

EFFECT OF CPW EDGES CHAMFERING TO THE PERFORMANCE OF ULTRA WIDEBAND ANTENNA

Raimi Dewan, Mohamad Kamal A Rahim, Mohamad Rijal Hamid, M.H. Mokhtar, M.F.M. Yusoff

Communication Engineering Department, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

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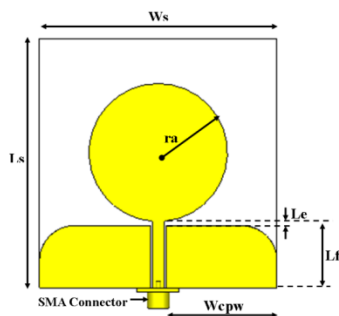
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*Corresponding author
raimidewan@gmail.com

Graphical abstract



Abstract

In this paper, an Ultra Wideband (UWB) antenna is presented. The antenna radiating patch is circular in shape with coplanar waveguide (CPW) feeding technique. The proposed chamfering to the outer edges of the ground plane successfully widens the -10 dB impedance bandwidth of the antenna to cover from 1.92 GHz up to 15.16 GHz (correspond to 155% fractional bandwidth). The antenna gain varies from 2 to 5 dB over the operating band. Parametrical studies have been conducted for four different conditions of the ground plane; without chamfering, chamfering on the inner edges, chamfering on the outer edges and both chamfering of inner and outer edges. The effects of distinguished chamfering conditions to antenna performance are analyzed. The measured and simulated results for reflection coefficients and radiation patterns (2.45 GHz, 3.5 GHz and 5.8 GHz) are presented. The corresponding realized gains are 2.14 dB, 2.85 dB and 3.4 dB respectively. The measured results satisfactorily agreed with the simulated ones. The antenna is 8 - 37 % wider bandwidth than previous research.

Keywords: Chamfering, reflection coefficient, wide bandwidth

Abstrak

Antena lebar jalur ultra (UWB) telah dibentangkan. Bentuk antenna tampalan tersebut ialah membulat dengan teknik suapan sesatah pandu gelombang (CPW). Antena yang dicadangkan ditalang pada sisi luaran satah bumi tersebut berjaya meluaskan lebar jalur -10 db untuk merangkumi daripada 1.92 GHz kepada 15.16 GHz (bersamaan peratus lebar jalur 155%). Gandaan antenna tersebut berbeza-beza dalam julat 2 ke 5 dB sepanjang lebar jalur. Kajian parametrik telah dijalankan untuk prestasi antenna bagi empat keadaan talangan; tanpa talangan, talangan sisi dalam, talangan sisi luar, talangan luar dan dalam sisi satah bumi antenna tersebut. Kesan-kesan talangan ke atas prestasi antenna telah dianalisis. Keputusan pengukuran dan simulasi untuk pekali pantulan dan corak radiasi (pada 2.45 GHz, 3.5 GHz dan 5.8 GHz) dibentangkan. Nilai gandaan masing-masing ialah 2.14 dB, 2.85 dB dan 3.4 dB. Perbandingan keputusan pengukuran berbanding simulasi agak memuaskan. Antenna tersebut 8 - 37 % lebih lebar lajur daripada penyelidikan lepas.

Kata kunci: Talang, pekali pantulan, luas lebar jalur

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1.0 INTRODUCTION

Ultra Wideband (UWB) frequency range has been allocated by Federal Communications Commission (FCC) in 2002 [1-2] which permits high rate of data transmission with low consumption of power [3]. Since then, a lot of research has been done on the design of antenna and microwave devices to accommodate the UWB requirements. Among the advantages of UWB antenna are wide bandwidth, low profile, high data rate, low cost, and good omnidirectional pattern [4-6].

In [7], an antenna with dome-shaped slot on the ground plane is designed for UWB applications. The excitation to the antenna via microstrip line fed chamfered rectangular patch. The wide impedance bandwidth is achieved by properly adjusting the dimensions of chamfered patch and slotted structure of the ground layer. The antenna covers from 2.2 to 12.9 GHz which correspond to 142% percentage bandwidth. However several factors must be manipulated to achieve a wider bandwidth such as the dimensions of slot, the slot positions on the ground plane, and the chamfering dimensions of the rectangular patch.

