Rectangular Microstrip Patch Antenna With Truncated Ground For Ultra Wide Band

[1]Abhishek Karwa, [2]Ashish Mathur

[1]Assistant Professor, JIET-SETG, Jodhpur, Rajasthan, India, karwa21@gmail.com, 9829949196.

[2]Associate Professor, JIET-SETG, Jodhpur, Rajasthan, India, ashish.mathur@jietjodhpur.ac.in, 9829444456.

Abstract— In this study, a rectangular patch with truncated ground microstrip antenna for ultra wide bandwidth is presented. The antenna has compact dimension of 16 mm x 18 mm (W_{sub} x L_{sub}), is constructed on FR4 substrate with thickness of 1.6 mm and relative dielectric constant of 4.4. The dimensional parameters for the antenna are introduced and their effects on the frequency characteristic have been investigated through a parametric study. The antenna is designed to operate over 3.1 to 11 GHz for S11< -10 dB. The simulated results show good agreement with the measured results. These characteristics make the antenna suitable for UWB applications.

Keywords— Patch antenna, truncated ground plane, microstrip-fed , monopole, UWB antenna, FR4 substrate, HFSS

INTRODUCTION

The applications of UWB antenna are in the medical imaging, high-accuracy radar, wall imaging and wireless communications [1]. The most important characteristics of these antennas are low cost, compact size and a good omnidirectional pattern. Therefore the monopole planar antennas are suitable for designing and fabrication [2].

The design of wideband antenna is very difficult task especially for hand-held terminal since the compromise between size, cost, and simplicity has to be achieved. In UWB communication systems, one of key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Due to their appealing features of wide bandwidth, simple structure, omnidirectional radiation pattern, and ease of construction several wideband monopole configurations, such as circular, square, elliptical, pentagonal, and hexagonal have been proposed for UWB applications [3]–[5].

Thus, a microstrip-fed monopole antenna is suitable candidate for integration with hand-held terminal owing to its attractive features such as low profile, low cost, and light weight.

In this paper, a compact ultra wideband microstip-fed printed monopole antenna. To achieve the maximum impedance bandwidth, a pair of notches is placed at the two lower corners of the patch and the notch structure is embedded in the truncated ground plane. Simulated and experimental results are presented to demonstrate the performance of a suggested antenna.

ANTENNA CONFIGURATION AND DESIGN

For patch antenna the length and width are used as calculated from the equations. The expression for ε_{reff} is given by Balanis as [6]:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{1/2} \qquad (1)$$

The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by Hammerstad as:

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (2)$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\,\Delta L \qquad (3)$$

For a given resonance frequency f_o , the effective length is given by

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}} \qquad (4)$$

For a rectangular microstrip patch antenna, the resonance frequency for TM mn mode is given by James and Hall as-

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2} \qquad (5)$$

For efficient radiation, the width W is given by –

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (6)$$

The first step is to design substrate of dimension 16 mm x 18 mm. The width W_f of the microstrip feedline is fixed at 2 mm. On the front surface of the substrate, a rectangular patch with size of 7 mm x 11 mm (W x L) is printed. The rectangular patch has a distance of L_3 to the ground plane printed on the back surface of the substrate.

Following Steps are applied to design an optimized geometry:

1) By cutting the two notches of suitable dimensions (W_1 x L_1) at the monopole's two lower corners, it is found that much enhanced impedance bandwidth can be achieved for the antenna. This phenomenon occurs because the two notches affect the electromagnetic coupling between the rectangular patch and the ground plane [7].

2) In addition, to achieve good wideband matching of the antenna, the separation L3 between the rectangular patch and the notch in the ground plane is used.

The modified truncated ground plane acts as an impedance matching element to control the impedance bandwidth of a square monopole [8]. The dimension of the notch (W_2 x L_2) embedded in the truncated ground plane and feed gap distance L_3 are important parameters in determining the sensitivity of impedance matching. Figure 1 shows the configuration of the proposed wideband antenna and the final optimal dimensions of the designed antenna are given in the table 1. The 3-D view of antenna simulated is shown in figure 2.

