NOVEL PLANAR INVERTED CONE RING MONOPOLE ANTENNA FOR UWB APPLICATIONS

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ABSTRACT

This paper presents a tapered microstrip-fed asymmetric planar inverted cone ring antenna (PICRA) for ultra-wideband (UWB) applications. The proposed antenna design is comprised of an asymmetric inverted cone ring as the radiating patch, a tapered microstrip-fed line and modified tapered ground plane. The proposed antenna which has the size of 23.6 x 40 mm^2, is fabricated to work on a substrate FR4 that has the relative permittivity (ε_r) of 4.4 and a thickness of 1.6mm to operate in the UWB band (3.1GHz to 10.6GHz) released by Federal Communications Commission (FCC) in 2002.It has been demonstrated to operate a wide impedance bandwidth from 3.1GHz to 15GHz, completely covering the range of UWB operation bandwidth. The simulated and measured results show that the proposed PICRA achieves a broad impedance bandwidth for VSWR < 2 and maintains the nearly omni-directional radiation characteristics. The parameters which affect the performance of the antenna characteristics are investigated in this paper.

KEYWORDS

Planar inverted cone ring antenna, PICA, ultra-wideband, asymmetric ring, compact antenna.

1. INTRODUCTION

Since the Federal Communication Commission (FCC) released the bandwidth of 3.1 to 10.6 GHz for the unlicensed use of the ultra wideband (UWB) in February 2002, UWB technology has become the most promising candidate for wireless communications [1]. The demand for UWB antenna is also increasing. Among the UWB antenna designs, the planar monopole type antenna is widely used because of its wide operating bandwidth, simple structure, low cost, nearly omni-directional radiation patterns and so on. Recently, several monopole antenna configurations like circular, circular ring, rectangular, square ring, elliptical, elliptical ring, and triangular, have been proposed for UWB applications [2-9, 13, 14]. Some researchers also proposed for band-notched function to overcome the problems caused by electromagnetic interference between UWB and narrow bands like WLAN and WiMAX [5, 7, 12, 15]. One of the UWB antenna type is the planar inverted cone antenna (PICA) proposed by Suh[16,17]. The PICA is vertically mounted on a large ground plane and as a wide monopole antenna. Its bandwidth is impressive in view of its small size and mechanical simplicity. However, this type of planar inverted cone antenna is not the most suitable for portable communication systems due to the protruding part of PICA. The printed slot and CPW-fed planar inverted cone antenna are also proposed in [10, 11]. However, they are large in size and fail to retain its wide band matching when the size is reduced.

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In this paper, a new asymmetric planar inverted cone ring monopole antenna (PICRA) for UWB applications is introduced and optimized. An asymmetric planar inverted cone ring patch is achieved by etching the planar inverted cone hole in the planar inverted cone patch. The tapered and slotted ground plane is used to enhance the performance of the antenna.

2. ANTENNA DESIGN

Fig. 1 shows the geometry of the proposed asymmetric planar inverted cone ring monopole antenna. The antenna, having compact dimensions of 23.6 x 40 mm^2, is fabricated on the FR4 substrate with a thickness of 1.6mm and relative permittivity (ε_r) of 4.4. The proposed asymmetric planar inverted cone ring monopole antenna is composed of asymmetric planar inverted cone ring radiating element, a 50Ω microstrip feed line and a partial ground plane. The outer and inner rings of the proposed antenna are tangent at the top. On the other side of the substrate, the partial ground plane is tapered at the top corner sides and slots are added at the top to get a better impedance matching. In order to match the resistance of radiating element with the microstrip feed line, a linear tapered section has been used to connect these two parts.

