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SMALL SEMI-CIRCLE-LIKE SLOT ANTENNA FOR ULTRA-WIDEBAND APPLICATIONS

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Abstract—In this paper, a small modified circle-like slot antenna with modified radiating patch, for UWB applications is proposed. The proposed antenna consists of a modified radiating patch with novel notch and a semi-circle-like with a slope which provides a wide usable fractional bandwidth of more than 135% (3.07–16.26 GHz). By optimizing the notched radiating patch, the total bandwidth of the antenna is greatly improved. The designed antenna has a small size of $27.5 \times 27.5\,\text{mm}^2$.

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 printed slot 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 microstrip slot antenna with different geometries have been experimentally characterized [2–4] and automatic design methods have been developed

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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].

In this letter, we propose a novel modified microstrip slot antenna with increased impedance bandwidth, for UWB applications. At first, by optimizing the shape of radiating patch, the total bandwidth of the antenna is greatly improved. Moreover, by optimizing the radius of the ground plane slot and angle of slope, much wider impedance bandwidth can be produced. In this design, the proposed antenna can operate from 3.07 to 16.26 GHz and unlike other antennas reported in the literature to date, the proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications. The size of the designed antenna is much smaller than the UWB antennas reported recently. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and experimental results are presented to demonstrate the performance of a suggested antenna.

2. ANTENNA DESIGN

The proposed slot antenna fed by a 50-Ohm microstrip line is shown in Fig. 1, which is printed on a FR4 substrate of thickness 0.8 mm, and permittivity 4.4. The width W_f of the microstrip feedline is fixed at 1.5 mm. The basic antenna structure consists of a radiating patch, a feedline, and a ground plane with semi-circle-like slot. 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_{sub} with semi-circle-like slot is placed. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission.

By cutting a modified notch of suitable dimensions at the radiating patch a new configuration can be constructed. The truncated radiating patch is playing an important role in the broadband characteristics of this antenna, because it can creates additional surface current paths in the antenna. As a result, an improvement in the p impedance bandwidth of the basic antenna is achieved [9].

The width of the notch embedded in the ground plane is important parameter in determining the sensitivity of impedance matching. The modified truncated ground plane acts as an impedance matching element to control the impedance bandwidth of the proposed antenna [10], because it helps matching of the patch in a wide range

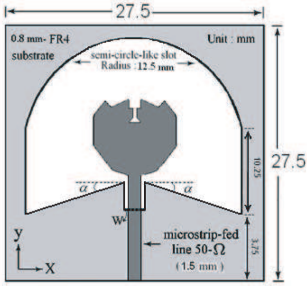


Figure 1. Geometry of proposed antenna with semi-circle like slot.

of frequencies. This is because the truncation creates a capacitive load that neutralizes the inductive nature of the patch to produce nearly-pure resistive input impedance [10]. Using a bevel increases the upper-edge frequency, and it is possible to control this frequency by adjusting the bevel angle [9]. Therefore the angle α (the slopes of lower edge in the ground plane slot) is another important factor in determining frequency bandwidth and impedance matching. By optimizing these parameters, a compact antenna is produced.

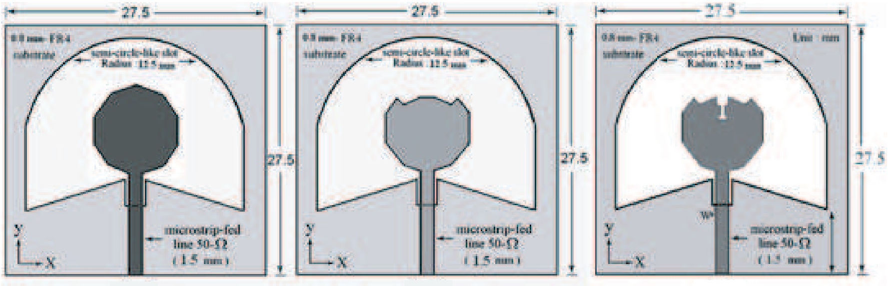
3. RESULTS AND DISCUSSIONS

In this Section, the microstrip slot 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) [11].

The optimal dimensions of the designed antenna are as follows: $W_{sub} = 27.5\,\text{mm}$, $L_{sub} = 27.5\,\text{mm}$, $W_f = 1.5\,\text{mm}$, $L_f = 6.4\,\text{mm}$, $R = 12.5\,\text{mm}$, $W = 2\,\text{mm}$, and $\alpha = 10.71°$.