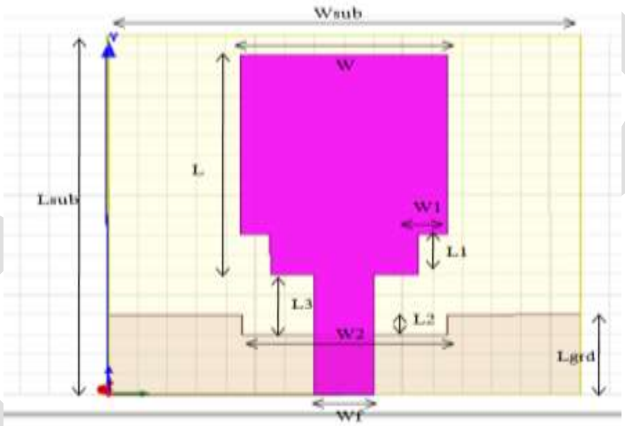

Figure 1: Configuration of the antenna

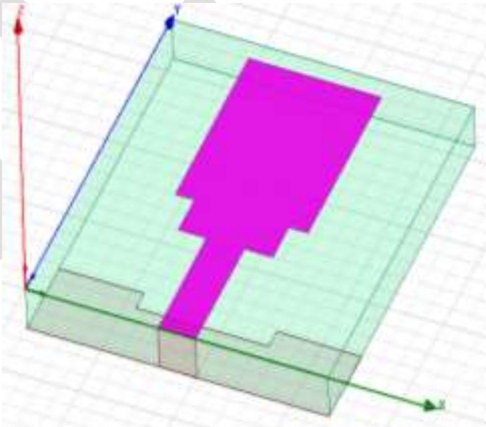

Figure 2: 3-D view of antenna

Table 1: Dimensions of Antenna (After Optimization)

W_{sub}	L_{sub}	W	L	W_1	L_1	W_2	L_2	L_3	W_f	L_{grd}
16	18	7	11	1	2	7	1	3	2	4

RESULTS

A) SIMULATED RESULTS

The microstip-fed monopole antennas with various parameters (L1 and L2) were constructed and studied to demonstrate the proposed bandwidth-enhancement technique. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [9].

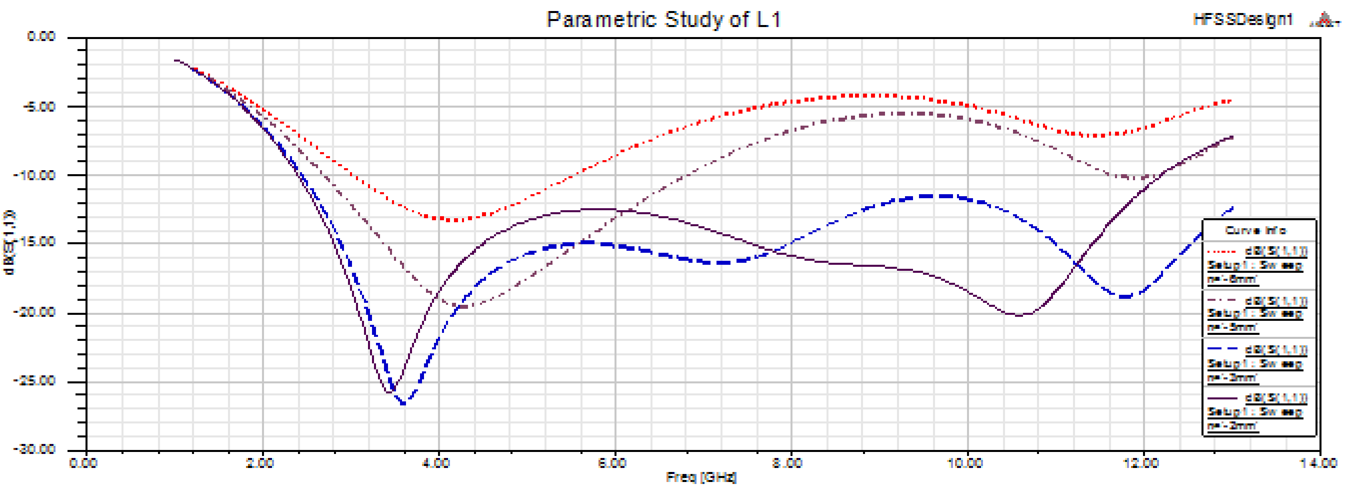

Figure 3: Simulated return loss for various L_1 at the two lower corner of the proposed monopole antenna. (W_1 is fixed at 1mm)

Figure 3 shows the simulated return loss curves for various notch sizes (W_1 x L_1). As the notch sizes (W_1 x L_1) are changed from 1mm x 6 mm to 1 mm x 2 mm, the impedance bandwidth becomes greater than 6 GHz, with decrease of the upper frequency f_U. It is also observed that the upper frequency f_U is significantly affected by the variation in notch length L_1. On the other hand, the lower frequency f_L is insensitive to the change of L_1.

