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UWB Partial Ground with Slit Circular Microstrip Patch Antenna Design

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ABSTRACT: In this paper different kind of Ultra Wideband (UWB) microstrip antenna consisting of a circular monopole patch with stepped feed line, with a 10 dB return loss bandwidth from 2 to 10 GHz is designed. This antenna was designed on FR4 substrate and dielectric substrate with $\epsilon_r = 4.4$. These antenna operated at UWB frequency and it designed by using CST Software based on the characteristic impedance for the transmission line model. The parameters like substrate dimension, feed size and ground plane which affect the performance of the antenna in terms of its frequency domain and time domain characteristics are investigated.

KEYWORDS: Microstrip line feed, Microstrip antenna, Partial ground plane, Ultra Wideband Antenna

I. INTRODUCTION

A microstrip antenna is one who offers low profile and light weight. It is a wide beam narrowband antenna can be manufactured easily by the printed circuit technology such as a metallic layers in a particular shape is bonded on a dielectric substrate which forms a radiating element and another continuous metallic layer on the other side of substrate as ground plane. Not only the basic shapes any continuous shape can be used as the radiating patch. Instead of using dielectric substrate some of the microstrip antennas use dielectric spacers which results in wider bandwidth but in the cost of less ruggedness. Microstrip antennas are low profile antenna and mechanically rugged and can be easily mounted on any planar and non-planar surfaces. The size of microstrip antenna is related to the wavelength of operation generally $\lambda / 2$. The applications of microstrip antennas are above the microwave frequency because below these frequencies the use of microstrip antenna doesn't make a sense because of the size of antenna. At frequencies lower than microwave, microstrip patches don't make sense because of the sizes required. Now a day's microstrip antenna is used in commercial sectors due to its inexpensiveness and easy to manufacture benefit by advanced printed circuit technology. Due to the development and ongoing research in the area of microstrip antenna it is expected that in future after some time most of the conventional antenna will be replaced by microstrip antenna.

UWB has a number of encouraging advantages that are the reasons why it presents a more eloquent solution to wireless broadband than other technologies. Firstly, according to Shannon-Hartley theorem, channel capacity is in proportion to bandwidth. Since UWB has an ultra wide frequency bandwidth, it can achieve huge capacity as high as hundreds of Mbps or even several Gbps with distances of 1 to 10 meters Secondly, UWB systems operate at extremely low power transmission levels. By dividing the power of the signal across a huge frequency spectrum, the effect upon any frequency is below the acceptable noise floor [2]. A Ultra Wideband technology is defined as a system that occupied over 500MHz of bandwidth or occupy a fractional bandwidth of 20% or greater. Ultra Wideband uses radio modulation technique to achieve a wide bandwidth by transmitting very short pulses (in nanosecond or less) with very low power utilization. This makes Ultra Wide band differs from conventional narrowband systems. Starting 2002, the usage of unlicensed Ultra Wideband operation was authorised by FCC (Federal Communication Commission) of United States of America (USA) [1].

The advantages of printed microstrip antenna are [2] light weight and low volume, low profile planar configuration which can be easily made conformal to host surface, low fabrication cost, hence can be manufactured in large quantities, supports both, linear as well as circular polarization. Microstrip antenna can be easily integrated with microwave integrated circuits (MICs), and mechanically robust when mounted on rigid surfaces. However, microstrip antennas also have several disadvantages. The disadvantages are narrow bandwidth, low efficiency, low gain,

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extraneous radiation from feeds and junctions, poor end fire radiator except tapered slot antennas, low power handling capacity and surface wave excitation [3, 4].

The whole paper is organized in four sections. In the First section we will describe microstrip patch antenna's different models. In second section we describe different geometrical shapes and design parameters. After that we discuss the results obtained and in the last we will explain the future scope of the antenna's.

