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Diamond-Shaped Monopole Antenna with WLAN Band-Stop Function for UWB Wireless Communications

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Abstract

In this study, a novel design of printed monopole antenna with band-notched function for ultra wide-band (UWB) applications is proposed .The antenna structure consists of a diamond-shaped radiating patch with stair-shaped slits and a ground plane with a pair of boomerang-shaped slots which provides a wide usable fractional bandwidth of more than 125% with notch band around 5.05-5.98 GHz. In the proposed design, by cutting a pair of boomerang-shaped slots in the ground plane, the usable upper frequency of the antenna is extended from 10.4 GHz to 14 GHz and a good impedance bandwidth can be obtained. To generate a band-notched characteristic, a pair of stair-shaped slits was cut at the diamond-shaped radiating patch. The simulated and measured results show that the antenna design exhibits an operating bandwidth (VSWR<2) from 3 to 14 GHz with the rejected band in 5-6 GHz to suppress any interference from wireless local area network (WLAN) systems. The antenna exhibits good radiation behavior within the UWB frequency range.

Keywords: Diamond-shaped antenna, monopole antenna, ultra-wideband Communication.

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, 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 [3-9].

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. Nowadays, to mitigate this effect many UWB antennas with various band-notched properties have developed [7-10]. Many techniques are used to introduce notch band for rejecting the interference in the UWB antennas [10-13].

In this paper, a new design of monopole antenna with WLAN band-notched function for UWB applications is proposed. In the proposed antenna, by using the diamond-shaped radiating patch an also by cutting a pair of boomerang-shaped slits in the ground plane, a good impedance bandwidth is obtained. I addition, by cutting a pair of stair-shaped slits at the diamond-shaped radiating patch, a single frequency band-notched performance can be achieved.

The notched frequency is controllable by changing the length of the embedded slits. So the designed antenna can be used in UWB systems to reduce interference between UWB and other wireless communication systems. The designed antenna has a small size. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest.

II. ANTENNA DESIGN

The structure of proposed monopole antenna fed by a microstrip line is shown in Fig. 1. The dielectric substance (*FR4*) with thickness of 1.6 mm with relative permittivity of 4.4 and loss tangent 0.018 is chosen as substrate to facilitate printed circuit board integration.

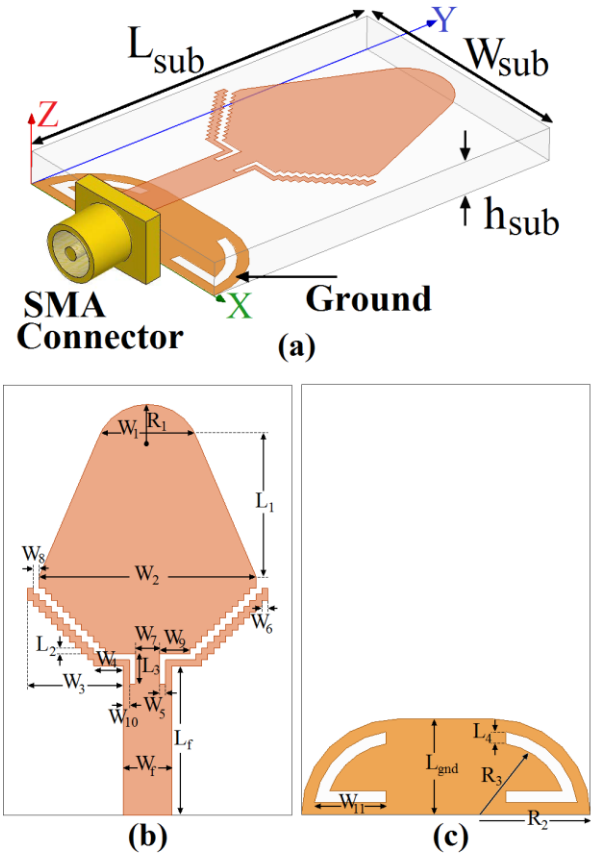

Fig.1. Structure of the proposed antenna, (a) side view, (b) top layer, and (c) bottom layer.

The structure of proposed monopole antenna fed by a microstrip line is shown in Fig. 1. The dielectric substance (*FR4*) with thickness of 1.6 mm with relative permittivity of 4.4 and loss tangent 0.018 is chosen as substrate to facilitate printed circuit board integration. The basic monopole antenna structure consists of a diamond-shaped radiating patch, a feed line, and a ground plane. The proposed antenna is connected to a 50-Ω SMA connector for signal transmission. The radiating patch is connected to a feed line of width W_f and length L_f .The width of the microstrip feed line is fixed at 2 mm, as shown in Fig. 1. On the other side of the substrate, a conducting ground plane with width of W_{sub} and length of L_{gnd} is placed. Final values of the presented design parameters are specified in Table. 1.