The simulated return loss curves with different values of L_2 are plotted in Figure 4 when W_2 is fixed at 7 mm. From the simulation results in Figure 4, it is found that the 10 dB impedance bandwidth decreases as the notch length L_2 decreases.

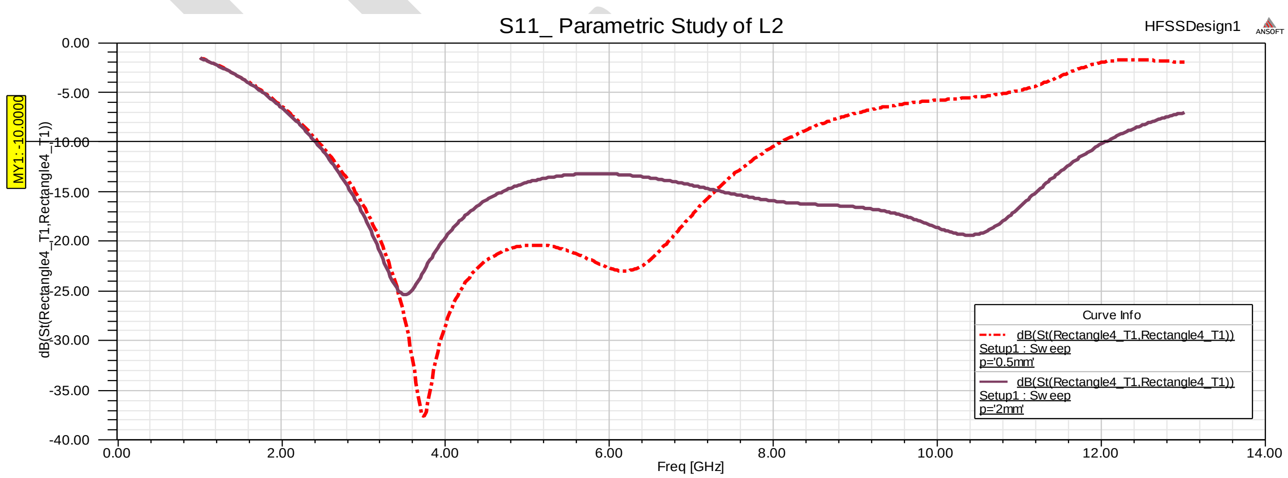

Figure 4: Return loss curves with different values of L_2

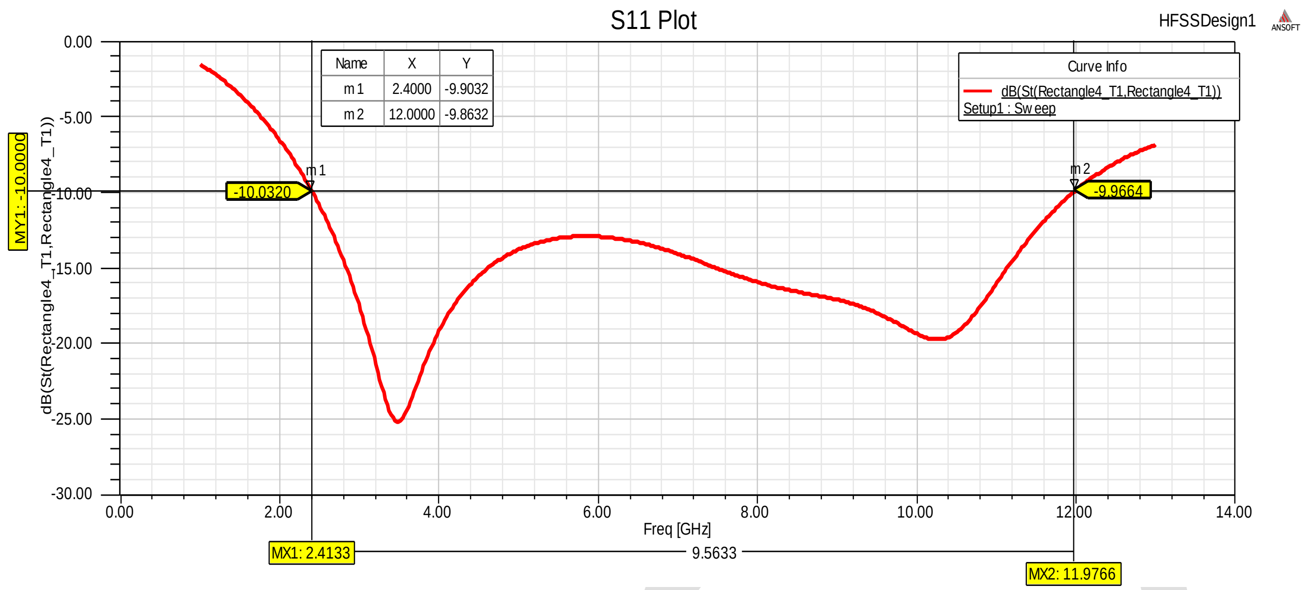

Figure 5: Return loss curves with Optimized value of L_2 (ie L_2 = 1mm)