In [8], a wide bandwidth antenna is achieved through the manipulation of the stub dimensions and additional strips which connecting the ground plane to the antenna feeding. However the design only achieved a wide bandwidth from 4.4 to 11 GHz (85.7% percentage bandwidth). The paper reported that the antenna is for UWB applications but it did not satisfactorily cover the entire UWB range (3.1-10.6 GHz). Parameters optimization of several steps of stub dimensions also increases the simulation time. It is desirable to have less parameter to be manipulated to eventually achieve a wide bandwidth antenna.

In [9], a Sierpinski fractal geometry is introduced to the octagonal-shaped antenna to achieve wider bandwidth. The reported antenna has the bandwidth from 2.4 GHz to 12.1 GHz which corresponds to percentage bandwidth of 133.79%. However, the widening bandwidth by second iteration of the fractal geometry is only about 0.6 GHz taken into account that the operating range of initial geometry is approximately from 3 GHz to 12.1 GHz.

In this paper an UWB antenna is proposed with single chamfering on each of the outer edges of the CPW ground plane. The implemented chamfering improves the impedance matching toward the antenna. Thus, a wide -10 dB bandwidth is successfully achieved from 1.92 GHz up to 15.16 GHz.

2.0 UWB ANTENNA DESIGN AND EDGES CHAMFERING

The Ultra Wideband (UWB) antenna is designed on FR4 substrate with permittivity, thickness and loss tangent of 4.5, 1.6 mm and 0.019 respectively with copper as the conductive material. Figure 1 shows

the geometry of the antenna. The outer edges of the CPW ground planes are chamfered with a radius of 8.42 mm. The antenna dimensions are shown in Table 1

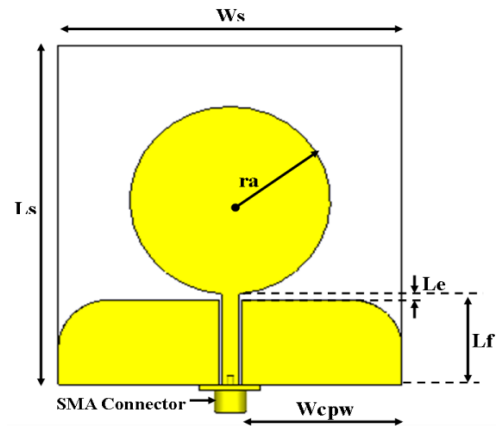


Figure 1 Antenna geometry

Table 1 Antenna dimensions

Parameter	Length (mm)	Parameter	Length (mm)
Le	1.05	ra	16.61
Lf	16.04	Wcpw	26.57
Ls	60.00	Ws	57.00

Initial studies have been carried out for various edges chamfering and without chamfering as shown in Figure 2(a)-(d). The effect of different types of edges chamfering of CPW ground plane to the antenna are investigated. The various chamfering conditions to the antenna performance is observed.

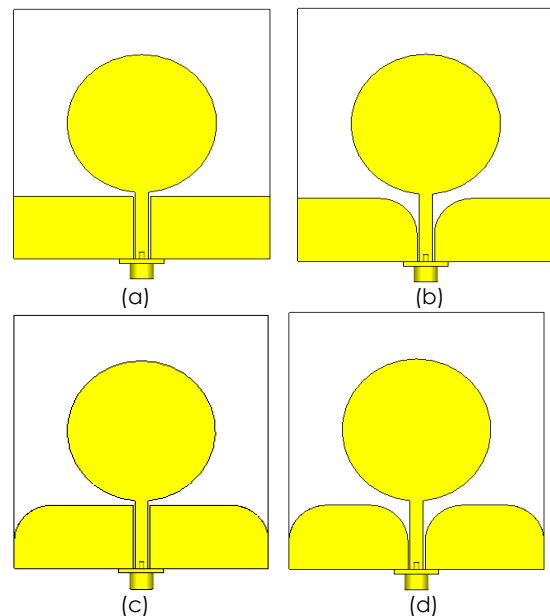


Figure 2 (a) conventional CPW with no edges chamfering. Chamfering of CPW ground plane at (b) inner edge, (c) outer edge, and (d) both inner and outer edge.

