A NOVEL APPROACH FOR EFFICIENCY ENHANCEMENT AND SIZE MINIATURIZATION OF UWB PRINTED ANTENNAS

Ramu PILLALAMARI [1)], Sasibhushana Rao GOTTAPU [2] S. Srinivasa KUMAR [1]
[1)] *Deputy Manager, Reliance Technology and Innovation Centre, Reliance Communications Ltd. India*
[1] *Radio Frequency and Microwave Laboratory, Dept. of Electronics and Communication Engineering Jawaharlal Nehru Technological University Kakinada, Andhra Pradesh, India*
[2] *Andhra University, Visakhapatnam, Andhra Pradesh, India*
Corresponding Author: ramu06410230@gmail.com

Abstract: **The printed antenna is one of the most preferred antenna structures for low cost and compact design of wireless communication systems. In this paper we have investigated a new approach for improving the radiation efficiency and performance of the antennas with the size miniaturization, in particular we have simulated two types of UWB printed monopole antennas for proving this approach with results: circular patch and Compact Miniaturized Semi-Circular patch UWB monopole antennas and in detail investigation was presented on size miniaturization in order to achieve very compactness and high radiation efficiency with out degradation of the functional parameters and overall performance. Simple rectangular microstrip lines are used for feeding the printed monopole antennas. This UWB monopole antenna designed works well for the whole UWB frequency band 3.1-10.6GHz.**

Key words: *UWB, Semicircular, Miniaturization printed monopole antennas, Microstrip lines.*

I INTRODUCTION

Ultra-Wideband (UWB) commonly refers to signal or system that either has a large relative bandwidth (BW) or a large absolute bandwidth. Such a large BW offers specific advantages with respect to signal robustness, information content and/or implementation simplicity. But such systems have some fundamental differences from the conventional narrowband systems. The Federal communications Commission (FCC) has designated the 3.1 to 10.6 GHz band with Effective Isotropic Radiated Power (EIRP) below -40dbm/kHz for UWB Communications [1]-[3].

Some UWB antennas are much more complex than other existing single band, dual band and multi-band antennas [4]-[5]. Most of the UWB monopole antennas are investigated till today is non-planar as in and due to its protruded structure they cannot be integrated with integrated circuits and they are fragile [6]-[7]. Few researchers have also studied printed monopole Antennas [8]-[9].

Miniaturization has inherent advantages, among them higher speed, lower cost, and greater density. Smaller electronics devices are generally faster because the signals do not have to travel as far within the device. Packing more functionality into a smaller or same-sized device reduces the cost of electronics [10].

In this paper, we will investigate UWB antennas which are basically printed microstrip antennas with etched ground plane and besides that some qualitative techniques for size miniaturization in the proposed antennas with out degradation of the functional parameters and overall performance. First we will investigate in depth the circular disk printed monopole antenna as shown Fig. 1(a) and modify its structure by size miniaturization techniques like etching out some portion of its patch and reducing its dimensions to make it more compact as shown in Fig. 2(a) for UWB applications. The second UWB antenna has slightly less BW but high radiation efficiency than the previous one but it has reduced size and very compact. We have used simple 50 Ω rectangular microstrip lines as feed lines for printed UWB antennas which are properly matched to the antenna impedance [11]-[12]. And also we maintained some gap “g” between the circular patch and the ground plane in order to get proper impedance matching as well as huge bandwidth, simply saying that it was a one of the design parameter of proposed antennas in order to meet UWB applications. . It has been observed that such monopole antennas are suitable for UWB operations from the Ansoft High Frequency Structure Simulator (HFSS) results [13].