The optimized notch length L_2 on the truncated ground plane is 1 mm. The simulated return loss curves with the optimal notch length L_2 =1mm for various notch widths W_2 on the truncated ground plane are plotted in Figure 6. As the notch width W_2 increases, the lower frequency f_L is slightly changed and the upper frequency f_U is markedly increased. It is observed that the notch width W_2 is the most critical parameter to determine the upper frequency f_U. The notch width W_2 is chosen as 7 mm to yield near optimal bandwidth.

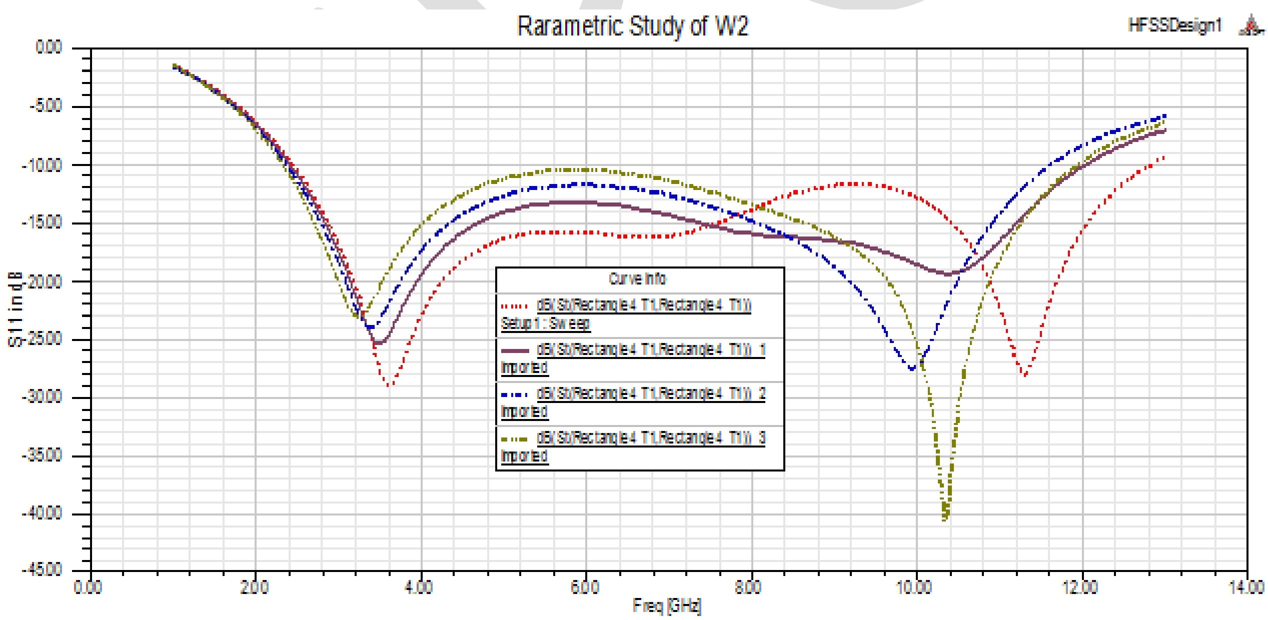

Figure 6: Return loss curves with various values of W_2

Figure 7 shows the simulated voltage standing wave ratio (VSWR) against frequency of the antenna. Based on the simulated result, the VSWR value ranges from 1 to 2 throughout the frequency range of 2.41GHz to 12.05GHz. The result indicates that the VSWR complies with the UWB characteristic and the same frequency region also displays the return loss curve less than –10 dB, as seen in figure 5.