1. Microstrip antenna's analytical model:

II. CIRCULAR MICROSTRIP ANTENNA

Circular patch is the second most widely used geometry for the microstrip patch antenna. As in rectangular microstrip antenna we have two degree of freedom (length and width) to control the antenna characteristics, here we have only radius of circular patch. A circular microstrip antenna is shown in figure below

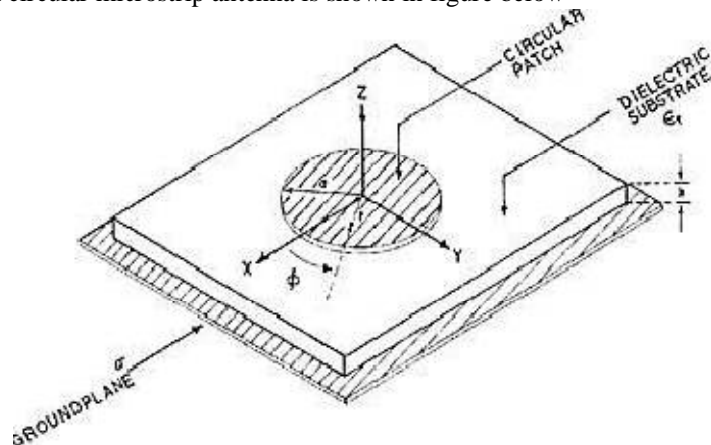


Figure 3.5 Circular Patch Antenna

As shown in figure Metallic Circular patch with radius a is placed a height h above the ground plane. Dielectric substrate separates the patch and ground plane and the patch is fed at a point r distance from the centre at a angle ϕ from the x -axis. The circular patch antenna can be analysis by considering the patch as a cavity with two perfect conductor electric wall above and below (patch and ground plane) and magnetic walls along the edges. The electric field below the circular patch can be given by:

$$E_z = E_0 J_n(kr) \cos(n\phi)$$

And the magnetic field components can be given by:

$$H_r = -\frac{j\omega\epsilon n}{k^2 r} E_0 J_n(kr) \sin(n\phi)$$

$$H_\phi = -\frac{j\omega\epsilon n}{k} E_0 J'_n(kr) \cos(n\phi)$$

Where,

k = propagation constant

J_n = nth order Bessels function

J'_n = nth order derivative of Bessels function

The resonance frequency f_{mn} related to TM mode can be given as:

$$f_{mn} = \frac{X_{mn} \cdot c}{2\pi \epsilon_{eff} \sqrt{\epsilon_r}}$$

Where

X_{mn} = mth zero of derivative of Bessel's function of nth order

c = velocity of light in free space

a_{eff} = effective radius of circular patch

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$$a_{eff} = a \cdot \left[1 + \frac{2h}{\pi \epsilon_r a} \left(\ln \left\{ \frac{\pi a}{2h} \right\} + 1.7726 \right) \right]^{\frac{1}{2}} \quad \text{for } \frac{a}{h} \gg 1$$

and the actual radius of patch can be determined by

$$a = \frac{X_{mn} \cdot c}{2\pi \sqrt{\epsilon_r}} \left[1 + \frac{2h}{\pi \epsilon_r a} \left(\ln \left\{ \frac{\pi a}{2f_{mn} h} \right\} + 1.7726 \right) \right]^{-\frac{1}{2}}$$

Therefore radius of circular patch can be found using above equation.

III. PROPOSED PATCH ANTENNAS

3.1 Modified Circular Patch Antenna for UWB application

The designed antenna has two half circular patches which are overlapped to each other. A narrow rectangular slit is added to the patch to improve the performance of antenna. The proposed antenna is fabricated on an inexpensive and easily available dielectric material FR-4 with permeability of 4.4.