II. GEOMETRY OF CIRCULAR DISC UWB MONOPOLE ANTENNAS AND SIMULATION RESULTS

A. Circular patch UWB Monopole Antenna

The circular patch UWB antenna is designed on a FR4 substrate with 4.4 relative permittivity and 1.6 mm thickness. Some portion of the ground plane is etched in order to get the impedance matching as well as huge bandwidth. The final dimensions of the proposed UWB antenna after doing an extensive simulation study are:
The dimensions of Circular Patch: Radius (r) = 12 mm and metal thickness= 0.035mm; the dimensions of Substrate: W_1 = 46 mm and L_1 =52 mm; the dimensions of Ground: W_2 = 46 mm and L_2 =26mm; the dimensions of Microstrip line: W_3=2.6mm and L_3=27.5mm.
Where the “g” is gap between the ground plane and patch.

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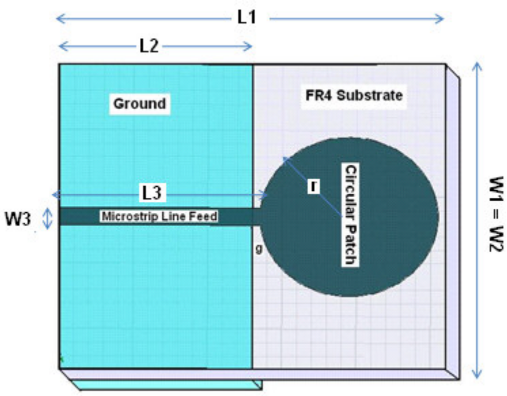

Fig. 1(a): Geometry of Circular UWB Antenna

The real part of antenna impedance is exactly 50 Ω at 3GHz, and 7.9GHz where the imaginary part of the antenna impedance equals zero as depicted in Fig. 1(c). Throughout the bandwidth of the UWB antenna, the real part of the antenna impedance varies from 25 Ω to 90 Ω whereas the imaginary part of the antenna impedance is in the range -32 Ω to +30 Ω that is not a major variation of the antenna impedance. The values of g, the antenna impedance, bandwidth (f_{low} is the lower start frequency of the antenna BW, f_{high} is the higher end frequency of the antenna BW and antenna BW is considered for those frequency range where the s_{11} is below -10dB), the maximum radiation intensity (Max U) in watt per steradian and the radiation efficiency are tabulated. Here the gap (g) between the circular patch and the ground plane below is the most crucial parameter for getting a broad BW.

TABLE I

g mm	F_{low} GHz	F_{high} GHz	Antenna Impedance Ω	P_{acc} W	P_{rad} W	Max U W/Sr	Peak Gain	η %
1	2.3	13.2	50	0.97	0.87	0.14	1.8	88

As we can see from Table I, the 'g' value is fixed at 1mm. The value of 'g' is very crucial for 50Ω impedance matching. The width of the ground plane also is an important factor in the antenna impedance and consequently the BW. Wider ground plane means longer input microstrip line and higher inductance and it affects the antenna fundamental resonant frequency and harmonic frequencies. Note the UWB performance of the monopole antenna is due to such closely resonating fundamental and harmonic frequencies. The first resonant frequency of the monopole antenna is determined by the diameter of the circular disc.

