The proposed antenna with final design was built and tested. Fig. 5 shows the measured and simulated VSWR characteristics of the proposed antenna. The antenna has the frequency band of 2.8 to 11.6 GHz with two rejection bands around 3.3.-3.7 and 5-6 GHz.

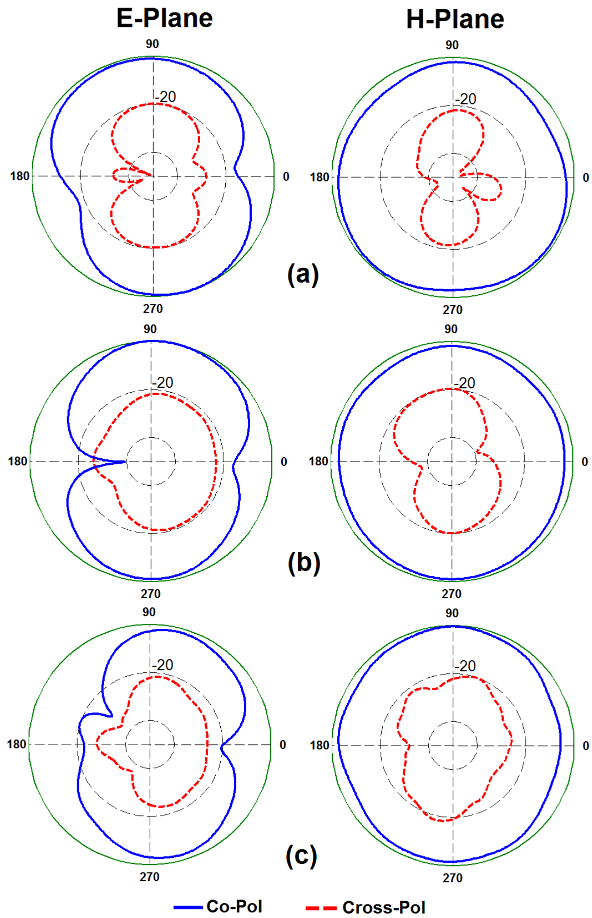

Fig. 6 Measured radiation patterns of the proposed antenna at (a) 4.5 GHz, (b) 7.5 GHz, and (c) 10.5 GHz.

Fig. 6 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 [18-20].

V. CONCLUSION

In this paper, a novel small monopole antenna with dual WiMAX/WLAN band-notched characteristic for UWB applications is proposed. In this design, the proposed antenna can operate from 3.01 to 10.70 GHz with two rejection bands around 3.3 to 3.7 GHz and 5 to 6 GHz. The designed antenna has a small size of $12 \times 18 \times 1.6$ mm^3. 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 application.

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