3.0 RESULTS AND DISCUSSION

Figure 3 shows the simulated reflection coefficients of non-chamfering conditions CPW ground plane of the antenna. It is observed that the antenna achieves wide impedance bandwidth from 1.94 GHz up to 14.72 GHz. However at 8.10 GHz, the reflection coefficient barely reaches -10.45 dB.

In practical situation, fabrication of devices usually degrades the antenna reflection coefficient to a certain level which greatly depends on the accuracy and precision of fabrication techniques used. Therefore, the exact -10.45 dB simulated reflection coefficient will usually result in tendency of the reflection coefficient of the fabricated devices to be greater than -10 dB. The fabricated devices will be prone to have non-continuous -10 dB bandwidth throughout simulated frequency range from 1.94 GHz to 14.72 GHz.

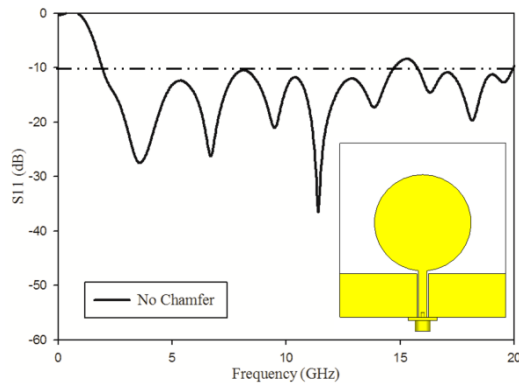


Figure 3 Simulated reflection coefficient of conventional CPW with no edges chamfering.

Figure 4 shows the parametrical studies of simulated reflection coefficient for UWB antenna with implemented chamfering on the inner edges of the CPW ground plane. It is observed that with three chamfering values (6.42 mm, 8.42 mm and 10.42 mm), the -10 dB bandwidth is not continuous from 3.1 GHz to 10.6 GHz which is the required bandwidth for UWB operating frequency range. Chamfering of 6.42 mm gives the best reflection coefficient value for -10 dB impedance bandwidth evaluation. The inner chamfering produces four wideband at 2.6-3.99 GHz, 4.36-6.48 GHz, 12.34-15.42 GHz and 17.36-19.98 GHz.

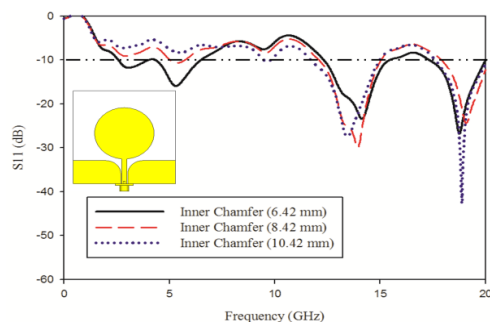


Figure 4 Simulated reflection coefficient of conventional CPW with Inner edge chamfering

Figure 5 shows the parametric simulation for various values of chamfering implemented at the outer edges of CPW ground plane of the UWB antenna. It is observed that the outer chamfering at any values of 6.42 mm, 8.42 mm and 10.42 mm improves the impedance matching of the antenna and successfully provides continuous -10 dB bandwidth from 1.92 GHz to 15.16 GHz. Another wideband frequency range is also observed at 16.22-19.76 GHz. 8.42 mm is selected as the best chamfering parameter value as it gives exceptionally good reflection coefficient value at 3.40 GHz-3.64 GHz.

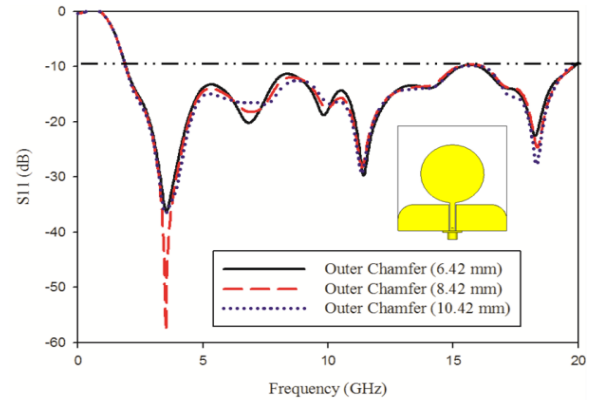


Figure 5 Simulated reflection coefficient of conventional CPW with outer edge chamfering

Figure 6 shows the simulated reflection coefficient of the UWB antenna where chamfering is implemented at both inner and outer edges of the CPW ground plane. 8.42 mm chamfering is done at both side of the edges. Dual -10 dB impedance bandwidths are observed at 12.17-15.06 GHz 17.93-20.26 GHz. However, the required 3.1 to 10.6 GHz impedance bandwidth is not achieved by chamfering of both sides of the CPW ground plane edges. Chamfering at both sides adversely affect the impedance matching to the antenna.