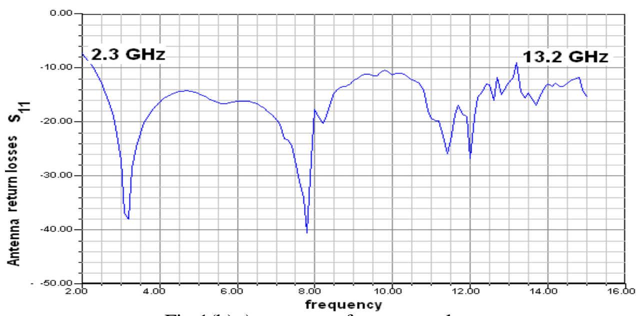

Fig 1(b):) s_{11} versus frequency plot

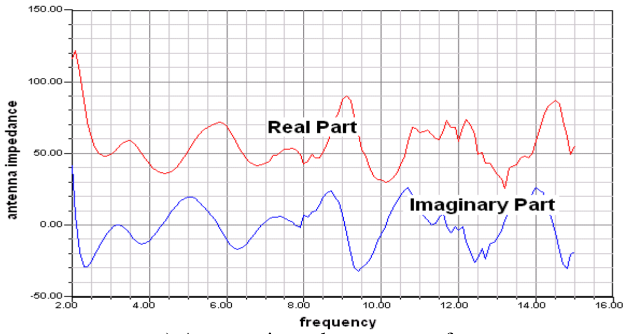

Fig. 1(c):) Antenna impedance versus frequency

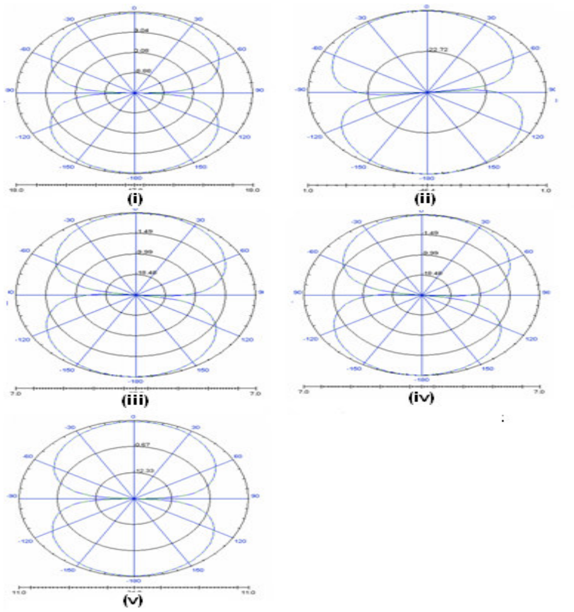

Fig. 1(d): E-plane radiation patterns at (i) 3 GHz, (ii) 5GHz, (iii) 7.5GHz, (iv) 10.6 GHz and (v) 12GHz

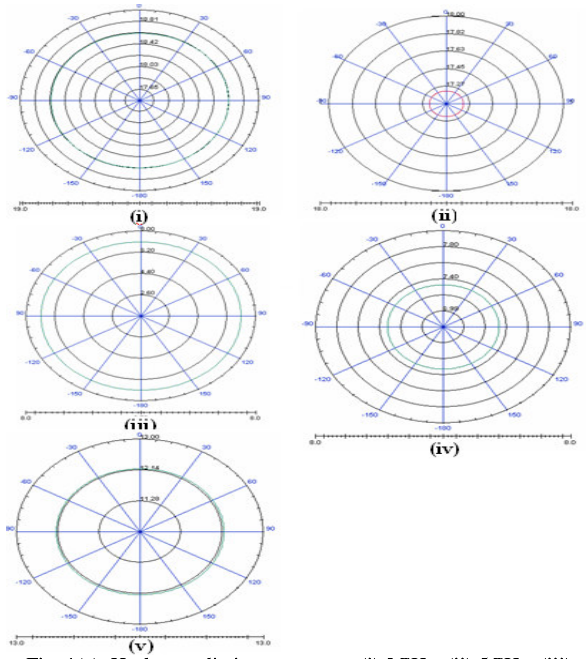

Fig. 1(e): H-plane radiation patterns at (i) 3GHz, (ii) 5GHz, (iii) 7.5GHz, (iv) 10.6 GHz and (v) 12GHz

The E-plane (i.e. vertical cut of 3D Radiation pattern) and the H-plane (i.e. horizontal cut of 3D Radiation pattern) radiation patterns of the circular disc UWB monopole antenna at 3, 5, 7.5, 10.6and 12 GHz are shown in Fig. 1(d) and 1(e). It can be observed that the E-plane radiation pattern is in the shape of figure "8" at 3GHz and the higher frequencies. It has maximum directivity at - 18^0 and - 180^0 at 3 GHz and at the frequency 10.6 GHz, it has been tilted to 10^0 and -19^0, as frequency increases it is slightly titled with 5^0 to 10^0. The H-plane radiation pattern on the other hand is purely omni-directional pattern throughout band of frequencies.