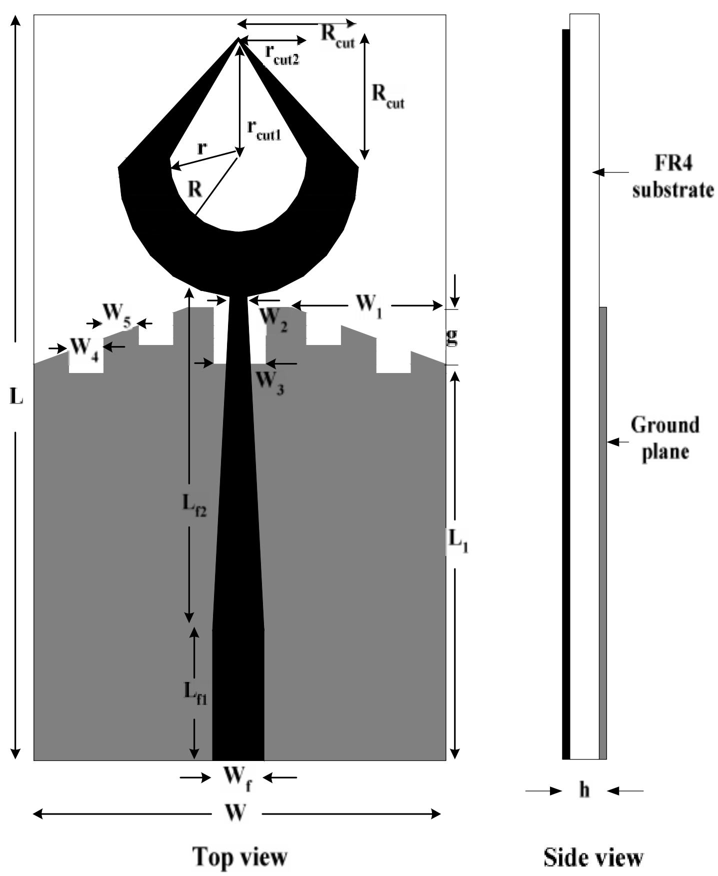


Figure 1. Geometries of the proposed asymmetric planar inverted cone ring monopole antenna

The evolvement of the proposed antenna is illustrated in Fig. 2. Fig. 2(a) is the primitive planar inverted cone antenna (PICA) with rectangular partial ground plane. Fig. 2(b) is the primitive asymmetric planar inverted cone ring antenna (PICRA) with tapered partial ground plane. The proposed asymmetric PICRA with modified ground plane is shown in Fig. 2(c). Fig. 3 illustrates the return loss of different antennas shown in Fig. 2. It can be seen that the primitive PICA antenna and PICRA antenna cannot get the impedance matching for whole UWB band. An ultra-wideband operation is realized by adding the slots at the top of the partial ground plane.

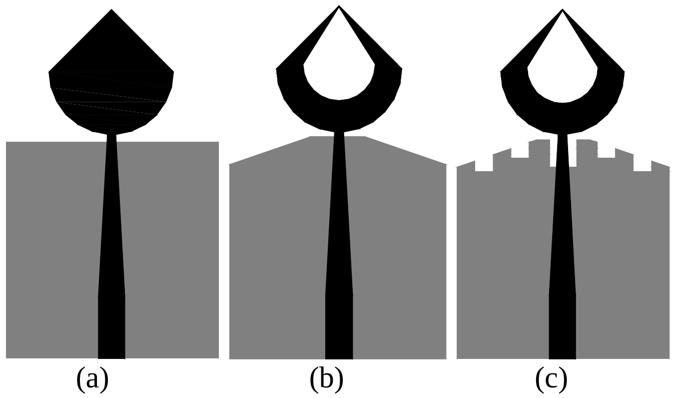


Figure 2. (a) Primitive PICA structure, (b) Primitive PICRA structure (c) Proposed PICRA structure

3. PARAMETRIC STUDY

The simulation tool Ansoft High Frequency Structure Simulator (HFSS) is used for performing the design and optimization process. In the optimization process, some parameters like asymmetric ring of radiating patch and the partial ground plane are the main factors. In order to achieve the desired UWB characteristics, the effects of the parameters of the asymmetric ring radiating patch and the partial ground plane on the antenna behavior are studied in this section. The three important design parameters that affect the antenna performance are the radius of inner ring (r), the tapered length at ground (g) and slot width (W_3). These three parameters are selected in the parametric study and study one parameter at a time and others are fixed to get better understanding for these parameters.

