Band-Notched Small Monopole Antenna using Triple E-Shaped Structures for UWB Systems

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Abstract ─ In this letter, a novel ultra wideband monopole antenna with frequency band-stop performance is designed and manufactured. The proposed antenna consists of two E-shaped structures in the radiating patch with a rotated E-shaped slot in the ground plane. The rotated E-shaped slot increases the bandwidth that provides a wide usable fractional bandwidth of more than 110% (3.05-11.50 GHz). In order to create band-rejected function, we use an E-shaped structure in the radiating patch and also by inserting a rotated coupled E-shaped strip we can improve band-notched performance and a frequency notch band of 5.07–5.92 GHz has been achieved. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications.

Index Terms ─ Band-Notched Function, E-Shaped Structure, Printed Monopole Antenna (PMA), Ultra-Wideband (UWB) Communications.

I. INTRODUCTION

Communication systems usually require smaller antenna size in order to meet the miniaturization requirements of radio-frequency (RF) units [1]. It is a well-known fact that planar monopole antennas present really appealing physical features such as simple structure, small size, and low cost. Due to all these interesting characteristics, planar monopole 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 monopoles with different geometries have been experimentally characterized [2]-[5].

The frequency range for UWB systems between 3.1–10.6 GHz 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, so the UWB antenna with a band-notched function is required. Lately to generate the frequency band-notched function, several modified planar antennas with band-stop characteristic have been reported [6]-[11]. In [6]-[9], different shapes of the slots (i.e., rectangular, square ring, W-shaped and folded trapezoid) are used to obtain the desired band-notched characteristics. Single and multiple [10] half-wavelength U-shaped to generate the frequency band-notched function, modified planar slits are embedded in the radiation patch to generate the single and multiple band-notched functions,

Submitted On: July 25, 2012
Accepted On: Oct. 24, 2012

respectively. In [11], band-stop function is achieved by using a T-shaped coupled parasitic element in the ground plane.

In this letter, a different method for designing a novel and compact microstrip-fed monopole antenna with band-notched characteristic for UWB applications has been presented. In the proposed antenna for bandwidth enhancement, we use a rotated E-shaped slot in the ground plane and by using two E-shaped structures with variable dimensions in the radiating patch a band-stop performance can be created. The presented monopole antenna has a small size of 12×18 mm^2.

II. ANTENNA DESIGN

The presented small monopole antenna fed by a microstrip line is shown in Fig. 1, which 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 $L_f + L_{gnd}$. 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 of width and length is placed. The proposed antenna is connected to a 50Ω SMA connector for signal transmission.

In this study, based on defected ground structure (DGS), a rotated E-shaped slot in the ground plane is used to perturb an additional resonance at higher frequencies and increase the bandwidth [12]. Also, based on electromagnetic coupling theory (ECT), for generating band-stop performance we use two E-shaped structures in the radiating patch. In this structure, the coupled E-shaped strip is playing an important role in the band rejected characteristics of this antenna [13]. By inserting the coupled E-shaped strip, the desired high attenuation near the notch frequency can be produced.

The final values of proposed antenna design parameters are as follows: $W_{sub} = 12mm$, $L_{sub} = 18mm$, $h_{sub} = 1.6mm$, $W_f = 2mm$, $L_f = 3.5mm$, $W = 10mm$, $W_S = 4mm$, $L_s = 1.5mm$, $W_{S1} = 1.25mm$, $L_{S1} = 1mm$, $W_{S2} = 0.5mm$, $L_{S2} = 1.75mm$, $W_e = 1.5mm$, $L_e = 4.75mm$, $W_{e1} = 0.25mm$, $L_{e1} = 4.75mm$, $W_P = 6.5mm$, $L_P = 8mm$, $W_{P1} = 1.5mm$, $L_{P1} = 6mm$, $W_{P2} = 1.5mm$, $L_{P2} = 2mm$, $W_d = 1.2mm$, and $L_{gnd} = 3.5mm$.