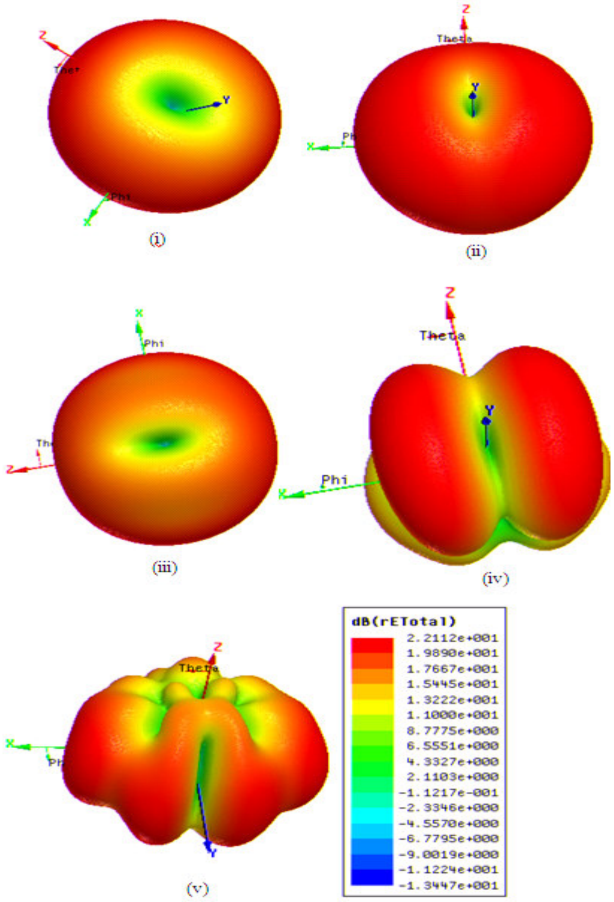

Fig. 1(f): 3D Radiation Plots at (i) 3GHz, (ii) 5GHz (iii) 7.5GHz, (iv) 10.6 GHz and (v) 12GHz

The simulated 3D radiation patterns of the proposed antenna at 3, 5, 7.5, 10.6 and 12 GHz are shown in the Fig. 1(f). The radiation pattern resembles a doughnut, similar to that of a dipole pattern, at the first resonant frequency i.e. 3GHz. At the second resonant frequency i.e. at 5GHz and the third resonance frequency i.e. at 8GHz the radiation pattern is somewhat like pinched doughnut (i.e. omni directional). As the frequency moves toward the upper end of the bandwidth The radiation pattern becomes some what distorted as it reaches higher frequencies (i.e. 10.6GHz and12 GHz).

B. Compact Miniaturized Semi-Circular patch UWB-Monopole Antenna

This Compact Miniaturized Semi-Circular patch UWB monopole antenna is designed directly from the circular disc UWB-Monopole antenna with some modifications in the radiating patch as well as on Width of the substrate. The circular patch antenna became a very compact semicircular UWB antenna after size miniaturization as shown in Fig. 2(a) with its reduced dimensions. We have used the same FR4 substrate with 4.4 relative permittivity and 1.6 mm thickness. The final optimal dimensions of the UWB-monopole antenna after extensive simulation study are:
The dimensions of Patch: Radius (r) = 12mm and metal thickness= 0.035mm; the dimensions of Substrate: W_1^1 = 34 mm and L_1^1 = 50 mm; the dimensions of Ground: W_2^1 = 34 mm and L_2^1 = 26mm; the dimensions of Microstrip line: W_3^1=2.6mm and L_3^1=27.5mm.

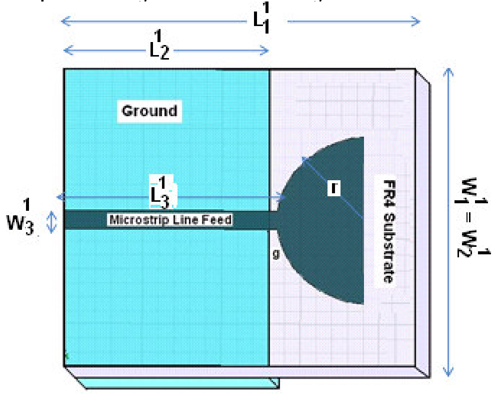

Fig. 2(a): Geometry of Circular UWB Antenna

After doing an extensive simulation study, we have fixed the dimensions of UWB monopole antenna and the value of "g" as 1mm. The antenna impedance, f_{low}, $f_{high,}$ the maximum radiation intensity (Max U) and radiation efficiency are tabulated in Table II.