Figure 2 shows the structure of the various semi-circle-like slot antennas. As shown in Fig. 3, it is observed that the lower frequency bandwidth is affected by using the rectangular notch in the ground plane, and the upper and lower frequency bandwidth is sensitive to the inverted T-shaped notch on the ground plane.

The simulated current distributions on radiating patch and the ground plane for the proposed antenna in Fig. 1 at 13.8 GHz are presented in Fig. 4. It can be observed in Fig. 4 that the current concentrated on the edges of the interior and exterior of the modified



(a) (b) (c)

Figure 2. (a) The ordinary deci-nominal antenna (without notch). (b) The deci-nominal without central notch in the radiating patch. (c) The proposed antenna.

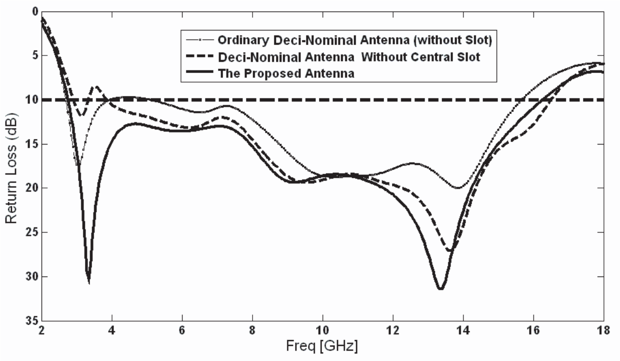


Figure 3. Simulated return loss characteristics for antennas shown in Fig. 2.

notch at 13.8 GHz. Therefore, the antenna impedance changes at this frequency due to the resonant properties of the notch. It is found that by using this notch, the third resonance occurs at 13.8 GHz in the simulation.

Another important parameter of this structure is the radius of slot on the ground plane. By adjusting R, the electromagnetic coupling between the radiating patch and the ground plane can be properly controlled [10]. Fig. 5 shows the return loss characteristics simulated for different values of R. It is seen that the lower-edge frequency of the impedance bandwidth is reduced with increasing R, but the matching became poor for larger values. Therefore it can seen that, the optimized gap R is 12.5 mm.

To minimize physical size of the proposed UWB antenna and

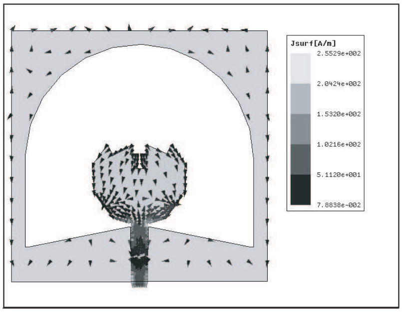


Figure 4. Simulated surface current distributions on the radiating patch and the ground plane for the proposed antenna shown in Fig. 1 at 13.8 GHz.

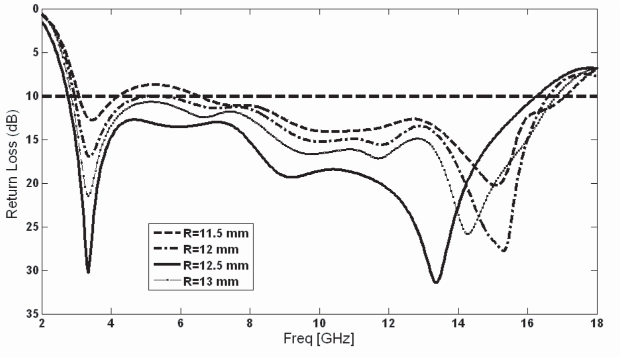


Figure 5. Simulated return loss characteristics for the proposed antenna for different values of R.

increase the impedance bandwidth, a notch is introduced into ground plane to alter the input impedance characteristics. Fig. 6 shows the return loss characteristics curves for different cases of the width of the notch W. As shown in Fig. 6, it is found out that when W is larger than 2 mm, the proposed antenna dose not satisfy the return loss requirement from 3.1 to 10.6 GHz. The optimized notch length W was found to be 2 mm, which provides a very wide bandwidth.

Using a bevel increases the upper-edge frequency, and it is possible to control this frequency by adjusting the bevel angle [9]. Therefore the angle α (the slope of lower edge in the ground plane slot) is other important factor in determining frequency bandwidth and impedance matching. By optimizing this parameter, a compact antenna is produced. The simulated return loss characteristics with different values of α are plotted in Fig. 7.

