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ULTRA-WIDEBAND SMALL SQUARE MONOPOLE ANTENNA WITH VARIABLE FREQUENCY BAND-NOTCH FUNCTION

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Abstract—In this paper, a novel printed monopole antenna for ultra wideband applications with variable frequency band-notch characteristic is presented. The proposed antenna consists of a stepped square radiating patch with modified W-shaped slot and a ground plane with rectangular sleeve and pair of L-shaped resonator which provides a wide usable fractional bandwidth of more than 130% (3.05–14.3 GHz). By cutting a modified W-shaped slot with variable dimensions on the radiating patch frequency band-stop performance is generated and we can control its characteristics such as band-notch frequency and its bandwidth. The designed antenna has a small size of $12 \times 18\,\text{mm}^2$ while showing the band rejection performance in the frequency band of 5.08 to 5.91 GHz.

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1. INTRODUCTION

Commercial UWB systems require small low-cost antennas with omnidirectional radiation patterns and large bandwidth [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 monopoles are extremely attractive to be used in emerging UWB applications, and growing research activity is being focused on them.

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, number of planar monopoles with different geometries have been experimentally characterized [2–4] and automatic design methods have been developed to achieve the optimum planar shape [5, 6]. Moreover, other strategies to improve the impedance bandwidth which do not involve a modification of the geometry of the planar antenna have been investigated [7, 8].

The frequency range for UWB systems between 3.1 to 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-stop performance is required. Recently to generate the frequency band-notch function, modified planar monopoles are used [9–11].

In this letter, a new band-notched printed monopole antenna is presented. The notched band, covering the 5.08–5.91 GHz WLAN band, is provided by using a modified W-shaped slot. Also by inserting a sleeve and a pair of L-shaped resonator in the ground plane, much wider impedance bandwidth can be produced, especially at the higher band. Experimental and simulated results of the constructed prototype are presented.

2. ANTENNA DESIGN

The square monopole antenna is shown in Fig. 1, which is printed on a FR4 substrate of thickness 1.6 mm, permittivity 4.4, and loss tangent 0.0018. The width W_f of the microstrip feedline is fixed at 2 mm The basic antenna structure consists of a square patch, a feedline, 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, as shown in Fig. 1. On the other side of the substrate, a conducting ground plane of width W_{sub} and length L_{gnd} is placed. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission.

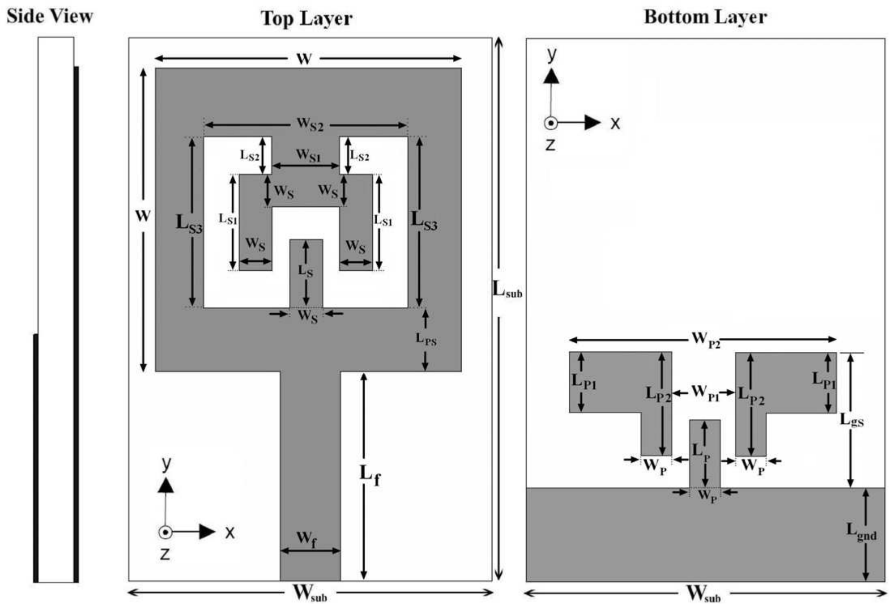

Figure 1. Geometry of proposed antenna.

The notched ground plane with sleeve and L-shaped is playing an important role in the broadband characteristics of this antenna, because they can adjust the electromagnetic coupling effects between the patch and the ground plane, and improves its impedance bandwidth without any cost of size or expense [12, 13].