Table II

g mm	F_{low} GHz	F_{high} GHz	Antenna Impedance Ω	P_{acc} W	P_{rad} W	Max U W/Sr	Peak Gain	η %
0.8	3.2	11.5	50	0.98	0.88	0.13	1.69	89.6
1	3	11.6	50	0.97	0.87	0.13	1.64	89.3

Note that modified circular disc UWB-Monopole antenna is more compact than the circular disc UWB-monopole antenna. It has better radiation efficiency although the antenna BW is reduced it is still much broader than UWB BW of 3.1 GHz to 10.6Hz. The real part of antenna impedance is exactly 50 Ω at 8.5GHz and 10.8 GHz when the imaginary part of antenna impedance cross zero as depicted in Fig. 2(c). It has maximum directivity at - 26^0 and -180^0 at 3 GHz and at the frequency 10.6 GHz, it has been tilted to 10^0 and -26.4^0. as frequency increases it is slightly titled with 5^0 to 10^0. The H-plane radiation pattern on the other hand is purely omni-directional pattern throughout UWB.

As far as the E-plane and H-plane radiation patterns they are quite similar to the previous antenna throughout the frequency regions which are shown in fig 2(d) and 2(e) at different resonant frequencies.

The simulated 3D radiation patterns of the proposed antenna at 3.1, 5, 8, 9, 10.6 and 11.2 GHz are shown in the Fig. 1(f). The radiation pattern looks like a doughnut. The radiation pattern is somewhat like pinched doughnut (i.e. omni directional) at the first resonant frequency i.e.at 3GHz, the second resonant frequency i.e. at 5GHz and the third resonance frequency i.e. at 8GHz respectively. As the frequency moves toward the upper end of the bandwidth; the radiation pattern is distorted slightly as it reaches higher frequencies (i.e.10.6GHz and 11.2 GHz.).