To understand the phenomenon behind this wide impedance

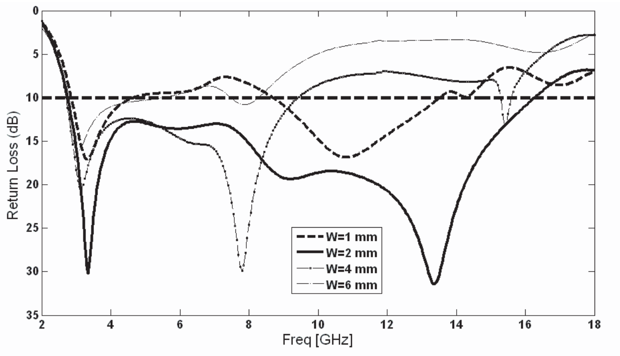


Figure 6. Simulated return loss characteristics curves for different cases of the width of the notch W.

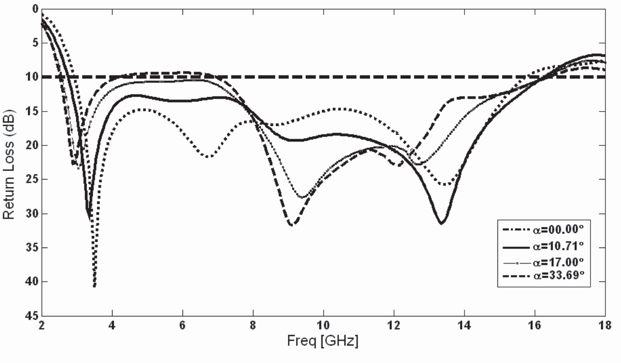


Figure 7. Simulated return loss characteristic for various values of α.

performance, the input impedance of the proposed antenna on a Smith Chart is shown in Fig. 8. Fig. 8 shows that the impedance bandwidth of the proposed antenna is as large as 13.19 GHz (from 3.07 to 16.26 GHz).

The proposed antenna with optimal design, as shown in Fig. 9, was fabricated and tested in the Antenna Measurement Laboratory at Iran Telecommunication Research Center (ITRC). Fig. 10 shows the measured and simulated return loss characteristics of the proposed antenna. The fabricated antenna has the frequency band of 3.07 to over 16.26 GHz. As shown in Fig. 10, 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 return loss characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

Figures 11(a) and (b) show the simulated and measured radiation

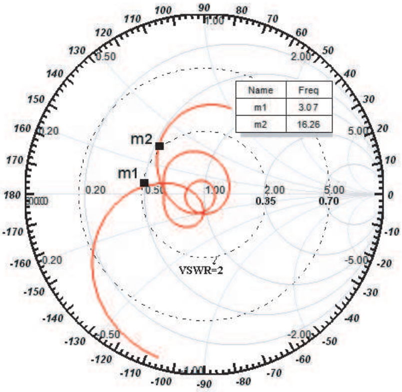


Figure 8. The simulated input impedance on a Smith chart of the proposed antenna.

Figure 9. Photograph of the realized antenna.

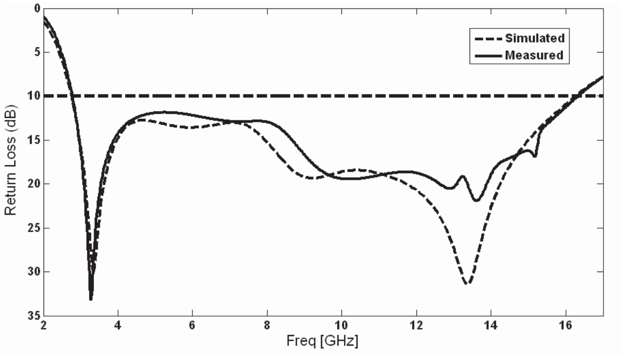


Figure 10. Measured and simulated return loss characteristics for the proposed antenna.

patterns at two UWB frequencies range 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. In order to demonstrate that the antenna actually radiates over a very wide frequency band, Fig. 11(c) shows the measured and simulated radiation patterns of the proposed antenna at new resonance frequency (13.8 GHz. It can be seen that the radiation patterns in x-z plane are nearly omnidirectional for the three frequencies, and also the measured radiation patterns agree very well with the simulated results in the

