A Broadband Double U-Slot Loaded Rectangle Patch and T-Stair Slot Antenna for UWB Applications

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Abstract: -In this paper a microstrip antenna loading with double U-slot loaded rectangle patch antenna and T- Stair slot loaded rectangular patch antenna is designed. Here, the shape of patch is rectangular and partial ground plane is used. The antenna designing is done by using HFSS simulation tool. Feeding is done by using microstrip feed line. After designing antenna we see the effect of variation in the dielectric material of substrate, width and length of U-shaped slot and T- Stair shaped slot, feed position and ground plane variation on antenna bandwidth is analyzed. Finally, the proposed antenna design gives optimum impedance bandwidth of 10 GHz operating over a frequency range of 4.1 to 14.1 GHz with VSWR < 2.These characteristics make the designed antenna suitable for various ultra wideband applications.

Keywords:-Microstrip Antenna, U-shaped slot, T-Stair shaped slot, Partial ground plane, Ultra wide band.

I. INTRODUCTION

Antennas are very important component in Wi-MAX and wireless communication system. There are different types of antennas exit practically which we used for transmit and receive EM waves. Out of these microstrip antenna is one of the most important antenna nowadays due to their attractive features such as low profile, light weight, low cost and ease in fabrication. Therefore, they are compatible with wireless communication integrated circuitry. But it has some disadvantages such as narrow bandwidth, low gain and low efficiency. There are some drawbacks in order to reduce these drawbacks such as slot loading over patch, reduction in length of ground plane etc. [1-2].

Federal Communication Commission (FCC) allocated a bandwidth of 7.5 GHz i.e. from 3.1 GHz to 10.6. It is generated by very short duration pulses generally in picoseconds therefore it provides very high data rate in the range of Mbps.There are several advantages of short duration pulses like it avoids multipath fading etc. This is widely used in radars and remote sensing applications. UWB antennas having return loss (S11< -10dB) high radiation efficiency over ultra wide band from 3.1 GHz to 10.6 GHz [3-5].

In the present paper, a double U-slot loaded rectangular patch and T-Stair slot loaded rectangular patch microstrip antenna is designed and analyzed. Two Broadband double Uslots as well as two Broadband double T-Stair slots can reduce the overall impedance of antenna. The slot reduces the area of copper sheet which leads to less value of quality factor hence bandwidth increases. The microstrip line is used for feeding because of its ease in fabrication and simple to match by controlling inset positions. A VSWR< 2 and S11< -10 dB is achieved for a frequency range of 6.5-14.8 GHz in U slot and 4.5-12.89 in T-stair slot with stable E- and H-plane radiation patterns. Now, figure 1 and figure10shows the antenna design.

The entire paper has been partitioned into seven parts. In II, literature reviews for microstrip patch antenna have been discussed. In III, antenna design for double U-slot rectangle patch antenna hardware structure is discussed. In IV, result and discussion has been discussed. In V, antenna design for double T-Stair slot rectangle patch antenna hardware structure is discussed. In VI result and discussion has been discussed. In VII comparison between the two antenna are shown and In VIII, conclusions and future scope of the paper work has been presented.

II. LITERATURE REVIEW

Baskaran*et al*. [2], proposed ultra-wideband microstrip antenna. In this paper, size of the substrate is 70mm*60 mm and use RT/Duriod 5870 substrate with dielectric constant ε = 2.33 and height h = 0.79 mm. Mohamed*et al*. [3], proposed compact microstrip antenna for ultra wideband applications. The fabricated antenna consists of a rectangular patch tapered from a microstrip feeding structure and a truncated ground plane. J.A. Ansari*et al*. [4], studied about the effect slot loading in a rectangular microstrip antennas. In this paper, first conventional microstrip antenna is designed which operates at frequency of 4 GHz. QU S.W.*et al*. [6], proposed compact rectangular L-shaped slot microstrip antenna for UWB applications. An ultra-wideband (UWB) microstrip antenna with half U-slot is analyzed using equivalent circuit model based on modal expansion cavity model. The effect of slot width ,slot length and distance between feed point allocation and slot are analyzed to obtain the optimum for UWB operation of the antenna. Antenna shows a lower frequency band from 3.262 GHz to 5.389 GHz (22.73) and upper operational frequency band 5.869 GHz to 9.033 GHz (47.69%). Results of the proposed antenna are in good agreement with the simulated results.