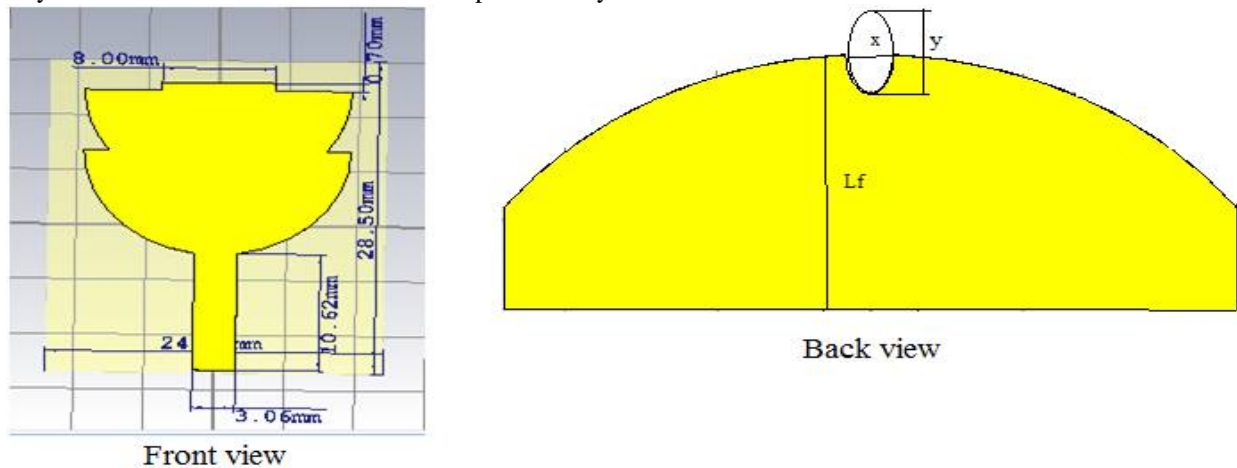


Figure 2 Front and Back View and Fabricated Antenna

Proposed microstrip antenna is fed by standard 50ohm microstrip feed line. Different parameters with their Optimized value of the proposed antenna are listed below in table:

Table 1 Dimensions of the Proposed 1st Design

Parameters	Description	Value (in mm)
R	Radius of half circular patch	9.5
A	Overlapping length	4
Lf	Length of feedline	10
Wf	Width of feedline	3.058
Lstub	Length of stub	0.7
Wstub	Width of stub	8
Lsub	Length of substrate	29.8
Wsub	Width of substrate	12.6

3.2 Elliptical Shape Microstrip Patch Antenna with Modified Groundplane

The second design is elliptical patch antenna with modified ground plane. FR-4 dielectric material is used as substrate with dielectric constant 4.4. Standard 50 ohm microstrip feedline is used to feed. The results show that the proposed antenna has the bandwidth (vswr=2) from 2.46 Ghz to 13.62 Ghz which covers the UWB band therefore the proposed

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antenna is a good candidate to be used for the UWB application. Partial ground plane is used here. For increasing the bandwidth as a ground plane strategy a rectangular notch and a narrow slit is made in the ground plane.

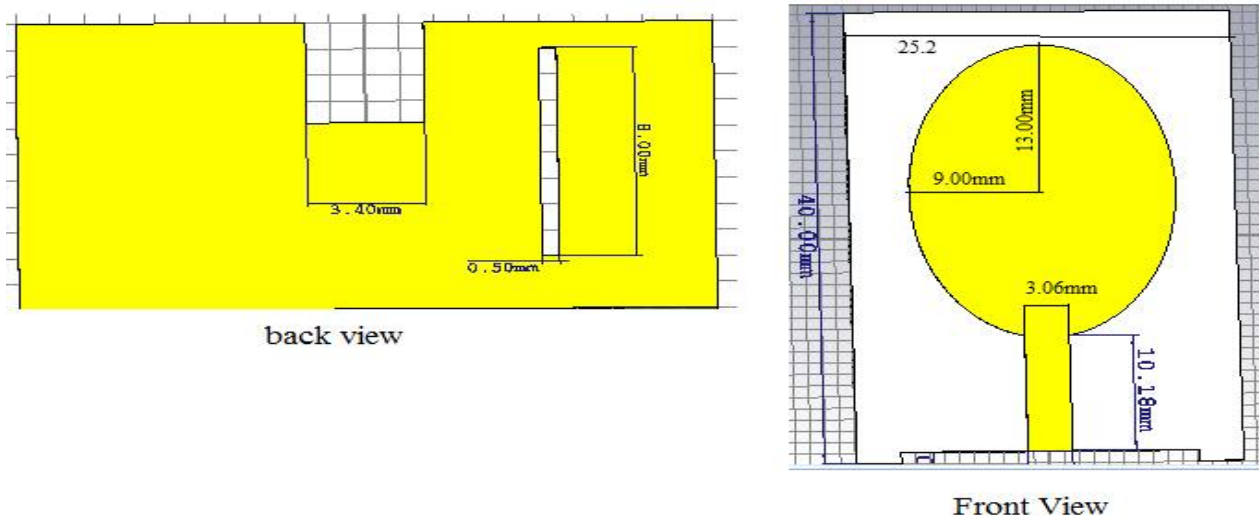


Figure 3 front and back view of proposed antenna

Parameter list with their values are written in the table below. All the dimensions are in millimetre.