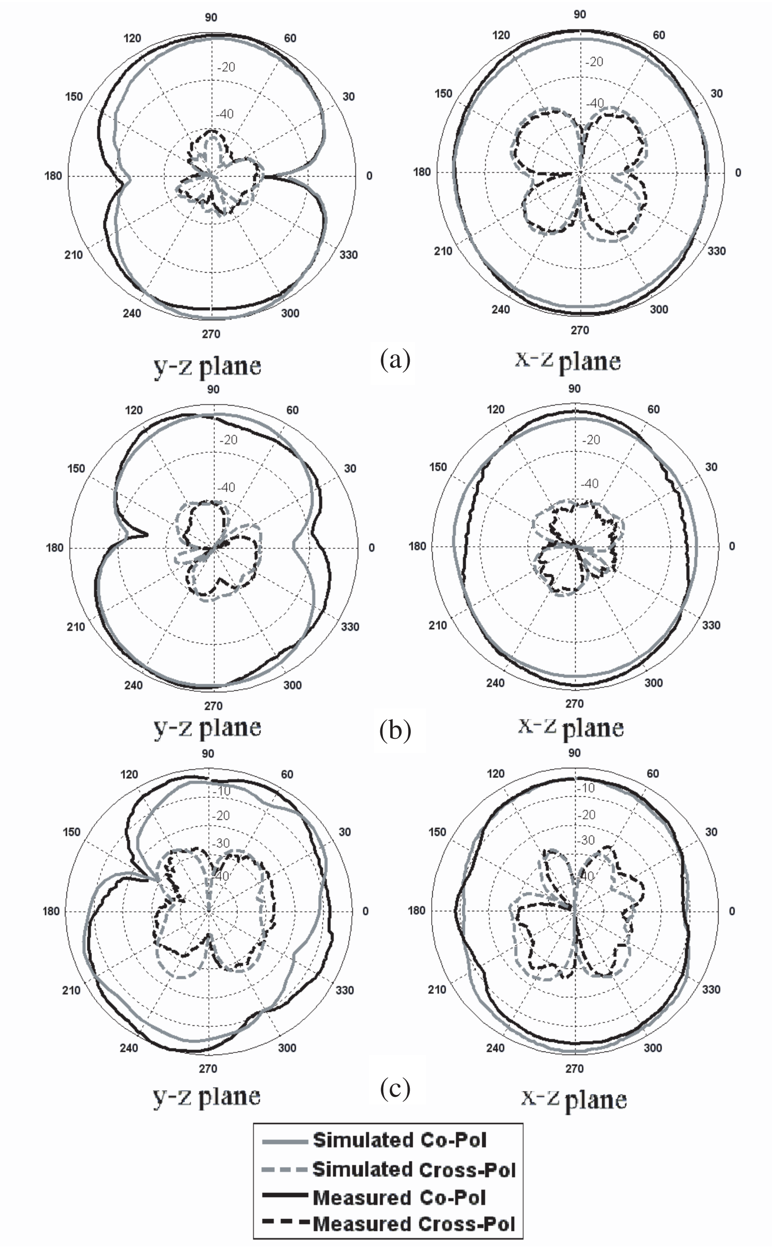


Figure 11. Measured and simulated radiation patterns of the proposed antenna. (a) 6 GHz, (b) 9 GHz, (c) 13.8 GHz.

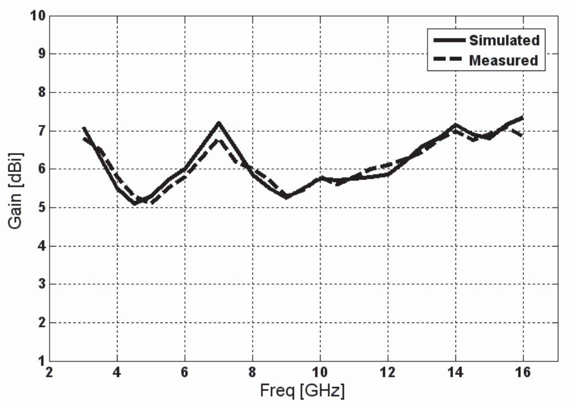


Figure 12. Measured and simulated antenna gain of the proposed antenna.

demonstrated frequencies. As shown in Fig. 11(c), similar agreement is obtained at higher frequencies.

Figure 12 shows the measured and simulated maximum gain of the proposed antenna at different frequencies up to 16 GHz. It can be seen that the measured peak gains agree very well with the simulated results in the desired frequencies and demonstrates a variation similar to other wideband antennas.

4. CONCLUSION

In this paper, a novel printed monopole antenna with wide bandwidth capability for UWB applications is proposed. In this design, the proposed antenna can operate from 3.07 to 16.26 GHz with $S_{11} < -10$ dB and unlike other antennas reported in the literature to date, the proposed antenna displays a good omni-directional radiation pattern even at higher frequencies. The size of the designed antenna is much smaller than the UWB antennas reported recently. Good return loss 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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