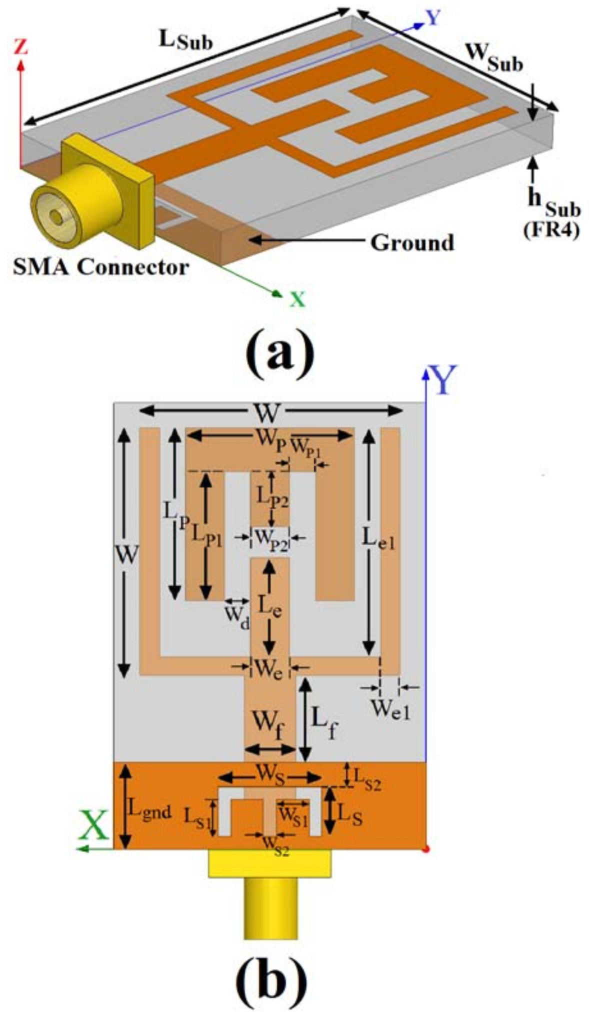

Fig. 1. Geometry of proposed slot antenna, (a) side view, (b) bottom view.

III. RESULTS AND DISCUSSIONS

The proposed microstrip Monopole antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The proposed microstrip-fed monopole antenna was fabricated and tested. The parameters of this proposed antenna are studied by changing one parameter at a time and fixing the others. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [14]. The configuration of the presented monopole antenna was shown in Fig. 1. Geometry for the ordinary square antenna (Fig. 2(a)), with a rotated E-shaped slot in the ground plane (Fig. 2(b)), E-shaped antenna with a rotated E-shaped slot in the ground plane (Fig. 2(c)) and the proposed antenna (Fig. 2(d)) structures are compared in Fig. 2.

Return loss characteristics for the structures that were shown in Fig. 2 are compared in Fig. 3. As shown in Fig. 3, it is observed that the upper frequency bandwidth is affected by using the rotated E-shaped slot in the ground plane and the notched frequency bandwidth is sensitive to the coupled E-shaped strip on the radiating patch. Also the input impedance of the various monopole antenna structures that studied on Fig. 3, on a Smith Chart is shown in Fig. 4.

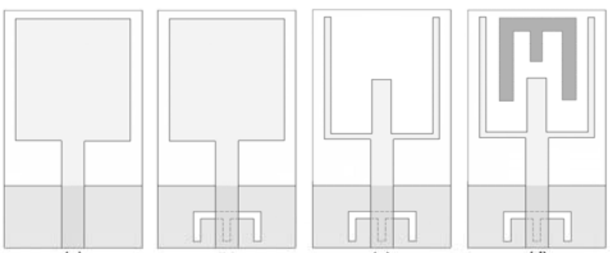

Fig. 2. (a) Ordinary square antenna, (b) with a rotated E-shaped slot in the ground plane, (c) E-shaped antenna with a rotated E-shaped slot in the ground plane, and (d) the proposed antenna structure.

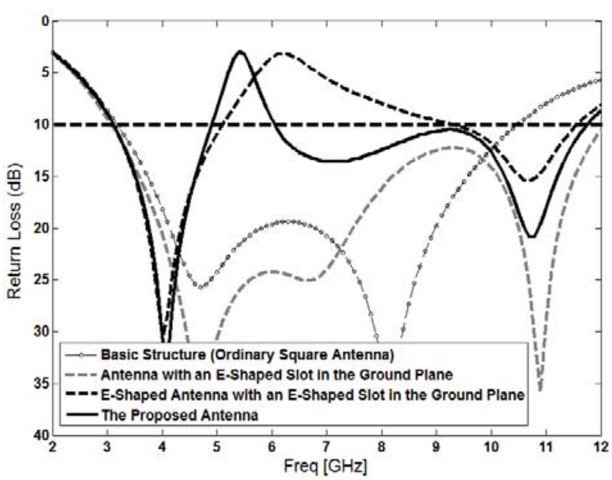

Fig. 3. Simulated return loss characteristics for the antennas shown in Fig. 2.