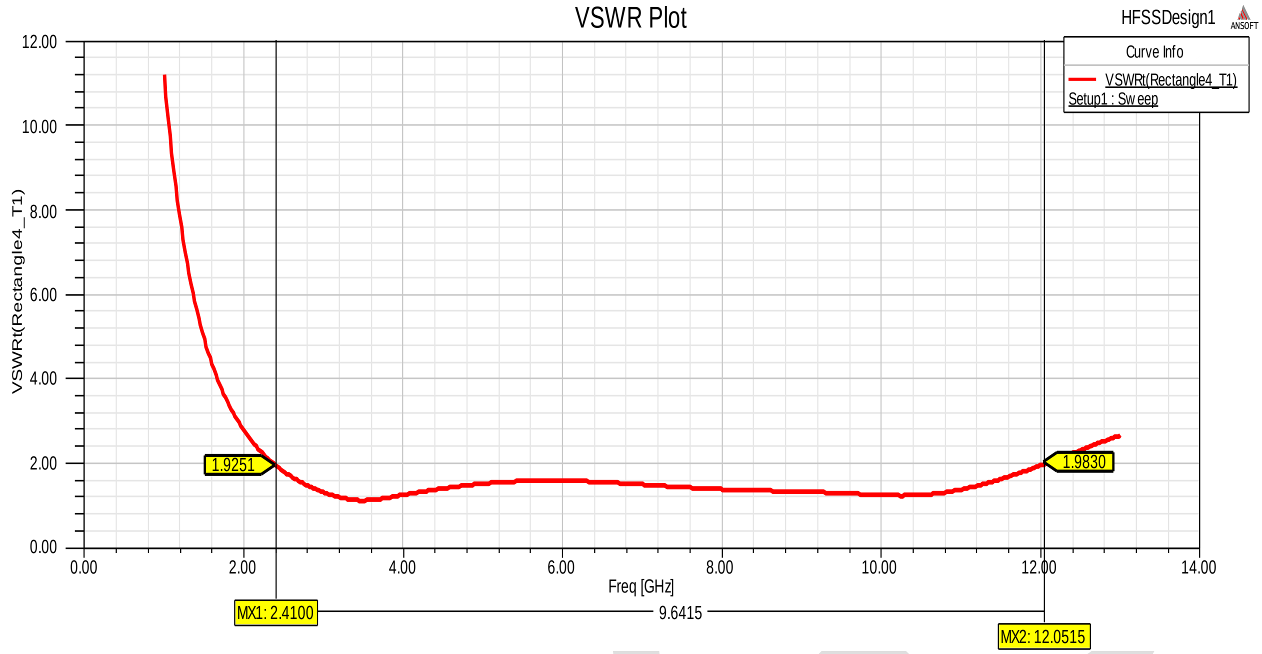

Figure 7: Simulated voltage standing wave ratio (VSWR)

OTHER CALCULATED PARAMETERS:

Some of the other important parameter of antenna are also calculated from the simulation out of which antenna gain plays a vital feature in determining antenna performance. The peak gain is shown in figure 8 at frequency 10GHz. Similarly the simulated directivity, radiation efficiency, radiated power, accepted power and incident power are also shown in figure 9 to figure 13 respectively.