Table 2 Dimensions of the Proposed 2nd Design

Parameters	Description	Value (in mm)
X	Major radius of ellipse	9
Y	Minor radius of ellipse	13
L _f	Length of feedline	10
W _f	Width of feedline	3.058
A	Length of notch	3.4
B	Width of notch	3.858
L _{sub}	Length of substrate	38.6
W _{sub}	Width of substrate	25.2
L ₁	Length of slit	8
W ₁	Width of slit	0.5

The front and back view of the proposed antenna is shown below. Structural view showing all the antenna parameters. Partial ground plane with curvy edges is used. Making a rectangular notch behind the feedline in ground plane and narrow rectangular slit in ground results in drastically improvement in the return loss curve.

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IV. SIMULATION RESULTS

The s11 vs frequency curve for the optimized parameters is shown below.

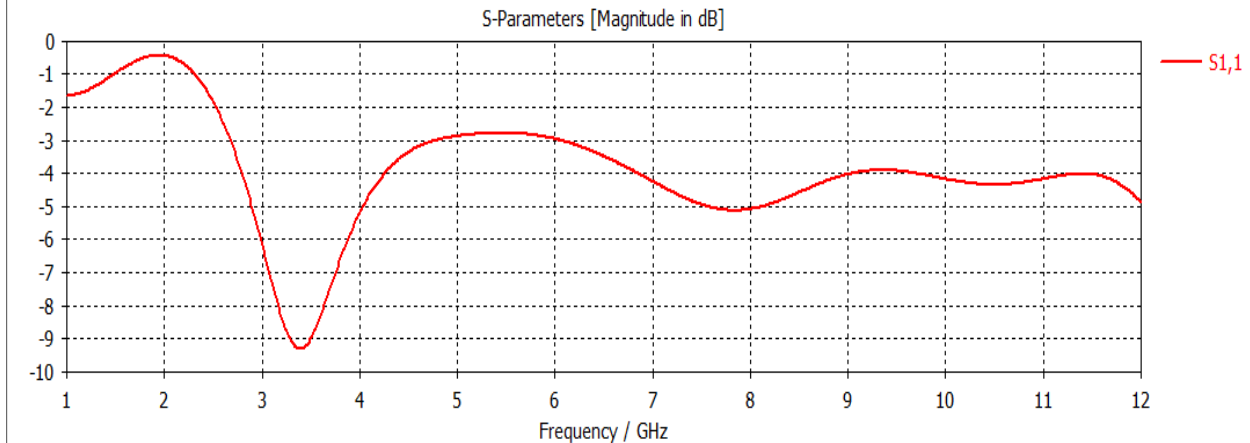


Figure 4. frequency vs s11 curve for optimized values

The effect of modifying the radius of patch effect on s11 parameter is observed. Figure below shows different s11 vs frequency curve for different values of radius r. It is observed that when we increase the radius the s11 vs frequency curve shifts towards lower frequency while on decreasing it shifts toward right. Therefore we can conclude that the two resonance frequencies we are getting are inversely proportional to the radius of the circular patch. It is also observed that for optimum value of radius $r=9$ the s11 is more deep.

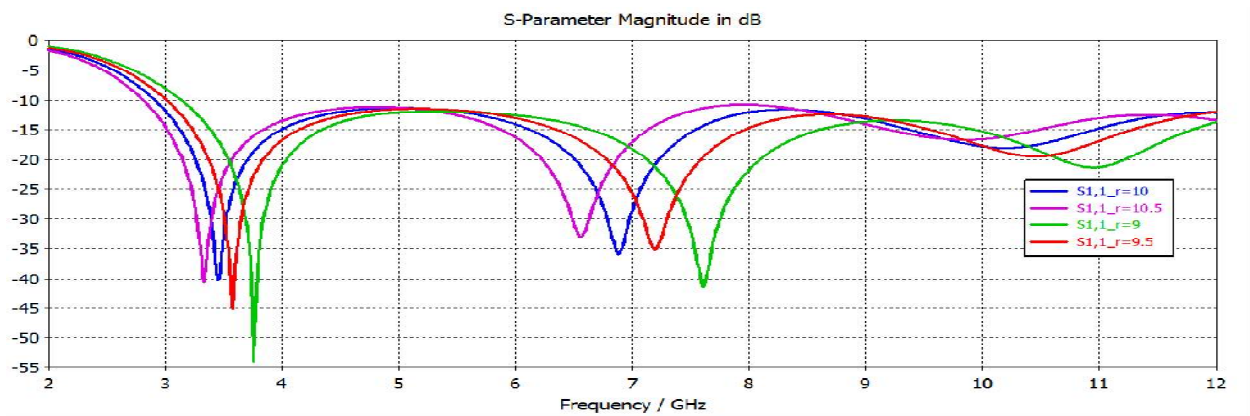


Figure 5 frequency vs s11 curve for different values of radius r

The overlapping of circular patches also affects the antenna characteristics and the value of overlapping length a is manually optimized. Figure shows s11 results for different value of a.