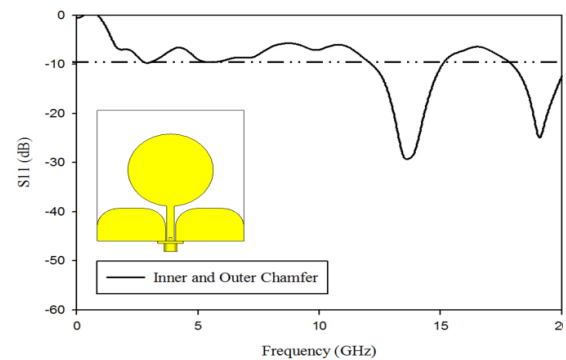
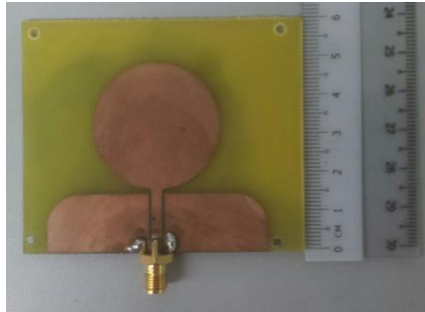
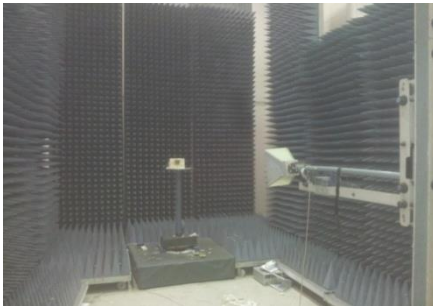


Figure 6 Simulated reflection coefficient of conventional CPW with both inner and outer edges chamfering

Figure 7(a) shows the fabricated UWB antenna with chamfering introduced to the outer edge of the CPW ground plane. The antenna reflection coefficient is measured using Vector Network Analyzer (VNA). The antenna is measured in anechoic chamber as in Figure 7(b) to measure the antenna radiation pattern (RP).



(a)



(b)

Figure 7 (a) Fabricated UWB antenna and (b) measurement setup of antenna for radiation pattern analysis.

The measured and simulated comparison results are shown in Figure 8. The measurement was done on frequency range from 9 kHz to 13.6 GHz in accordance with the lower and upper frequency limit of the Vector Network Analyzer (VNA). It is observed that the measured results satisfactorily agreed with simulated ones from 1.92 GHz up to 10.56 GHz. Although the measured result is slightly shifted to the right, the -10 dB bandwidth is consistent within the aforementioned frequency range. However, it is observed that at higher frequency from 10.56 GHz to 13.6 GHz the measured reflection coefficient curve characteristics is not consistent with the simulated ones at frequency higher than 10.5 GHz. It may be due to dielectric constant variations in the entire range of the material as opposed with the value of dielectric constant used in the simulation and the instability of FR4 material at higher frequency.