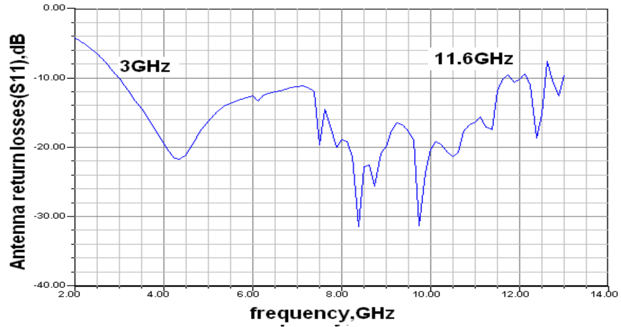

Fig. 2(b): s_{11} versus frequency plot

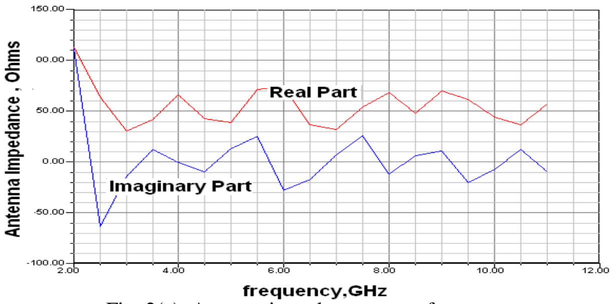

Fig. 2(c): Antenna impedance versus frequency

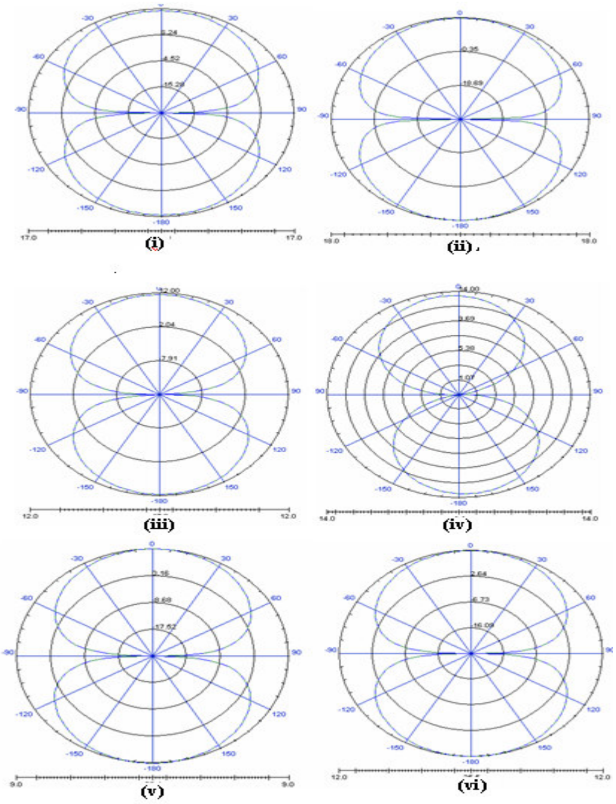

Fig. 2(d) : E-plane radiation patterns at (i) 3GHz, (ii) 5GHz, (iii) 8GHz, (iv) 9GHz, (v) 10.6 GHz and (vi) 11.2GHz

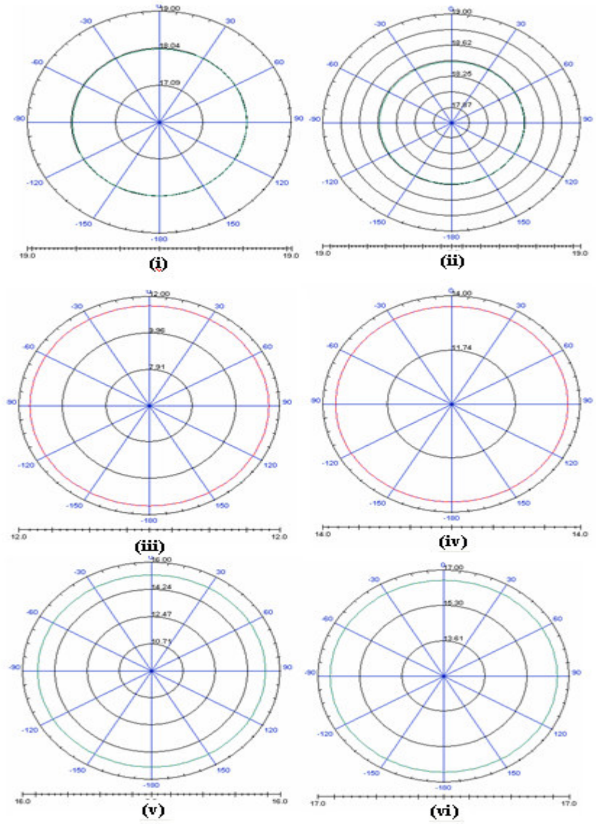

Fig. 2(e): H-plane radiation patterns at (i) 3GHz, (ii) 5GHz, (iii) 8GHz, (iv) 9GHz, (v) 10.6 GHz and (vi) 11.2GHz