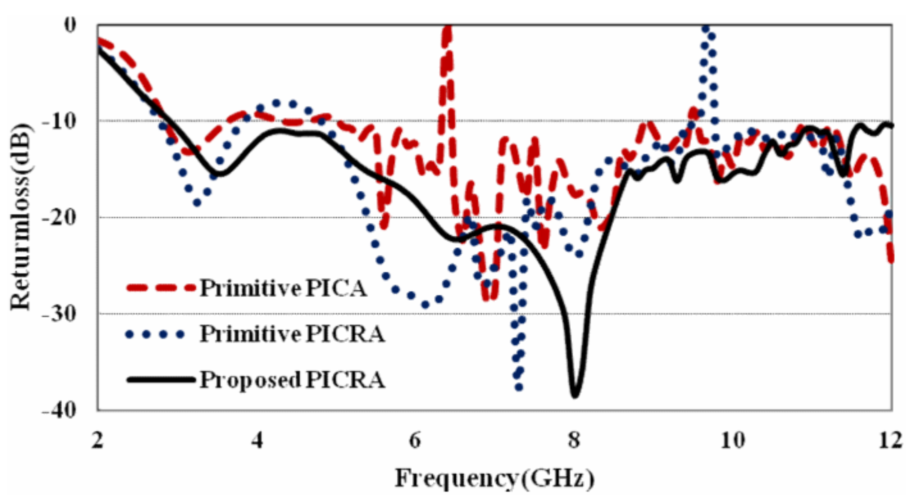


Figure 3. Comparisons of the return loss among the different antennas of Fig. 2

First of all, the primitive antenna and 50Ω microstrip feed line are calculated according to the substrate's relative permittivity and thickness. The planar inverted cone antenna (PICA) is designed and modified again to get planar inverted cone ring antenna (PICRA). And then the partial ground plane is modified to get the better impedance matching. Surface current distributions of the different antennas of Fig.2 at 6 GHz are studied for better understanding of the proposed antenna and are illustrated in Figure 4. It is seen that the current distributed in the proposed antenna is mainly along the microstrip feed line and lower edge of the radiating element. The current distributed on the partial ground plane is mainly along the upper edge and acts like the parts of the radiating patch.

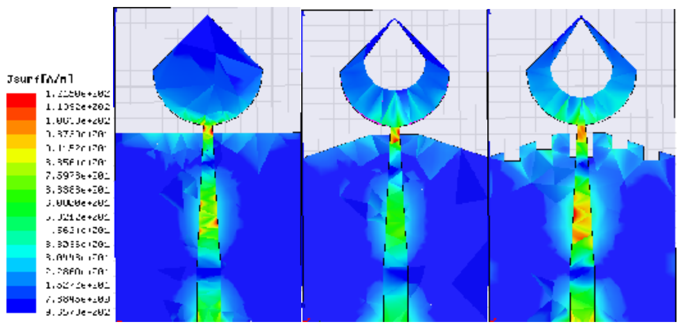


Figure 4. Simulated surface current distributions of different antennas at 6 GHz.