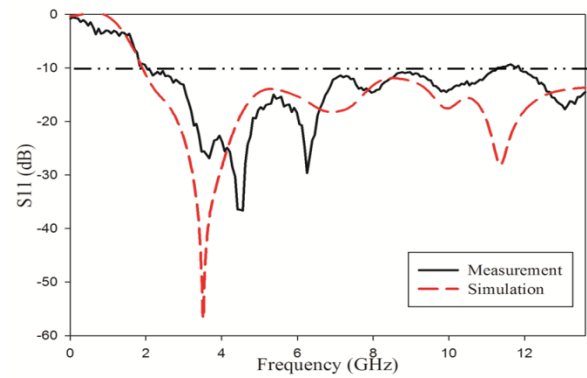
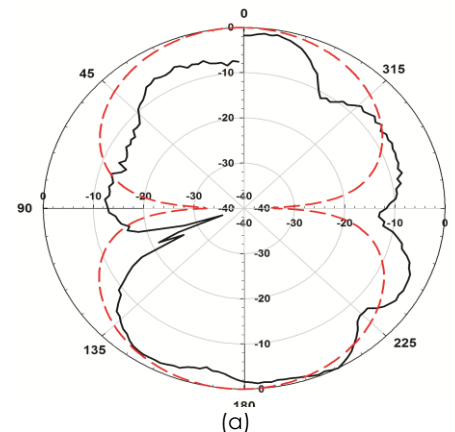
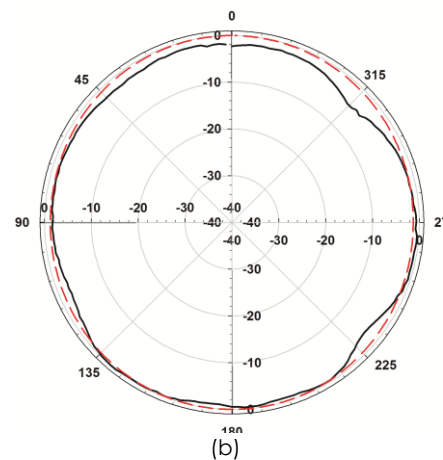


Figure 8 Measured and simulated reflection coefficient of conventional with outer edges chamfering

Figure 9(a)-(f) shows the radiation patterns at 2.45 GHz, 3.5 GHz and 5.8 GHz. It can be observed that near omni-directional radiation patterns are achieved for H-field at 2.45 GHz, 3.5 GHz and 5.8 GHz. E-field radiation patterns maintain 8-shaped for radiation patterns sampled at 2.45 GHz, 3.5 GHz and 5.8 GHz. The corresponding simulated realized gains are 2.14 dB, 2.85 dB and 3.4 dB respectively.



(a)



(b)