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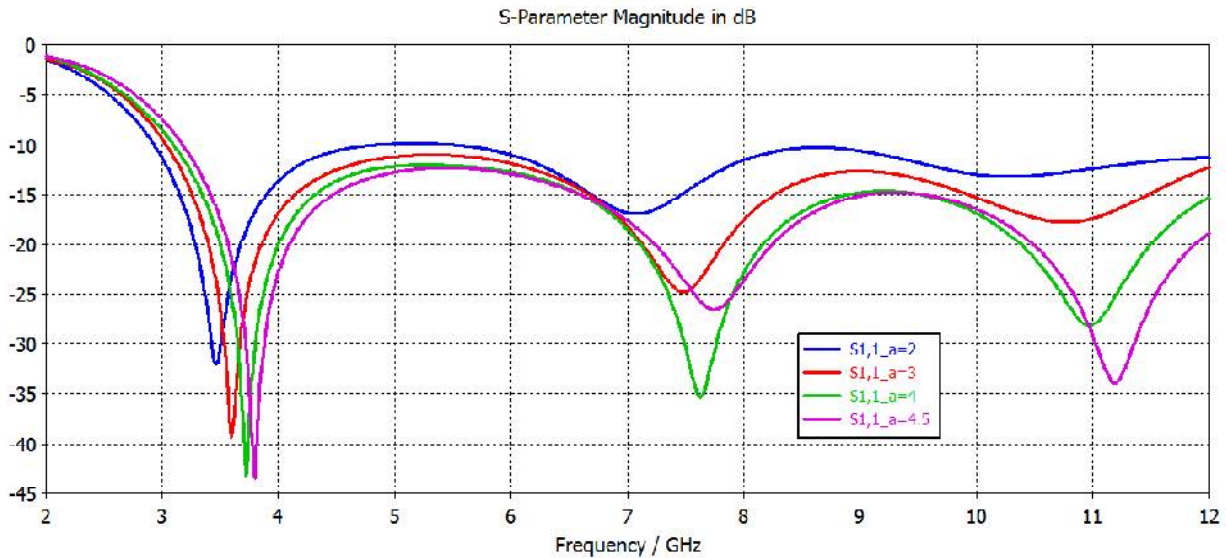


Figure 6 frequency vs s11 curve for different values of a

From the results it is clear that when the overlapping of the patches increases or decreases from its optimum value $a=4$ the s_{11} vs frequency curve shift upward. Figure below showing the Gain vs frequency curve. Antenna have maximum gain at 12 GHz 4.2 dB and minimum -5.6 dB and -1.1 dB at 2 GHz and 10 GHz respectively.