Table. 1. Dimensions of the designed Antenna

Parameter	W_{sub}	L_{sub}	h_{sub}	W_f
(mm)	18	12	1.6	2
Parameter	L_2	W_3	L_3	W_4
(mm)	0.25	4	1.25	1.25
Parameter	W_7	W_8	W_9	W_{10}
(mm)	1	0.25	1.25	0.25
Parameter	L_f	W_1	L_1	W_2
(mm)	6.25	4.2	5.7	9
Parameter	L_4	L_{gnd}	W_5	W_6
(mm)	0.5	4	0.25	0.25
Parameter	W_{11}	R_1	R_2	R_3
(mm)	2.9	2.2	3	4

III. RESULTS AND DISCUSSIONS

In this section, the microstrip 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) [14], for better impedance matching.

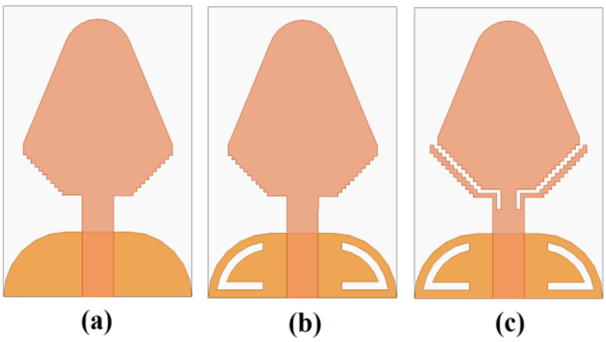

Fig.2. (a) Diamond-shaped monopole antenna, (b) diamond-shaped antenna with a pair of boomerang-shaped slots, and (c) the proposed antenna.

The structure of the various antennas used for simulation studies were shown in Fig. 2. VSWR characteristics for the diamond-shaped monopole antenna (Fig. 2(a)), the antenna with a pair of boomerang-shaped slots 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, by cutting the pair of boomerang-shaped slots in the ground plane, the usable upper frequency of the antenna is extended from 10.4 GHz to 14 GHz. In addition, the pair of stair-shaped slits was cut in the radiating patch are used to generate the WLAN frequency band-stop performance [15-17].

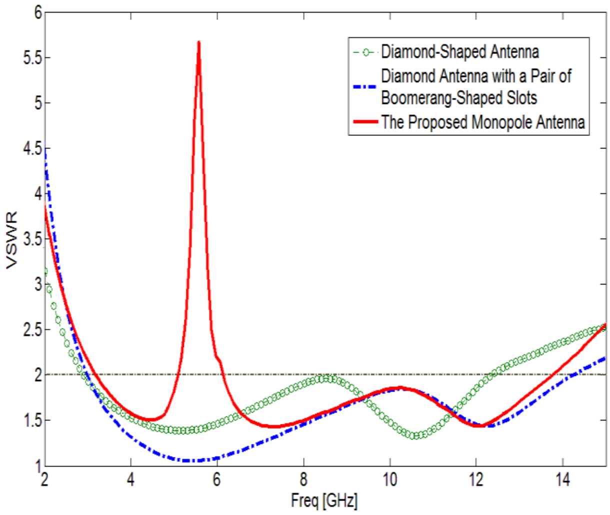

Fig.3. Simulated VSWR for the various structures shown in Fig. 2

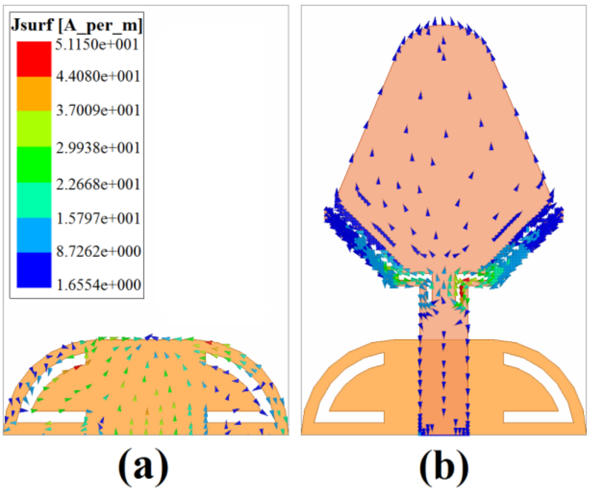

Fig.4. Simulated surface current distributions for the proposed antenna (a) in the ground plane at 12 GHz, (a) in the radiating patch at 5.5 GHz

The upper frequency bandwidth is significantly affected using the pair of boomerang-shaped slots in the ground plane. This behavior is mainly due to the change of surface current path in the ground plane as shown in Fig. 4 (a). The simulated current distribution for the proposed antenna at the notched frequency of 5.5 GHz is presented in Fig. 4 (b). As illustrated, the current mainly flows around the outer and inner of the pair of stair-shaped slits at the radiating patch results the stop-band property. [18-23].

The simulated VSWR curves with different values of L_3 are plotted in Fig. 5. As shown in Fig. 5, when the length of stair-shaped slits increases from 1 to 2 mm, the center of notched frequency is decreased from 6.5 to 4.5 GHz. From these results, we can conclude that the notched frequency is controllable by changing the length of the embedded slits at the radiating patch of the proposed antenna.