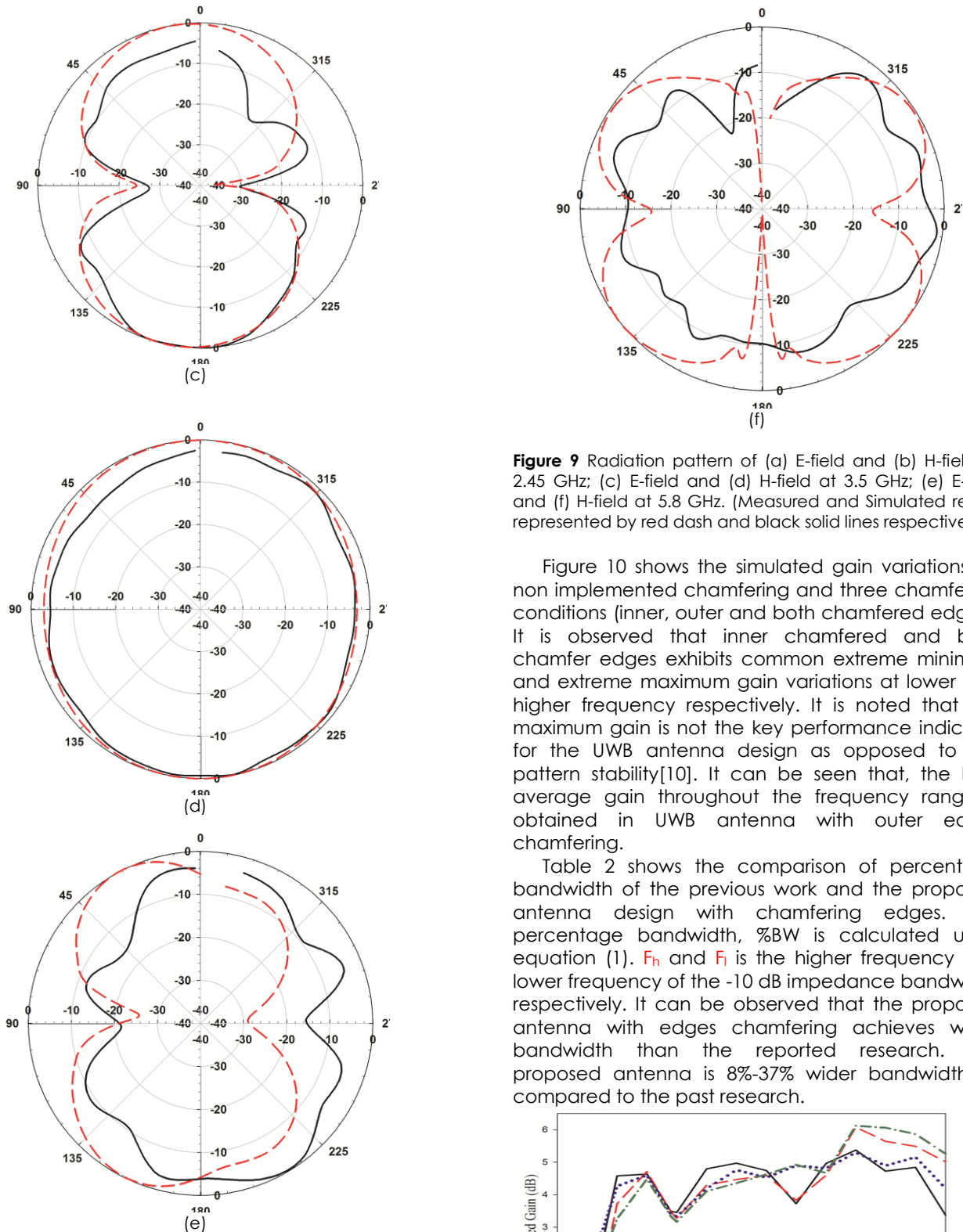


Figure 9 Radiation pattern of (a) E-field and (b) H-field at 2.45 GHz; (c) E-field and (d) H-field at 3.5 GHz; (e) E-field and (f) H-field at 5.8 GHz. (Measured and Simulated results represented by red dash and black solid lines respectively).

Figure 10 shows the simulated gain variations for non implemented chamfering and three chamfering conditions (inner, outer and both chamfered edges). It is observed that inner chamfered and both chamfer edges exhibits common extreme minimum and extreme maximum gain variations at lower and higher frequency respectively. It is noted that the maximum gain is not the key performance indicator for the UWB antenna design as opposed to the pattern stability[10]. It can be seen that, the best average gain throughout the frequency range is obtained in UWB antenna with outer edges chamfering.

Table 2 shows the comparison of percentage bandwidth of the previous work and the proposed antenna design with chamfering edges. The percentage bandwidth, %BW is calculated using equation (1). F_h and F_l is the higher frequency and lower frequency of the -10 dB impedance bandwidth respectively. It can be observed that the proposed antenna with edges chamfering achieves wider bandwidth than the reported research. The proposed antenna is 8%-37% wider bandwidth as compared to the past research.

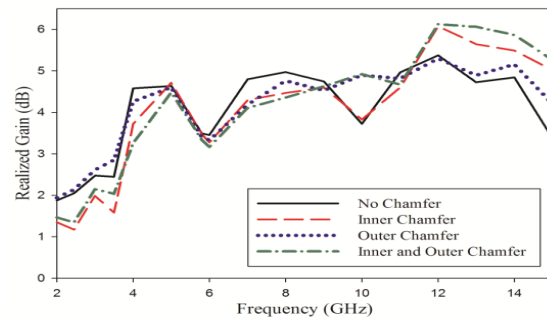


Figure 10 Simulated gain variations for antenna with various types of chamfering edges

$$\%BW = \frac{(F_h - F_l)}{F_c} \times 100\% \quad (1)$$

Where, centre frequency, $F_c = \frac{F_l + F_h}{2}$

Table 2 Comparison of bandwidth of reported UWB antenna as opposed to proposed design

Previous UWB antenna	Frequency (GHz)		percentage Bandwidth (%)
	Lower, F_l	Higher, F_h	
[11]	2.3	14.0	143.55
[12]	2.6	13.04	133.50
[13]	3.0	11.0	114.29
[14]	3.3	14.7	126.67
	5.1	18.2	112.45
Proposed design	1.92	15.16	155.04

4.0 CONCLUSION

An UWB antenna has been proposed. The wideband of the antenna is achieved by simple means of chamfering outer edges of the CPW ground plane of the antenna. The bandwidth covers from 1.92 GHz to 15.16 GHz with gain variations of 2 to 5 dBi in the entire frequency range.

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