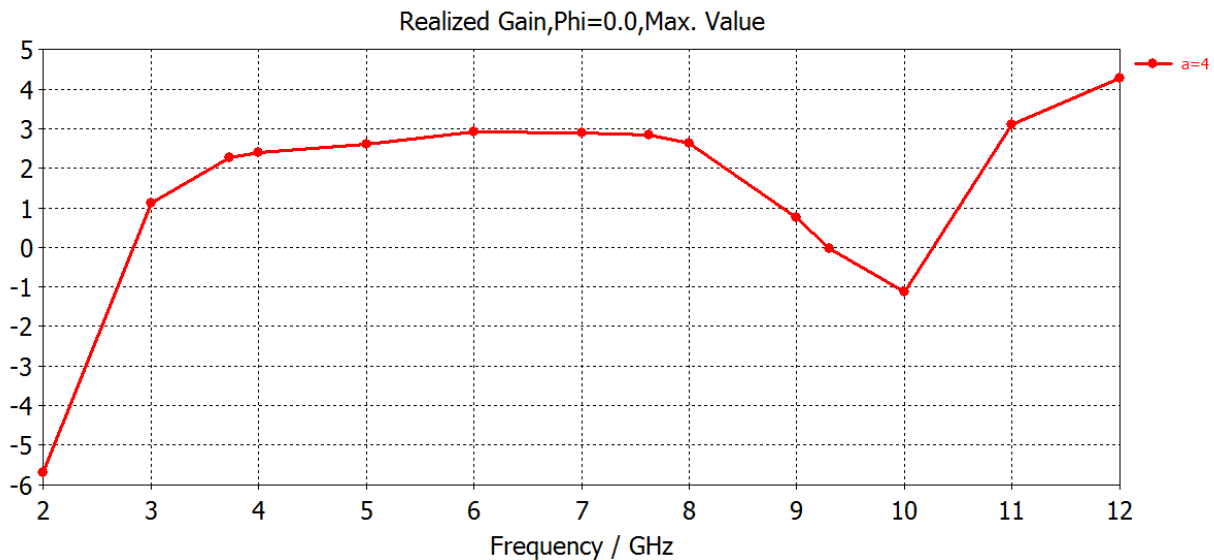


Figure 7 Realized Gain vs Frequency plot

4.2 Simulation Results of elliptical patch antenna:

The Graph below showing that how the return loss curve is improved by making a number of modifications in the ground plane.

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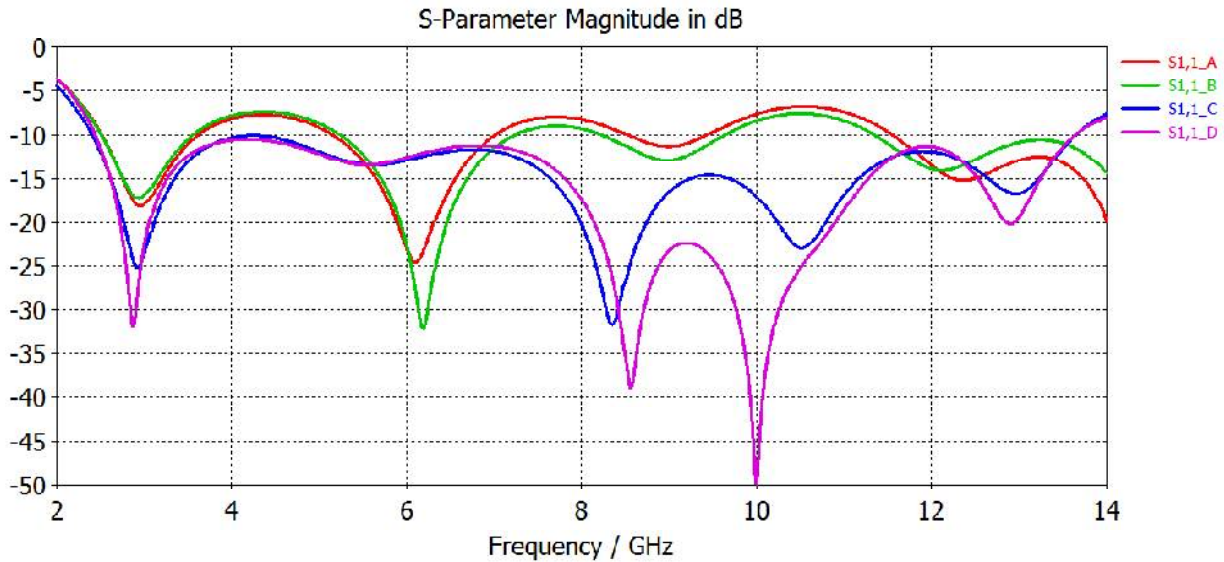


Figure 8 Return loss curve for different modifications in ground.

From graphs it can be observe that making the edges of rectangular ground plane smooth will not affect the return loss curve in lower frequency but at higher frequency it improves the return loss curve, the return loss curve shifts downside. By making a rectangular notch in ground plane just below the feedline results in drastically increase in the bandwidth. By introducing a narrow rectangular slit curve moves further downside. The return loss curve for different position of rectangular slit related to centre line is also observed. It is observed that changing the relative position of the slit not affects so much in lower frequency but effects on higher frequency.