The W-shaped slot perturbs the resonant response and also acts as a half-wave resonant structure [10]. At the notch frequency, the current concentrated on the edges of the interior and exterior of the W-shaped slot. As a result, the desired high attenuation near the notch frequency can be produced. The variable band-notch characteristics can be achieved by carefully choosing the parameters (L_{S1} and W_{S2}) for the W-shaped slot. In this structure, the width W_{S2}, is the critical parameter to control the filter bandwidth. On the other hand, the center frequency of the notched band is insensitive to the change of W_{S2}. The resonant frequency of the notched band is determined by L_{S1}.

3. RESULTS AND DISCUSSIONS

3.1. UWB Monopole Antenna

In this section, the planar 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 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 optimal dimensions of the designed antenna are as follows: $W_{sub} = 12\,\text{mm}$, $L_{sub} = 18\,\text{mm}$, $W = 10\,\text{mm}$, $W_f = 2\,\text{mm}$, $L_f = 7\,\text{mm}$, $L_{PS} = 2\,\text{mm}$, $L_{S3} = 5\,\text{mm}$, $W_{S2} = 6\,\text{mm}$, $L_{S2} = 1\,\text{mm}$, $W_{S1} = 2\,\text{mm}$, $L_{S1} = 3\,\text{mm}$, $W_S = 1\,\text{mm}$, $L_S = 2\,\text{mm}$, $W_P = 1\,\text{mm}$, $L_P = 2.5\,\text{mm}$, $W_{P1} = 3\,\text{mm}$, $L_{P1} = 2\,\text{mm}$, $W_{P2} = 10\,\text{mm}$, $L_{P2} = 3.5\,\text{mm}$, $L_{gS} = 4.5\,\text{mm}$, and $L_{gnd} = 3.5\,\text{mm}$.

Figure 2 shows the structure of the various square antennas. As shown in Fig. 2, it is observed that the upper frequency bandwidth is affected by using the rectangular sleeve in the ground plane and the upper and lower frequency bandwidth is sensitive to the L-shaped resonator on the backed plane.

The simulated current distributions on the ground plane for the various antennas as studied in Fig. 2 at 12.5 GHz are presented in

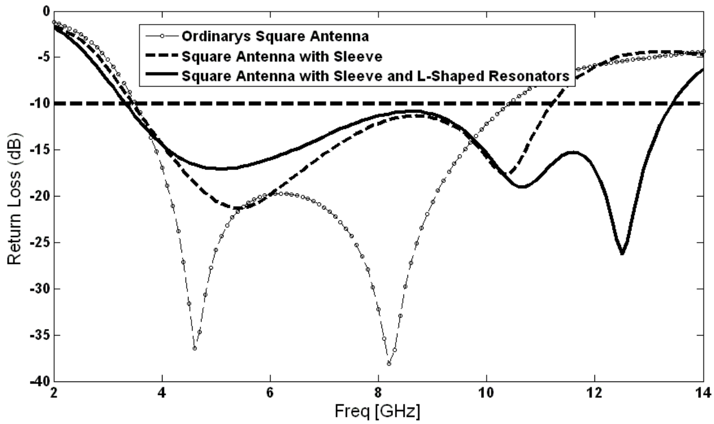

Figure 2. Simulated return loss characteristics for various square antennas. (a) The ordinary square antenna, (b) the square antenna with rectangular sleeve in the ground plane (c) the square antenna with rectangular sleeve and L-shaped resonator in the ground plane.

Fig. 3. It can be observed on Fig. 3(c) that the current concentrated on the edges of the interior and exterior of the L-shaped resonator at 12.5 GHz. Therefore the antenna impedance changes at this frequency due to the resonant properties of the L-shaped resonator. It is found out that by using this structure the third resonance occur at 12.5 GHz in the simulation.