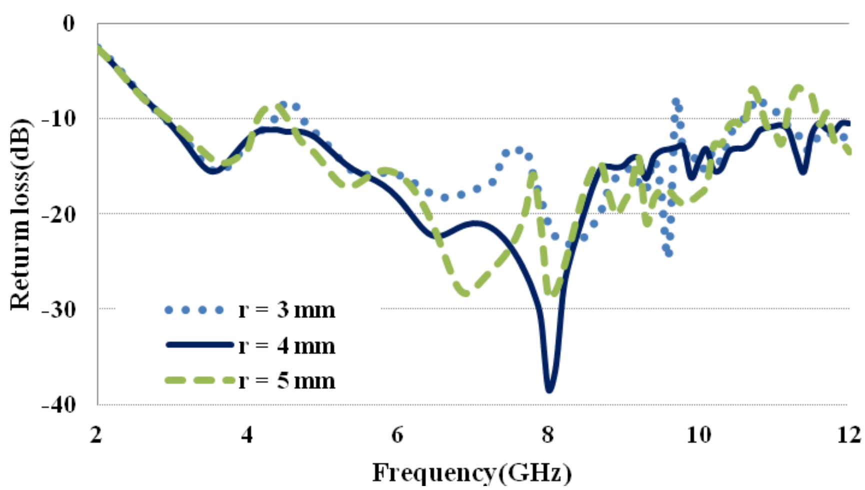


Figure 5. Simulated return loss against frequency for proposed PICRA antenna with various slot radius r

Fig. 5 illustrates the simulated return loss against frequency for proposed PICRA antenna with various slot radius r. It can be seen that the values of r effect obviously to the lower frequency and r = 4 mm is the best for broader bandwidth. Fig. 6 shows the simulated return loss against frequency for proposed PICRA antenna with various tapered length, g. It is seen that the first resonant frequency decreases with the increases of g and the second resonant frequency increases with the increases of g. Fig. 7 shows the simulated return loss against frequency for proposed PICRA antenna with various slot width, W_3. It is seen from Fig. 7 that the second resonant frequency shifts to lower frequency with the decreases of W_3.

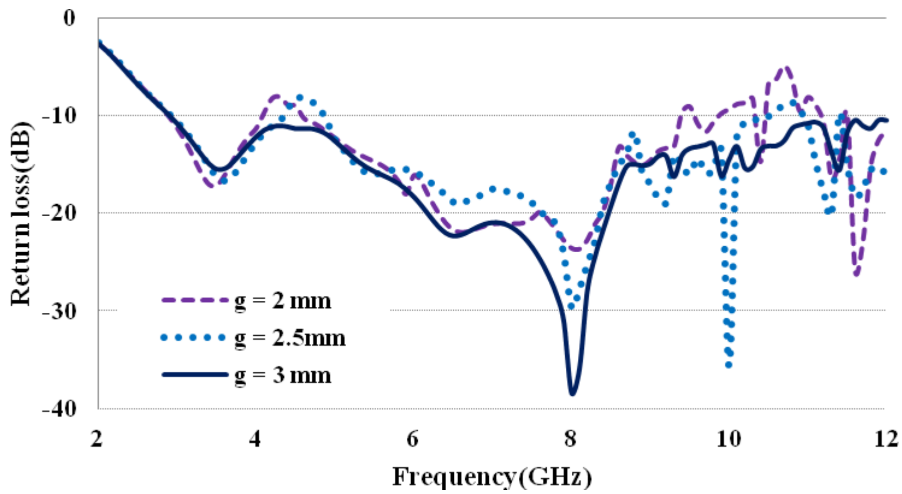


Figure 6. Simulated return loss against frequency for proposed PICRA antenna with various tapered length, g

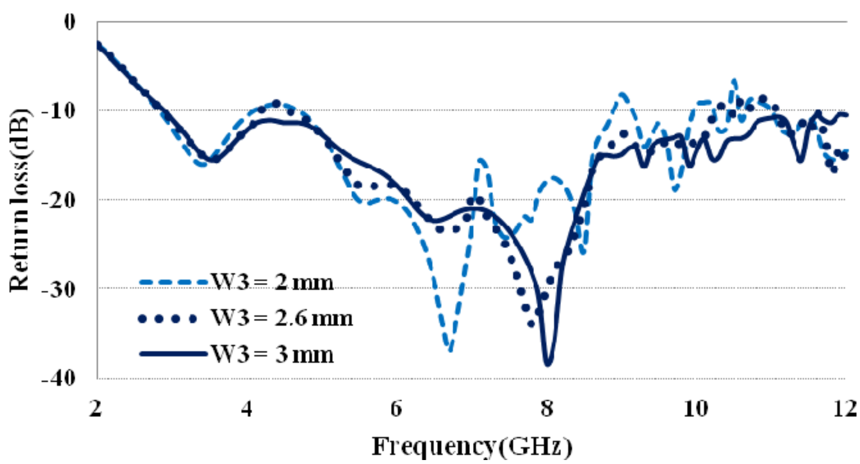


Figure 7. Simulated return loss against frequency for proposed PICRA antenna with various slot width, W_3

4. RESULTS AND DISCUSSION

After the parametric study of several adjustments on parameters, the final proposed antenna is achieved. The design parameters of the proposed antenna are given in Table 1.