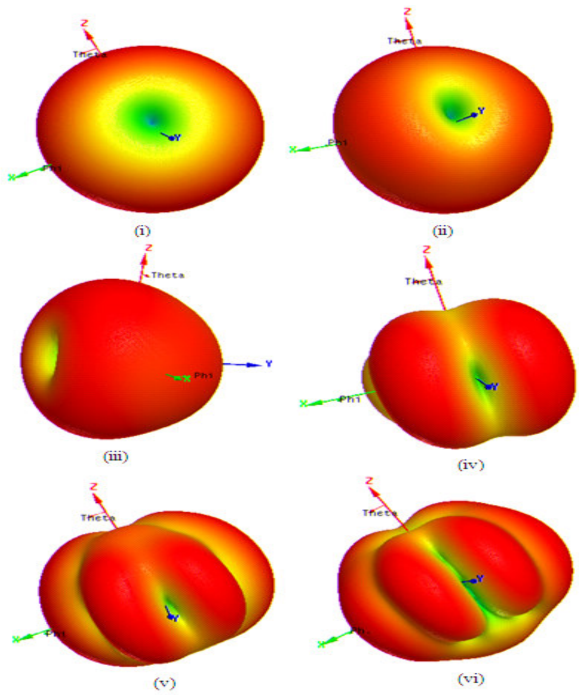

Fig. 1(f): 3D Radiation Plots at (i) 3.1 GHz, (ii) 5 GHz, (iii) 8 GHz, (iv) 9GHz, (v) 10.6 GHz and (vi) 11.2GHz

The radiation pattern variation from a simple doughnut at the lower frequencies to slightly distorted doughnut pattern at the higher resonances indicate that this antenna must have gone through major changes in its behavior, yet has omni directionality. The antenna has very less reflections and maximum radiation efficiency due to the proper impedance matching.

Table III

Circular Patch UWB Antenna		**Miniaturized Patch UWB Antenna**	
Parameters	**Values**	**Parameters**	**Values**
W_1 X L_1	46mmX52mm	W_1^1 X L_1^1	34mmX50mm
W_2 X L_2	46mmX26mm	W_2^1 X L_2^1	34mmX26mm
f_{low}	2.3 GHz	f_{low}	3 GHz
f_{high}	13.2 GHz	f_{high}	11.6 GHz
Efficiency in %	88.00	Efficiency in %	**89.3**
Compactness	Less	Compactness	**Very Good**

While size miniaturization, we got radiation efficiency in percentage of 89.6 at the value of “g” was 0.8mm consequently the lower end of frequency of the BW was shifted to 3.2GHz this was a serious problem according to the actual specified frequency bandwidth for UWB operations by FCC but this problem was overcome with the new value of “g” (i.e. 1mm), in both the UWB antennas the value of “g” is 1mm. At this particular instant the Lower end of frequency bandwidth was shifted back to 3GHz from 3.2GHz.

We can clearly understand the benefits and importance of the process of the size miniaturization in these UWB antennas in enhancing the results and also how the antenna parameters are affecting the overall performance of the antenna as shown in Table III. The dimensions of the substrate and the ground plane of the circular patch UWB antenna are (46mm X 52mm) and (46mm X 26mm), these dimensions are reduced to (34mm X 50mm) and (34mm X 26mm) respectively. This was the huge reduction in the size without disturbing of the antenna parameter and the performance.

III. CONCLUSION

In this paper, we have investigated two printed UWB monopole antennas which are basically printed microstrip antennas with the etched ground plane and also explained a novel approach for improving radiation efficiency and size miniaturizations step by step with proposed antenna structures. Printed UWB monopole antennas are less fragile, planar and can be integrated with the integrated circuits unlike monopole antennas which have non-planar or protruded structures above the ground plane. In particular, we have simulated two types of UWB monopole antennas namely circular patch UWB and Compact Miniaturized Semi-Circular patch UWB monopole antennas. The second antenna is very compact and has higher radiation efficiency then the first antenna and also clearly mentioned step by step, how the performance and compactness of the proposed antennas were enhanced and also tabulated corresponding resultant parameter, whereas the first antenna has slightly wider BW. The E-plane radiation patterns of both the printed monopole antennas are in the form of 8 shapes and it is slightly tilted at higher frequencies. The H-plane radiation pattern has omni-directional patterns throughout the frequencies of the BW. It has been observed that such monopole antennas are suitable for UWB operations from the Ansoft HFSS simulation results.

IV. ACKNOWLEDGMENTS

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