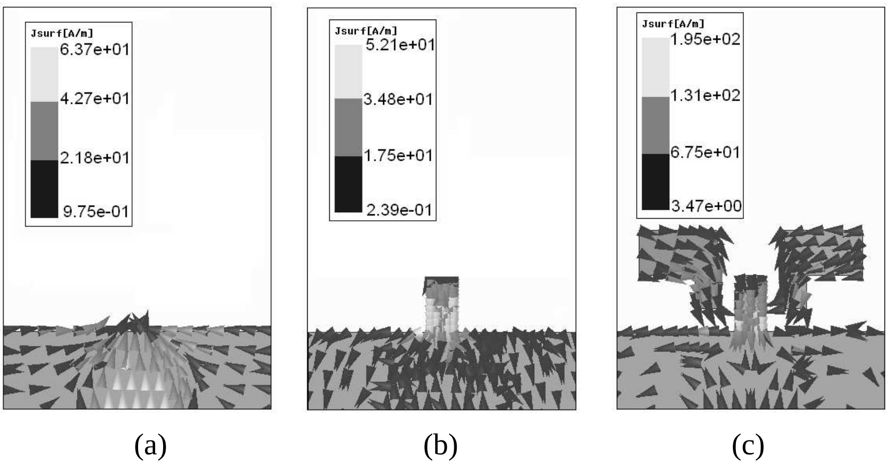

Figure 3. Simulated surface current distributions on the backed plane for the antennas studied in Fig. 2 at 12.5 GHz.

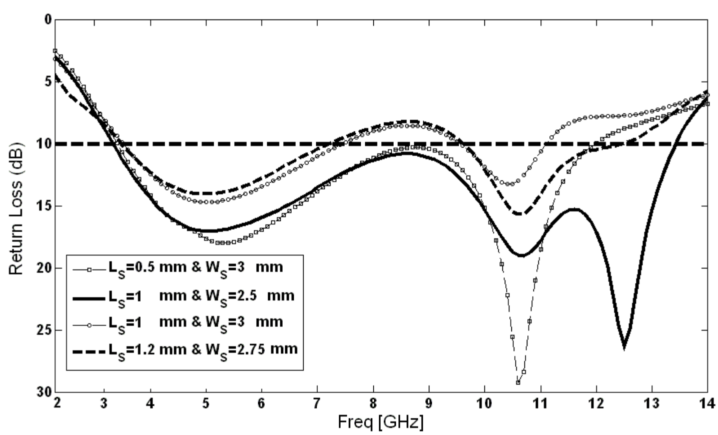

Figure 4. Simulated return loss characteristics for various values of sleeve dimension.

In this study, in order to enhance the impedance bandwidth characteristic a sleeve and two L-shaped resonators are inserted in the backed plane of the proposed antenna as displayed in Fig. 1.

Figures 4 and 5 show the effects of sleeve dimension and exterior length of L-shaped resonator on the impedance matching, respectively. From the simulation results in Fig. 4, it is found that the impedance bandwidth is improved at the upper frequency.

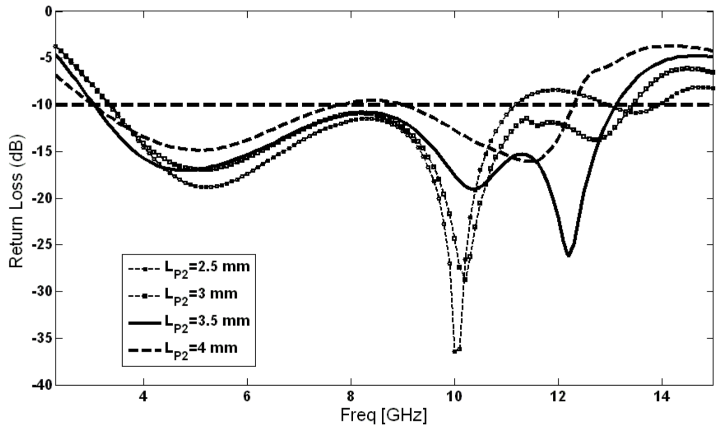

Figure 5. Simulated return loss characteristics for various values of L_{P2}.

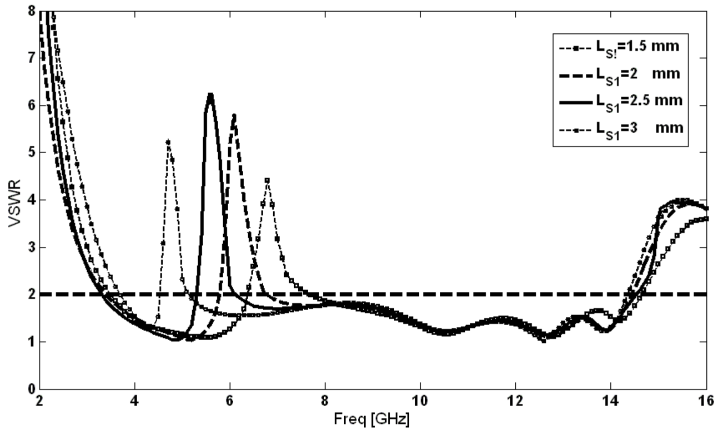

Figure 6. Simulated VSWR characteristic for various values of L_{S1}.