Table 1. Design parameters of the proposed antenna

Parameter	Value(mm)	Parameter	Value(mm)
W	23.6	W_4	2
L	40	W_5	2
L_1	21	r	4
W_1	8.8	R	7
L_{f1}	7	g	3
L_{f2}	18.1	r_{cut1}	6.3
W_f	3	r_{cut2}	4
W_2	1	R_{cut}	7
W_3	3		

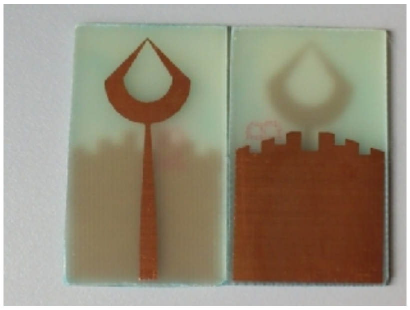


Figure 8. Photograph of the proposed antenna

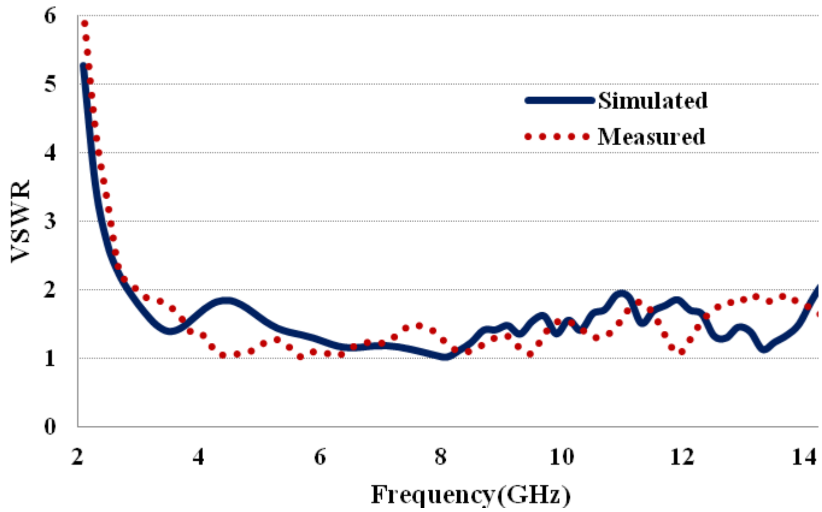


Figure 9. Simulated and measured VSWR characteristics against frequency for proposed antenna

In order to evaluate the performance of the optimized proposed antenna, a prototype of the proposed antenna was implemented and fabricated. The photograph of the fabricated antenna is shown in Fig. 8. The VSWR was measured by Agilent 8722ES Vector Network Analyzer. Fig. 9 illustrates the simulated and measured VSWR characteristics of the proposed PICRA antenna. The simulated bandwidth is from 2.9 GHz to 14.2 GHz and the measured bandwidth is from 3.1 GHz to 15 GHz. Compared with the simulated and measured results, the measured result shifts a little to higher frequency due to the fabrication accuracy, SMA connector to transmission line, which is not taken into account in the simulation results and the dielectric constant is not stable when the frequency increases. Both simulated and measured bandwidths completely cover the whole UWB operation bandwidth (3.1 GHz to 10.6 GHz) released by FCC. Fig. 10 illustrates for the input impedance characteristics of the proposed PICRA antenna. The resistance and reactance of the proposed antenna are matched for the whole band.