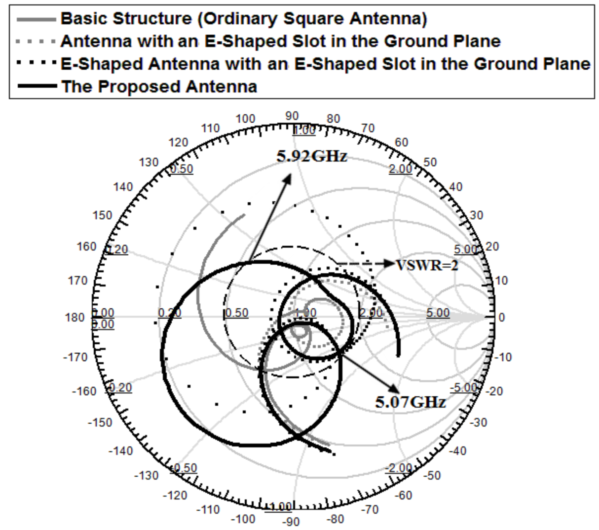

Fig. 4. The simulated input impedance on a Smith chart of the various monopole antennas structures shown in Fig. 2.

In order to understand the phenomenon behind this additional resonance performance, the simulated current distributions on the ground plane for the proposed antenna at 10.9 GHz are presented in Fig. 5(a). It is found by cutting a rotated E-shaped slot in the ground plane, third resonance at 10.9 GHz can be achieved.

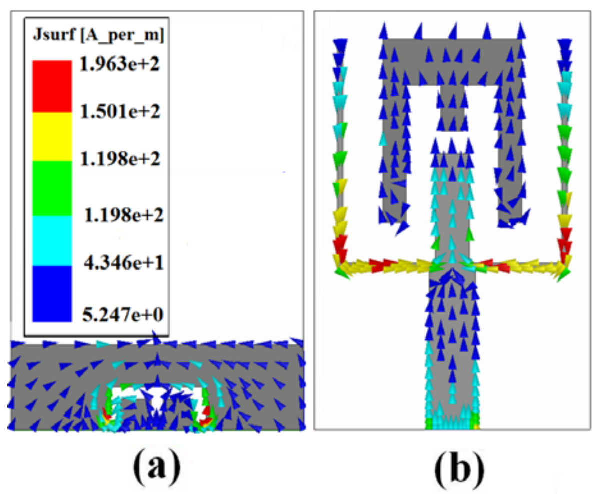

Fig. 5. Simulated surface current distributions for the proposed monopole antenna, (a) in the ground plane at 3.5 GHz, and (b) on the radiating patch at 5.5 GHz.

Other important design parameters of this structure are E-shaped structures on the radiating patch. Fig. 5(b) presents the simulated current distributions on the radiating patch at the notched frequency (5.5 GHz). As shown in Fig. 5(b), at the notched frequency the current flows are more dominant around of the E-shaped strip structures.

Figure 6 shows the simulated VSWR curves with different values of L_P. As shown in Fig. 6, when the exterior length of the coupled E-shaped strip increases from 5.5 to 9.5 mm, the center of notched frequency is decreases from 6.1 to 4.9 GHz. From these results, we can conclude that notched frequency is controllable by changing the exterior length of the coupled E-shaped strip.

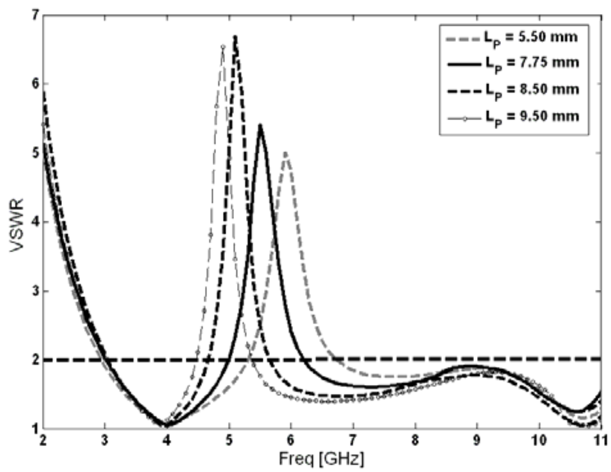

Fig. 6. Simulated VSWR characteristics for the proposed antenna with different values of L_P.