3.2. UWB Monopole Antenna with Variable Frequency Band-notch Characteristic

The simulated VSWR curves with different values of L_{S1} are plotted in Fig. 6. As shown in Fig. 4, when the interior height of the W-shaped slot increases from 1.5 to 3 mm, the center frequency of notched band is decreases from 6.9 to 4.8 GHz. From these results, we can conclude that the notch frequency is controllable by changing the interior height of the W-shaped slot.

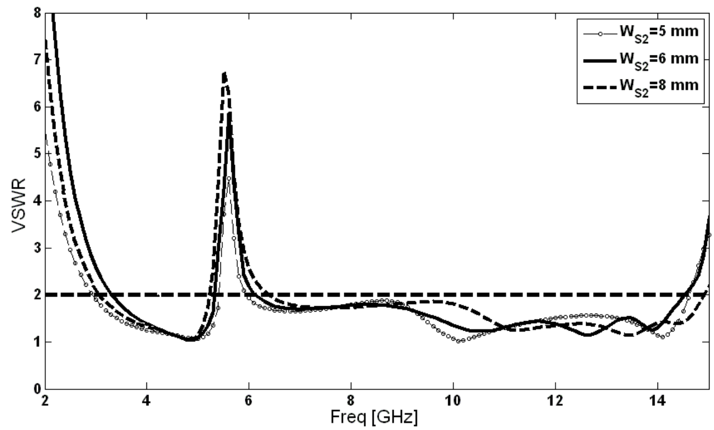

Figure 7. Simulated VSWR characteristic for various values of W_{S2}.

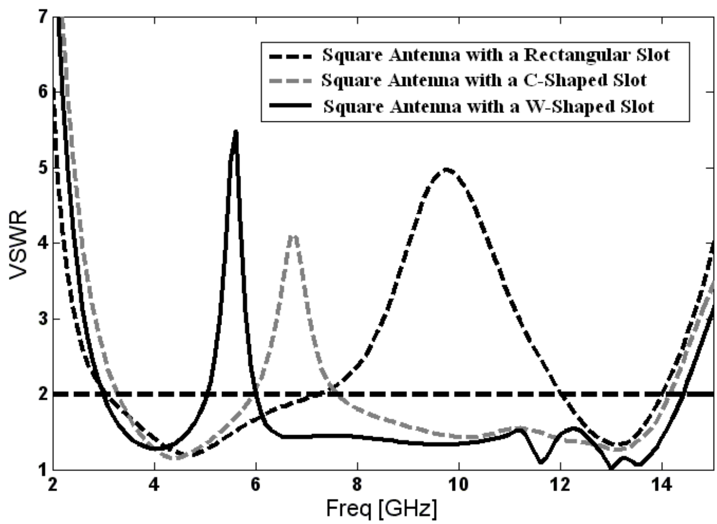

Figure 8. Simulated return loss characteristics for antennas shown in Fig. 8.

Figure 7 illustrates the simulated VSWR characteristics with various values of W_{S2}. As the width of the W-shaped slot increases from 5 to 8 mm, the filter bandwidth is varied from 0.8 to 1.3 GHz.

Figure 8 shows the simulated VSWR curves for the UWB square antenna with various slots. It can be observed in Fig. 8 that by using W-shaped slot the notched band central frequency is affected by using various slots in the radiating patch, therefore by using W-shaped slot the notch function in WLAN band can be obtained with a small size antenna, and also by using W-shaped slot the VSWR amplitude in notched band can be increased. To understand the phenomenon behind this good notched band performance, Fig. 9 shows the simulated current distributions on the radiating patch for the UWB square antenna with various slots in the notched band central frequency. It can be observed in Fig. 9 that by using W-shaped slot the current concentrated on the edges of the interior and exterior of the W-shaped notch at 5.5 GHz. Therefore, the antenna impedance changes at this frequency due to the notched band properties of the W-shaped slot.