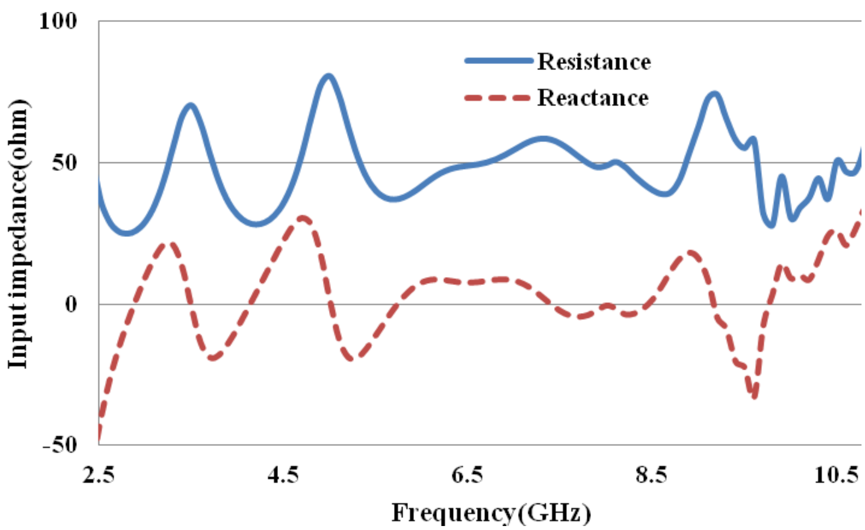
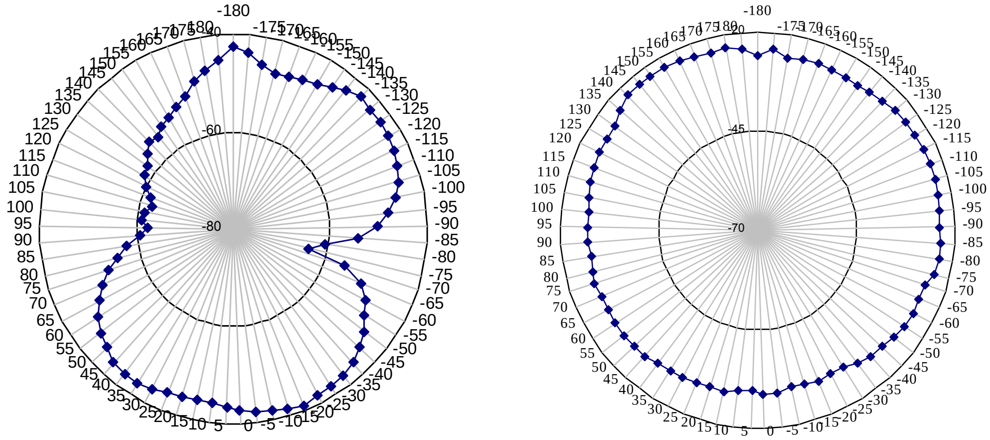
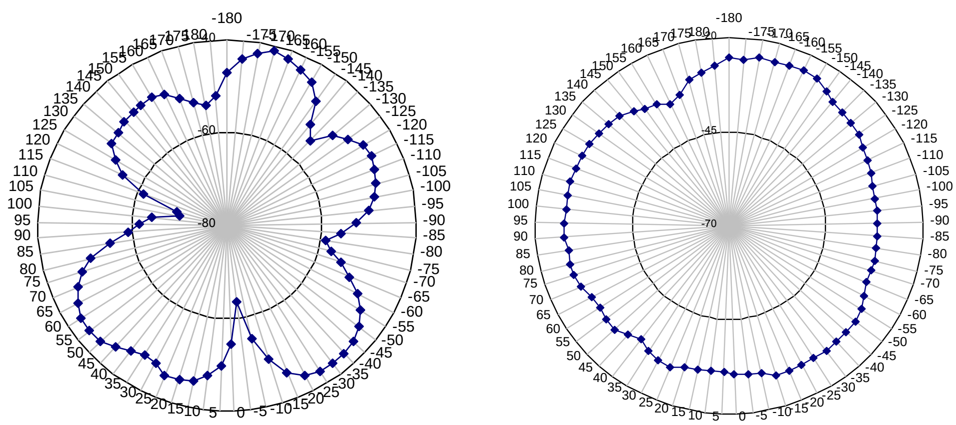