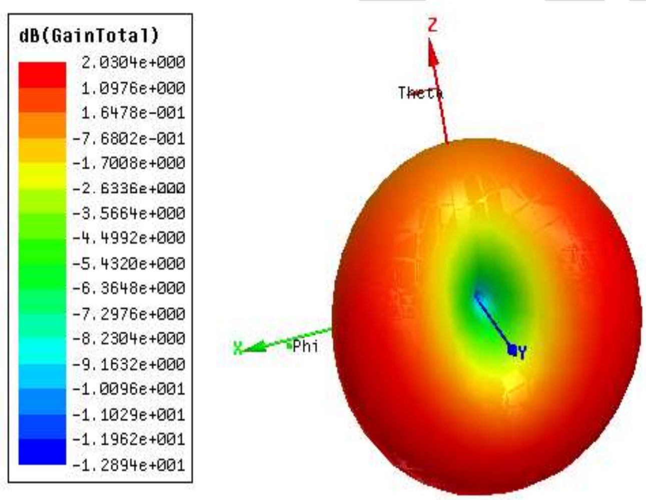

Figure 8: 3D polar plot for gain of antenna

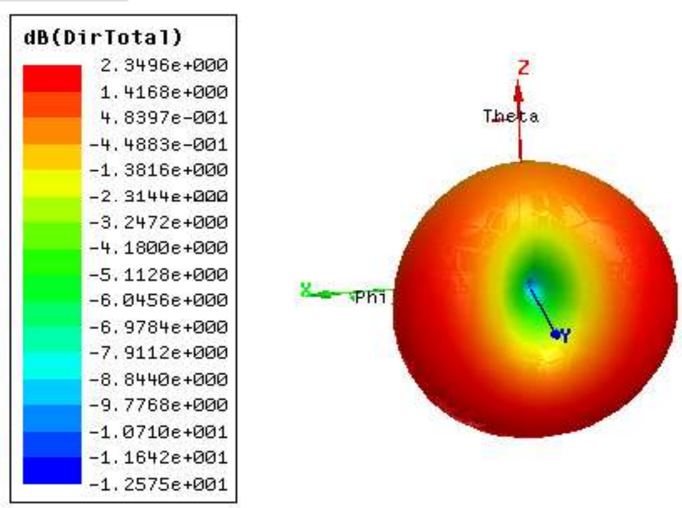

Figure 9: 3D polar plot for directivity of antenna

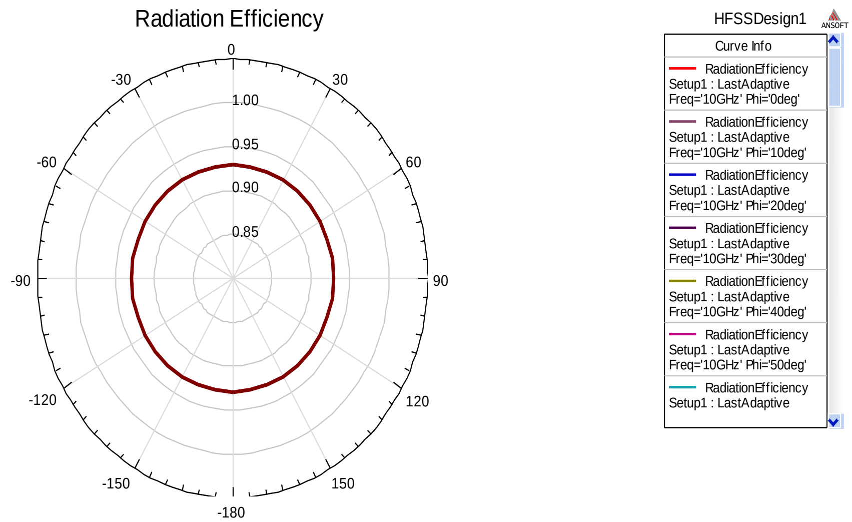

Figure 10: Plot for Radiation Efficiency of antenna

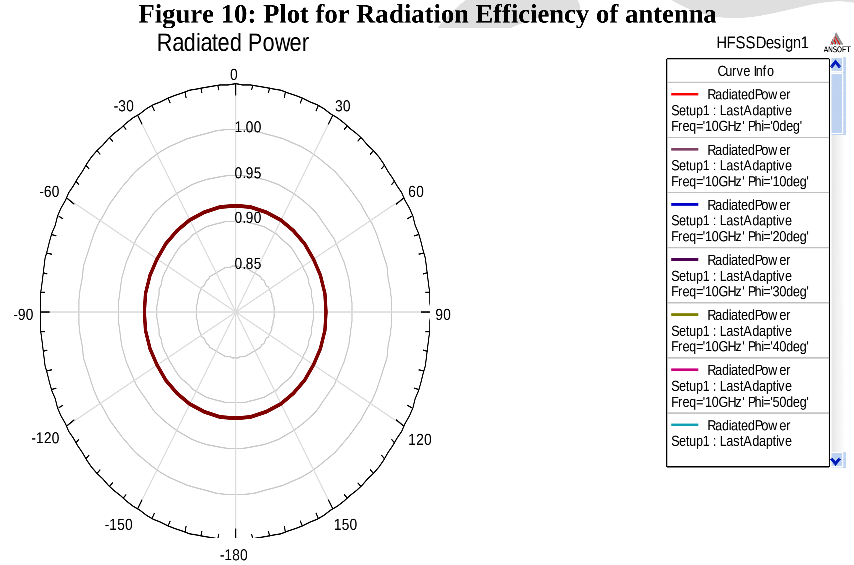

Figure 11: Plot for Radiated Power of antenna

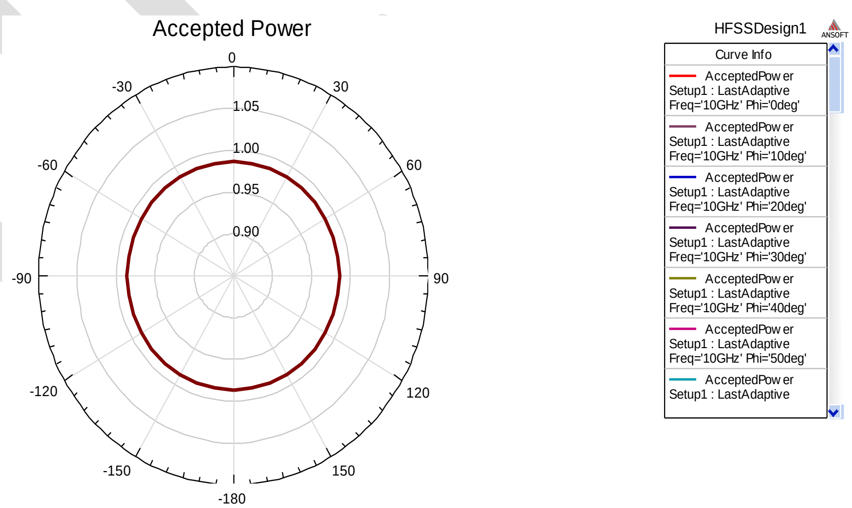

Figure 12: Plot for Accepted Power of antenna

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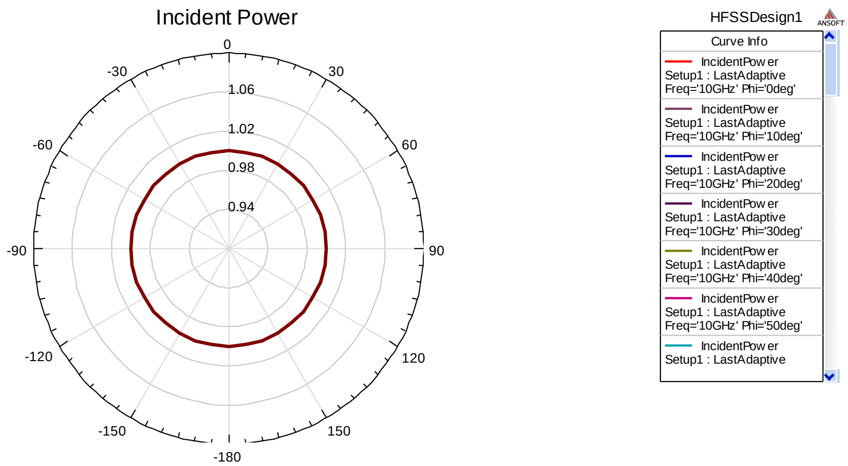

Figure 13: Plot for Incident Power of antenna

The mathematical values of simulated gain, directivity, radiation efficiency, radiated power , accepted power and incident power at frequency 10 GHz are also given in table 2

Table 2: Mathematical Values of antenna Parameter

Parameter	Value
Gain	2.03 dB
Directivity	2.34 dB
Radiation efficiency	93%