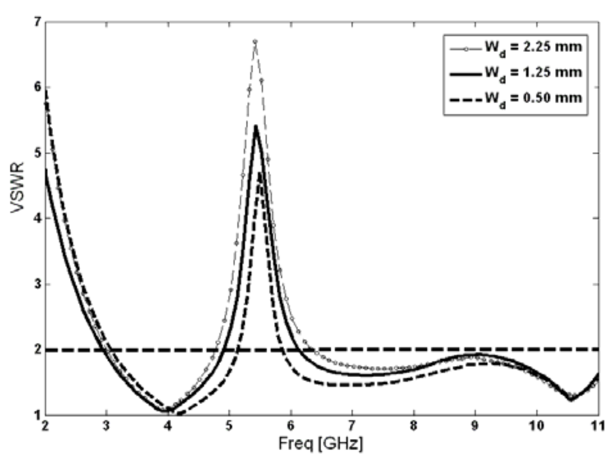

Fig. 7. Simulated VSWR characteristics for the proposed antenna with different values of W_d.

Another main effect of the coupled E-shaped strip occurs on the filter bandwidth. In this structure, the width of W_d is a critical parameter to control the filter bandwidth. Figure 7 illustrates the simulated VSWR characteristics with various length of W_d .When the width of W_d increases from 0.5 to 2.25 mm, the filter bandwidth is varied from 0.7 to 1.9 GHz. Therefore the bandwidth of notched frequency is controllable by changing the width of W_d.

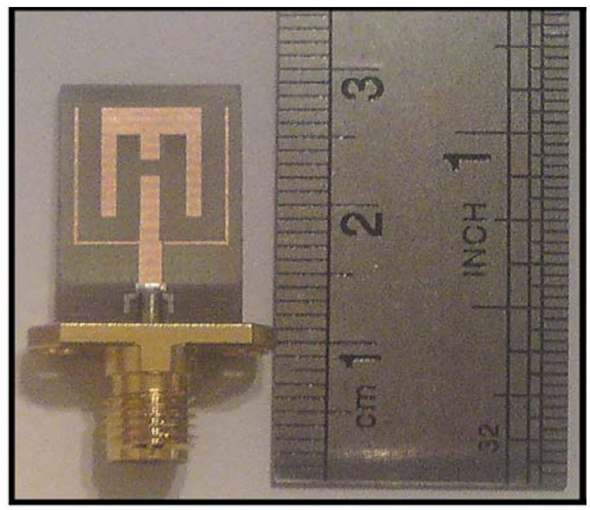

Fig. 8. Photograph of the realized printed monopole antenna.

The proposed antenna with final design, as shown in Fig. 8 was built and tested. Measured and simulated VSWR characteristics of the proposed antenna were shown in Fig. 9. The fabricated antenna has the frequency band of 3.05 to 11.5 GHz with a bad-stop function aroud of 5-6 GHz.

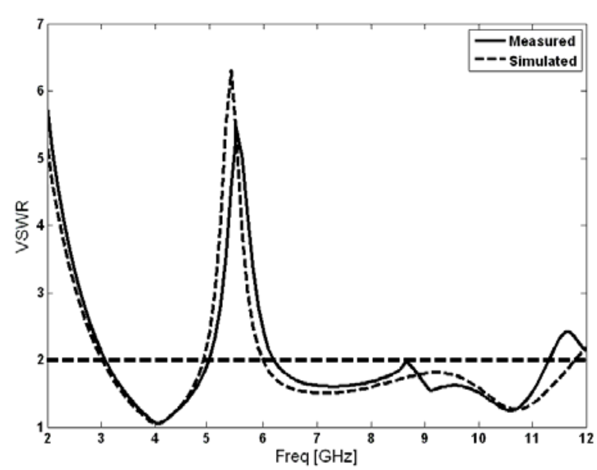

Fig. 9. Measured and simulated VSWR characteristics for the proposed antenna.