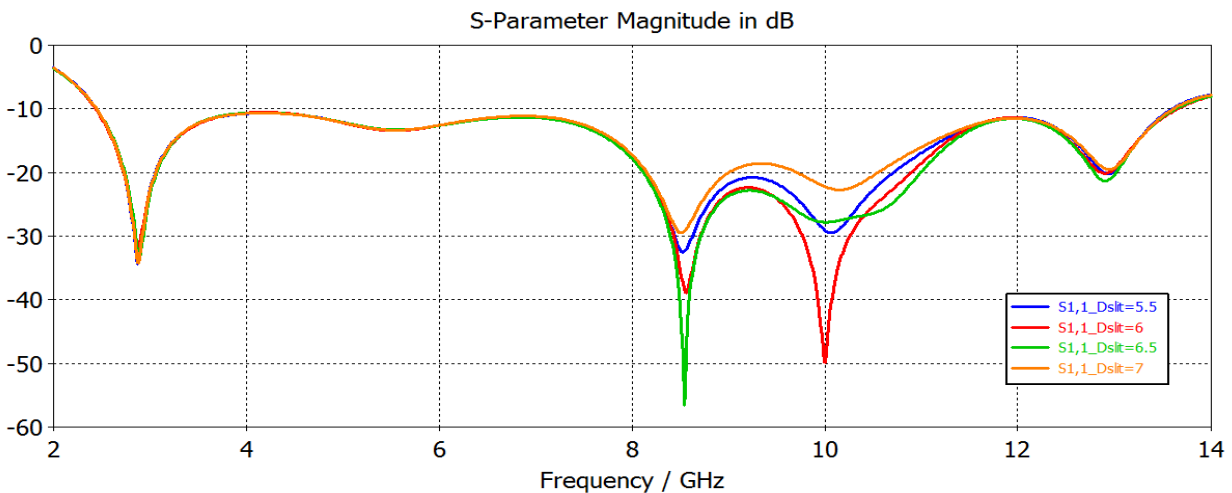


Figure 9 Return loss curve for different position of slit.

Effect of length and width of rectangular notch on the return loss curve is also shown in figure.

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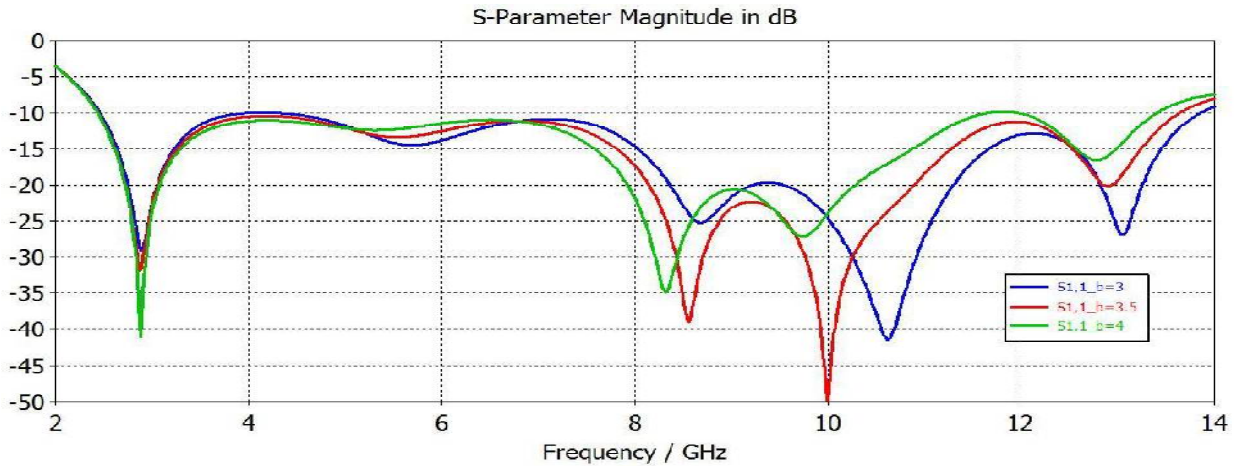