Radiated power	92%
Accepted power	98%
Incident power	99%

B) MEASURED RESULTS

The set up for antenna measurement using vector network analyzer is used for the calculation of return loss values at DRDO, Jodhpur and it is concluded that the antenna covered less then -10dB value for almost UWB range. Using the vector network analyzer instrument, result of return loss values for 1.44GHz to 11.2 GHz is obtained and compared with simulated results for designed antenna. Figure 14 shows measured return loss characteristics and figure 15 shows the measured VSWR characteristics of the antenna of the antenna. Measured impedance bandwidth is nearly similar as compare to simulated one. The fabricated antenna satisfies the 10-dB return loss requirement from 1.44 GHz to 11.2 GHz.

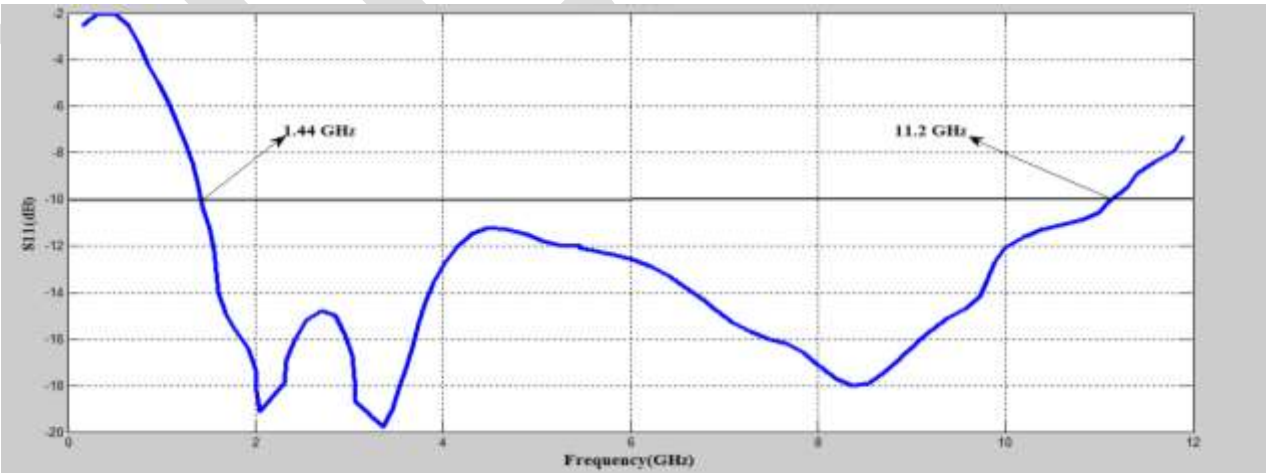

Figure 14 : Measured return loss characteristics of the antenna.