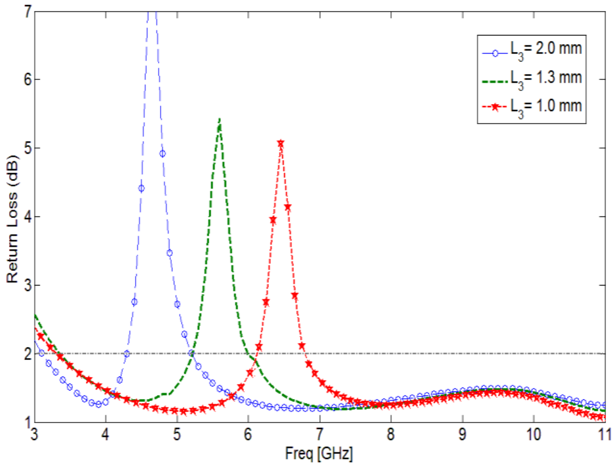

Fig.5. Simulated VSWR characteristic with different values of L3.

Fig. 6 shows the radiation patterns including the co-polarization and cross-polarization in the *H*-plane (*x*-*z* plane) and *E*-plane (*y*-*z* plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. It can be seen that the radiation patterns in *x*-*z* plane are nearly omnidirectional for the three frequencies. With the increase of frequency, the radiation patterns become worse because of the increasing effects of the cross polarization [24-30].

Fig. 7 shows the measured and simulated VSWR characteristics of the proposed antenna. As can be observed the antenna has a good frequency response in the frequency band of 3.01 to over 14.02 GHz. It also has a notched band around of 5-6 GHz of WLAN systems.

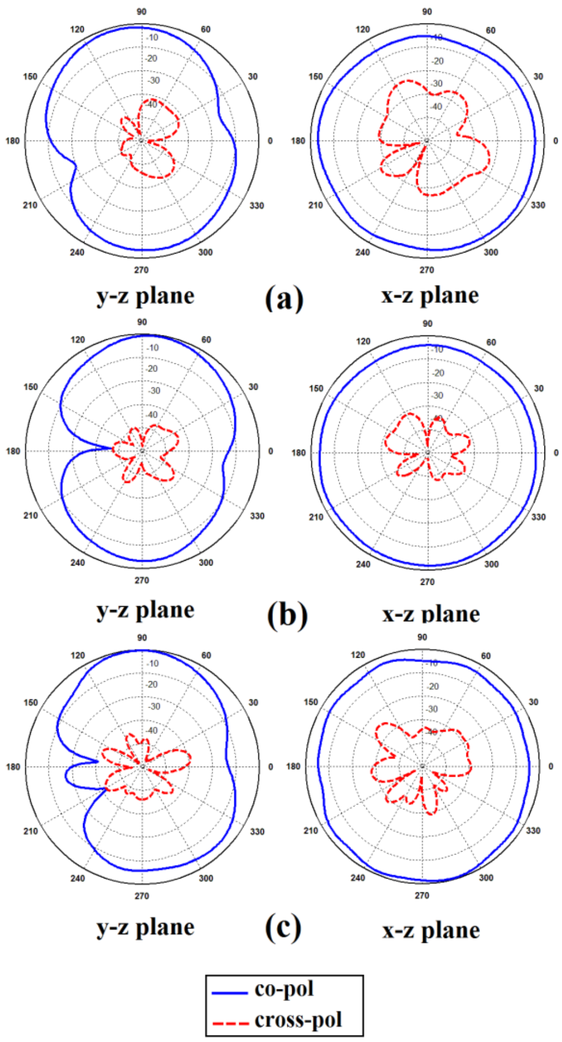

Fig.6. Radiation patterns of the proposed antenna, (a) 4 GHz, (b) 8 GHz, and (c) 12 GHz

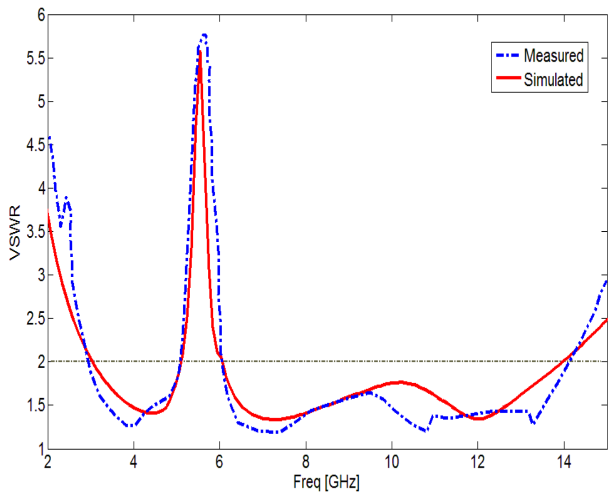

Fig.7. Measured and simulated VSWR characteristic for the proposed antenna

IV. CONCLUSION

In this paper, a new diamond-shaped monopole with enhanced bandwidth and variable stop-band notch characteristics for various UWB applications is proposed. The fabricated antenna has the frequency band of 3 GHz to over 14 GHz with a rejection band around 5-6 GHz. The proposed antenna has a simple configuration and small size. The proposed antenna configuration is simple, easy to fabricate and can be integrated into any UWB system.

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