Figure 10. Simulated input impedance of the proposed antenna

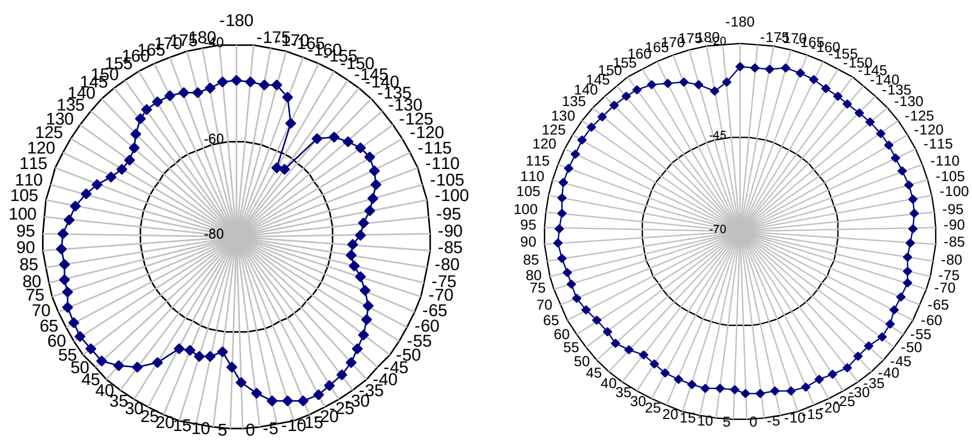
The measured radiation patterns of the proposed antenna at frequency of 4.5GHz, 6.5 GHz and 7.5GHz in two planes, E-plane and H-plane are shown in Fig. 11. In the H-plane, the radiation patterns at 4.5GHz and 7.5GHz are omni-directional and is nearly omni- directional at 6.5GHz. In the E-plane, the radiation pattern at 4.5GHz is nearly bidirectional and becomes more directional at 6.5GHz and 7.5GHz. Fig. 12 presents the simulated peak gain of the proposed antenna. The peak gain gradually increases with frequency and maximum is 11 at 11GHz.



at 4.5 GHz



at 6.5 GHz



at 7.5 GHz

E-plane H-plane

Figure 11. Measured radiation patterns at different frequencies

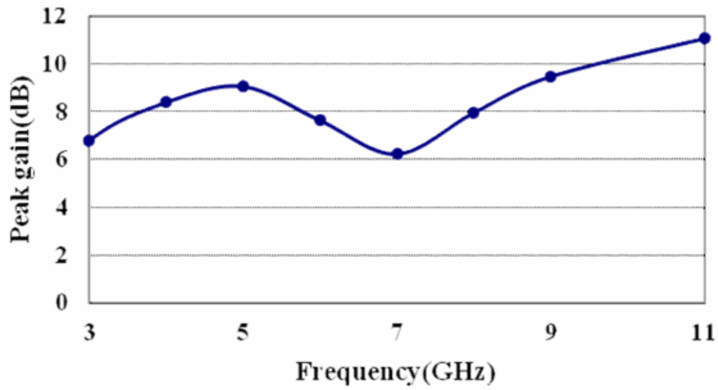


Figure 12. Peak gain of the proposed antenna.

5. CONCLUSIONS

A new asymmetric planar inverted cone ring monopole antenna (PICRA) for UWB applications is designed, fabricated and tested. The performance of the proposed antenna can be enhanced by using the tapered and slotted ground plane. The experimental results show that the PICRA achieves the impedance bandwidth from 3.1GHz to 15 GHz for VSWR < 2 and agree well with simulated results. The proposed antenna also maintains the nearly omni-directional radiation patterns with acceptable gain and is very suitable for UWB applications. The compact proposed antenna can easily be integrated with RF/microwave circuits for low cost manufacturing and suitable for various UWB applications and high speed pulse communications.

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