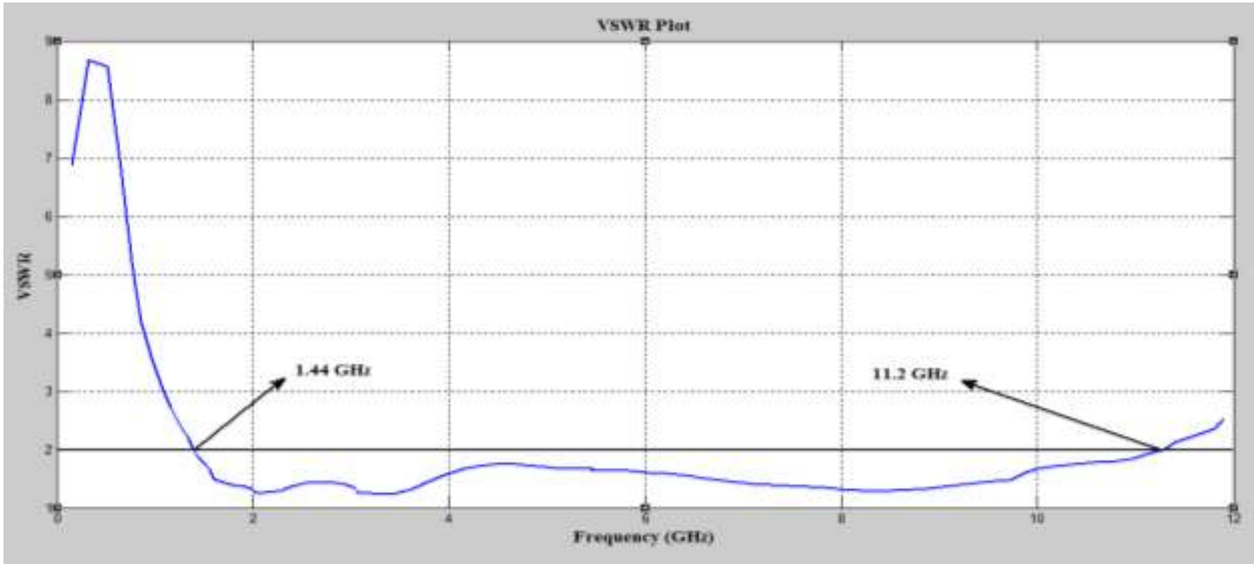

Figure 15: Measured VSWR characteristics of the antenna.

FABRICATION

The antenna structure is fabricated on a printed circuit board (PCB) using Photolithography technique and tested. The top and bottom view fabricated antenna is shown in Figure 16.

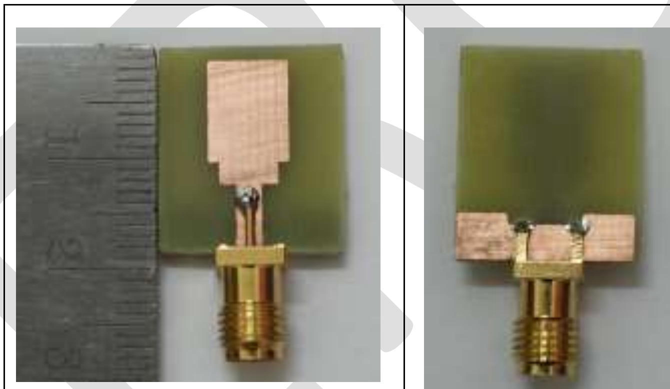

Figure 16: Front and back side view of fabricated antenna

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CONCLUSION

The fabricated antenna has advantages of small size, easy fabrication and simple construction. Antenna operates at 1.44GHz -11.2 GHz with Absolute Bandwidth 9.2 GHz. Radiation performance of patch antenna is also presented in this paper. The radiation efficiency 93% is achieved and we conclude that proposed geometry is applicable for ultra wide band from 3.1 GHz to 10.6 GHz. In future the radiation performance of rectangular patch antenna can be improved by using different feeding techniques.

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