Figure 10 Return loss curve for different value of notch length b

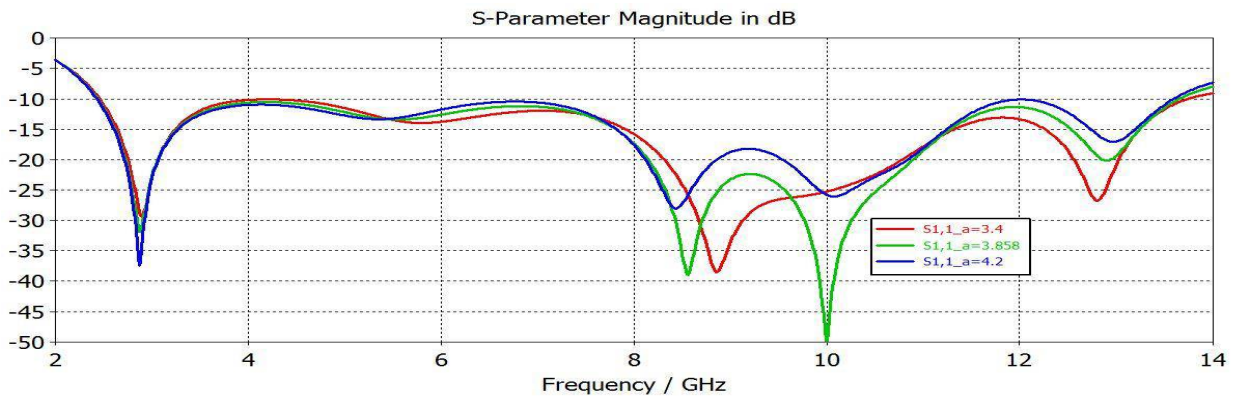


Figure 11 Return loss curve for different value of notch width a

From the above two graphs it is observed that the effect of notch dimension on return loss curve is more for the higher frequency as compared to lower frequencies

The realized gain plot are shown below, With maximum 4dB at 11GHz and minimum -4dB at 8GHz.

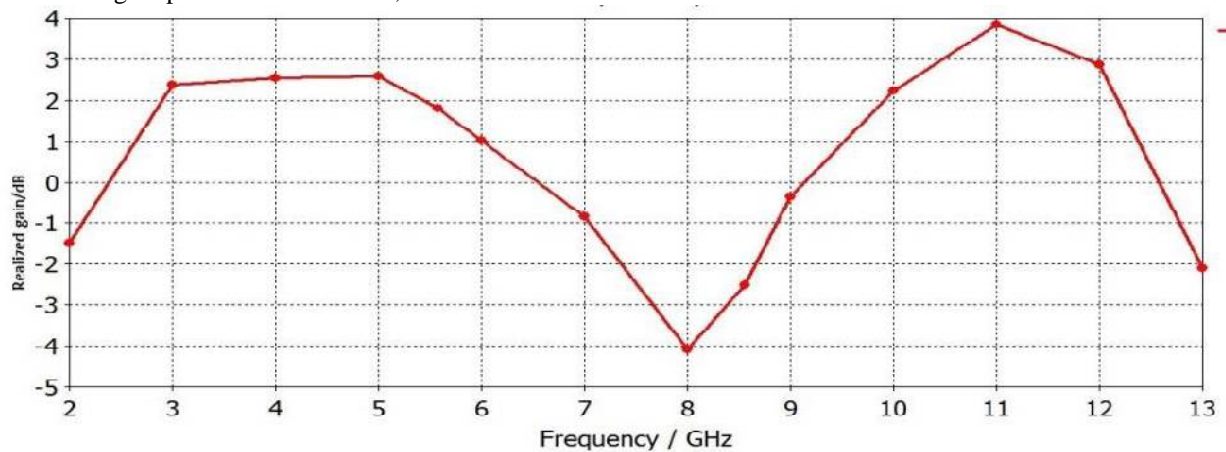


Figure 12 Realized Gain vs Frequency plot



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V. CONCLUSION

This paper describes two different microstrip patch antenna designs with different shapes. Both are designed to work in UWB with different band notches for different applications like (WiMAX) operating in 3.3-3.7 GHz, (WLAN) for IEEE 802.11a 5.15-5.825 GHz, Downlink X-band satellite communication systems in 7.25 - 7.75 GHz, 4.5-4.8 GHz INSAT / Super-Extended C-Band (Indian National Satellite systems). The easiest and most common method to achieve a band notch is making a narrow slot of different shapes into the radiating patch of the antenna, will affect the current flow in the patch, different type of shapes is used to make the slots are used to get the band-notched in the desired frequency band. These proposed antenna structure's simulation is carried out using the CAD software Microwave Studio in Computer Simulation Technology Simulator (CST), one commercial 3-D full-wave electromagnetic simulation software. The Simulated results are presented, shows the usefulness of the proposed antenna structure for UWB applications

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