The proposed antenna with optimal design, as shown in Fig. 9, was built and tested in the Antenna Measurement Laboratory at Iran Telecommunication Research Center (ITRC). Figs. 10 and 11 show the measured and simulated VSWR and return loss characteristics of the proposed antenna, respectively. The fabricated antenna has the frequency band of 3.05 to over 14.3 GHz with a rejection band around 5.08 to 5.91 GHz. As shown in Figs. 10 and 11, there exists a discrepancy between measured data and the simulated results this could be due to the effect of the SMA port. In order to confirm the accurate VSWR and return loss characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

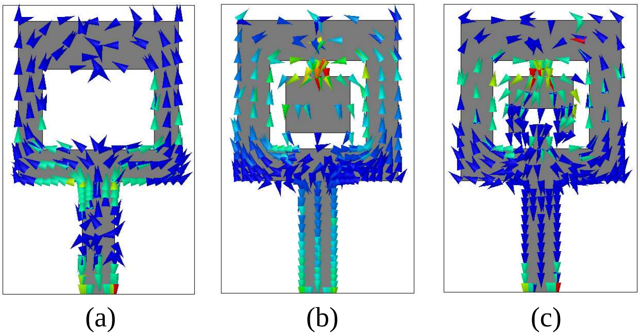

Figure 9. Simulated surface current distributions on radiating patch for the square antenna with various slots, (a) rectangular slot at 10 GHz at 5.5 GHz.

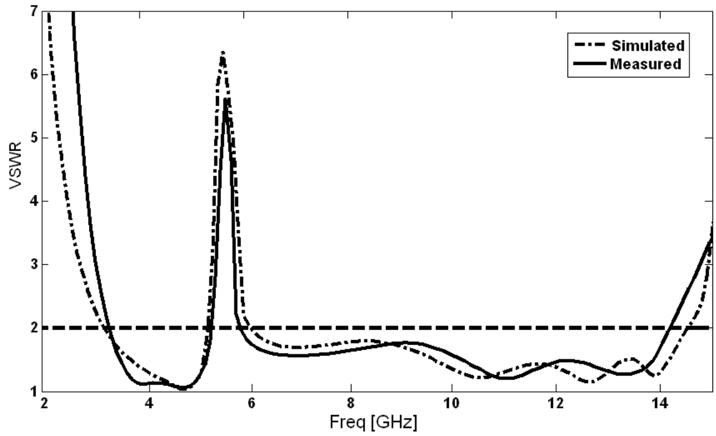

Figure 10. Measured and simulated VSWR for the proposed antenna.

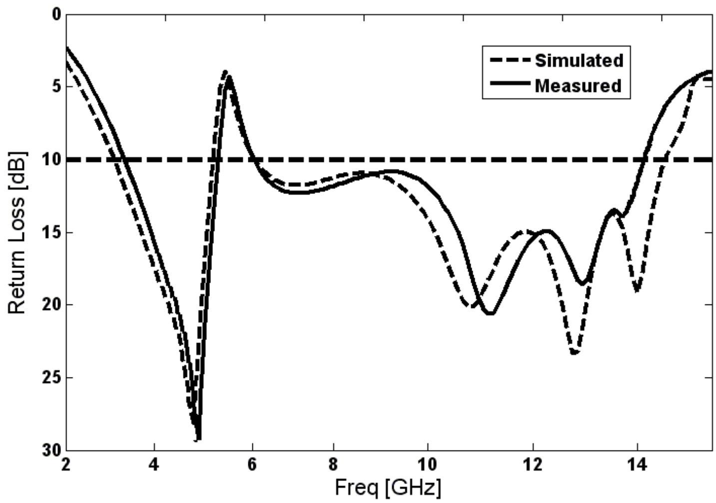

Figure 11. Measured and simulated return loss for the proposed antenna.

Figure 12 shows the measured radiation patterns including the co-polarization and cross-polarization in the H-plane (xz plane) and E-plane (y-z plane). It can be seen that the radiation patterns in xz plane are nearly omnidirectional for the three frequencies.

Figure 13 shows the measured maximum gain of the proposed antenna with and without W-shaped slots. A sharp decrease of maximum gain in the notched frequency band at 5.5 GHz is shown. For other frequencies outside the notched frequency band, the antenna gain with the filter is similar to those without it.