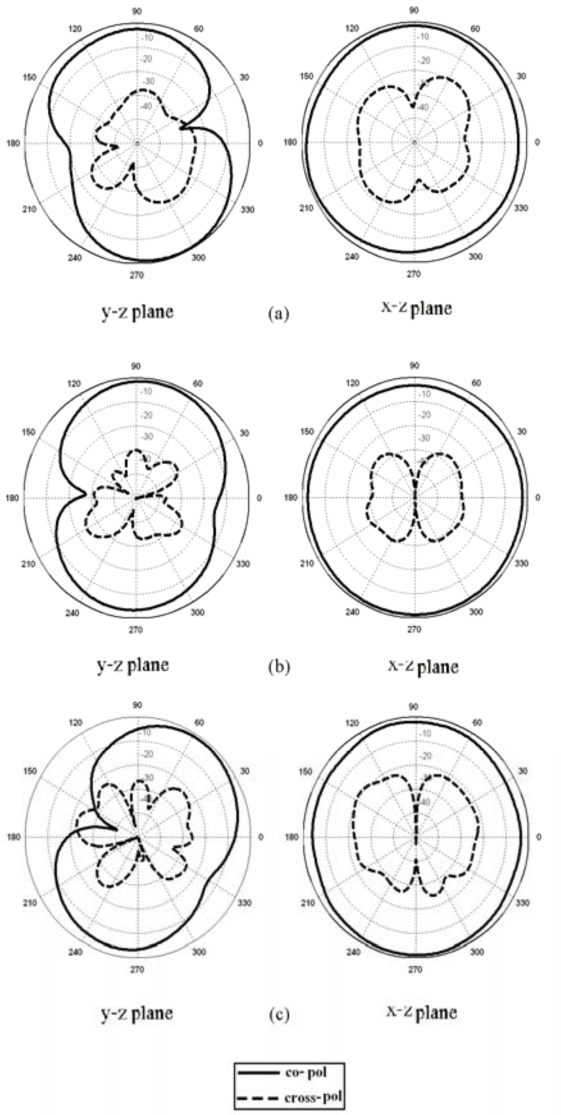

Fig. 10. Measured radiation patterns of the proposed antenna (a) 4 GHz, (b) 7 GHz, and (c) 10 GHz.

Figure 10 illustrates the measured radiation patterns, including co-polarization and cross-polarization in the H–plane (x-z plane) and E-plane (y-z plane). It can be seen that the radiation patterns in *x-z* plane are nearly omnidirectional for the three frequencies. The maximum gain of the proposed antenna was shown in Fig. 11. A sharp decrease of maximum gain in the notched frequency band at 5.5 GHz is shown in Fig. 11. For other frequencies outside the notched frequency band, the antenna gain with the filter is similar to those without it.

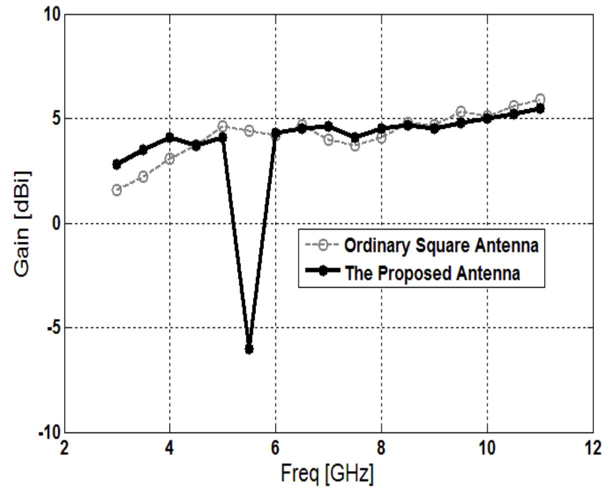

Fig. 11. Gain comparisons for the ordinary square antenna (simulated), and the proposed antenna (measured).

V. CONCLUSION

A new small printed monopole antenna (PMA) with band-notched function for UWB applications presented, in this paper. The proposed antenna can operate from 3.05 to 11.80 GHz with WLAN rejection band around 5.07–5.92 GHz. In order to enhance bandwidth, we cut a rotated E-shaped slot in the ground plane and also by using two E-shaped structures at the radiating patch a frequency band-notched function can be achieved and improved. The designed antenna has a small size of 12×18 mm^2. Simulated and experimental results show that the proposed antenna could be a good candidate for UWB applications.

ACKNOWLEDGMENT

The authors are thankful to Microwave Technology (MWT) company staff for their beneficial and professional help (www.microwave-technology.com).

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