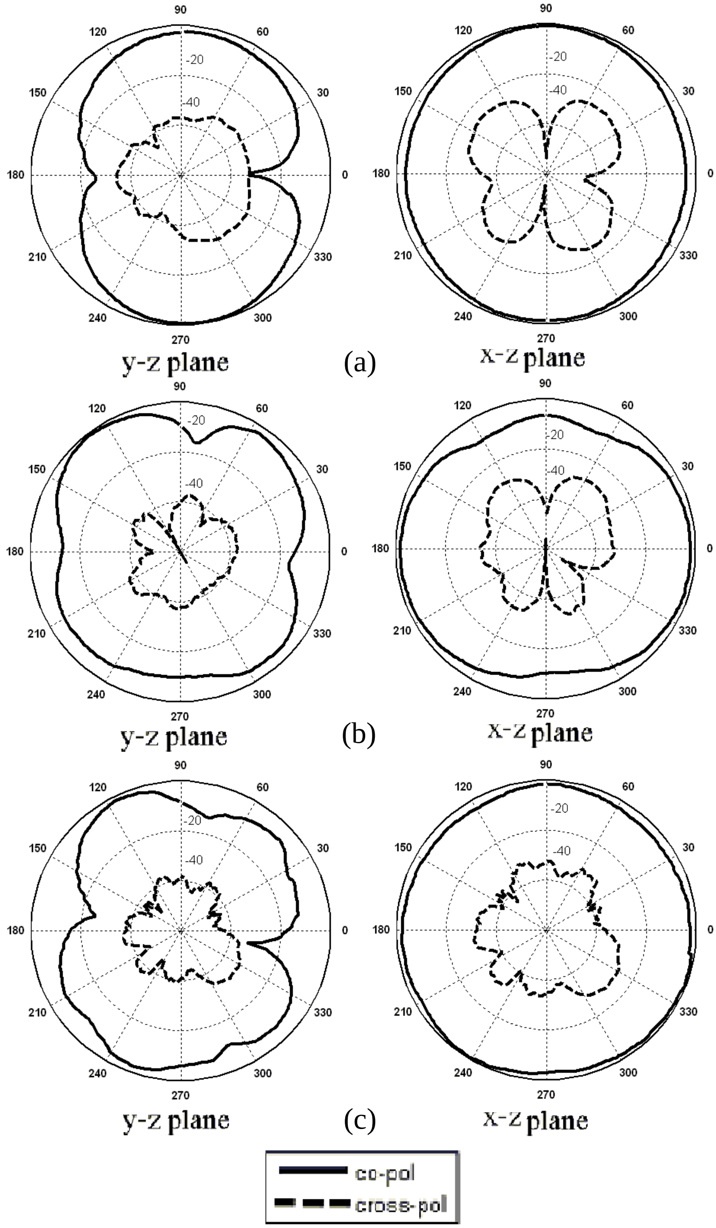

Figure 12. Measured radiation patterns of the proposed antenna. (a) 4 GHz, (b) 7 GHz, (c) 10 GHz.

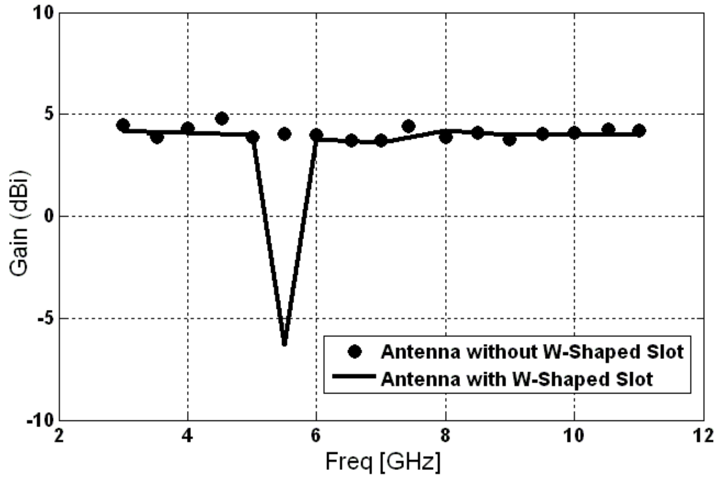

Figure 13. Measured antenna gain of the proposed antenna.

4. CONCLUSION

In this paper, a novel compact Printed Monopole Antenna (PMA) with variable band-stop characteristics has been proposed for UWB applications. The fabricated antenna has the frequency band of 3.05 to over 14.3 GHz with a rejection band around 5.08 to 5.91 GHz. The proposed antenna has a simple configuration and is easy to fabricate. Experimental results show that the proposed antenna could be a good candidate for UWB application.

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