S.No	Parameters	Dimensions	Material
1	Substrate	W_{sub}=30 mm L_{sub}=30 mm H_{sub}= 1.6mm	Varying
2	Rectangular patch	L_p= 16 mm W_p= 11.964mm	Copper
3	Ground Plane	W_g= 16 mm L_g= varying	Copper
4	U-Slot	L_{Hs}= Varying W_s= Varying	-
5	Feed line	W_f= 3.01mm L_f = 8 mm	Copper

III. ANTENNA DESIGN

In this paper, antenna is designed by using ANSOFT HFSS (High Frequency Structural Simulator) [4]. Method of finite element solver is used. Rectangular patch is 11.964 mm wide and 16 mm long. Dielectric material of substrate is varying and it is 30 mm wide and 30 mm long and height of the substrate is 1.5 mm. We take different types of substrate such as glass, FR4 epoxy, mica and Bakelite. Feeder position is varied at 0 mm, 1.5mm, 2.5 mm from the symmetrical position. . Ground plane is partial providing good impedance match with width 30mm mm and varying length. At different lengths of partial ground plane i.e. 7mm, 7.4mm, 7.8mm, 8mm, 8.4mm, 8.8mm and 9mm, effect on antenna bandwidth is observed. Double U-shaped slot is used to decrease the overall impedance. It provides good impedance matching and higher bandwidth.

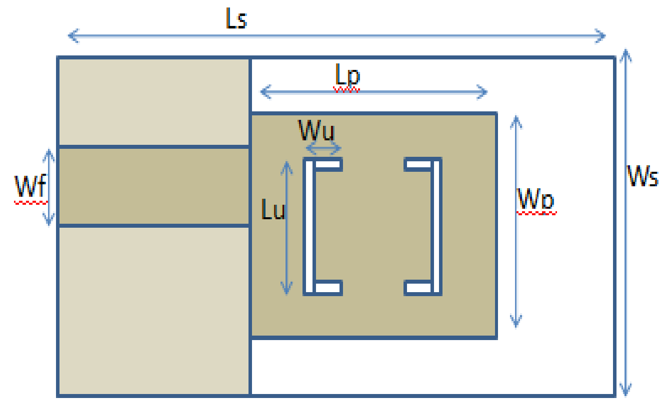

Figure 1: Design of Double U-slot loaded Rectangle Patch Microstrip Antenna

Table 1:shows the dimension of various parameters of antenna.

Width of microstrip antenna is simply given as

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

Where,

W= Width of Patch

ε_r = Dielectric constant of the substrate

Actual length of microstrip antenna is given as

$$L_{actual} = L_{eff} - \Delta L \quad (2)$$

Where,

L_{eff} = Effective length of the patch.

ΔL = Extended electrical length

Effective length of the patch is simply given by

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

Where,

ε_{reff} = Effective dielectric constant

For low frequencies the effective dielectric constant is essentially constant. At intermediate frequencies its values begin to monotonically increase and eventually approach the values of dielectric constant of the substrate. Its value is given by,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{-\frac{1}{2}} (4)$$

h = thickness of the substrate

In microstrip antenna, radiation occurs due to the fringing effects. Due to fringing effects electrical length of patch is greater than its physical length. This fringing depends on the width of patch and height of substrate [7].Now the extended electric length is given by

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.8)} \quad (5)$$

The width of microstrip line in microstrip antenna is given as follows:

For

$$\frac{W_{eff}}{h} \geq 2$$

$$W_{eff} = \frac{2h}{\pi}\left\{\frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - 0.\frac{61}{\varepsilon_r}\right] + B - 1 - \ln(2B - \right.$$

And for

$$\frac{W_{eff}}{h} \leq 2$$

$$W_{eff} = \frac{8he^{A}}{e^{2A} - 2} \quad (6)$$

$$W_f = W_{eff} - \frac{t}{\pi\left[1 + \ln\left(\frac{2h}{t}\right)\right]} \quad (7)$$

Where, A and B are given as follows

$$A = \frac{Z_{ol}}{60}(\frac{\varepsilon_r+1}{2})^{0.5} + \frac{\varepsilon_r-1}{\varepsilon_r+1}(0.23+0.11/\varepsilon_r)$$
$$B = \frac{377\pi}{2Z_{ol}\sqrt{\varepsilon_r}} \quad (8)$$

IV. RESULTS AND DISCUSSION

The results shown here are simulated on HFSS software. In HFSS, rectangular patch and partial ground plane are made up of PEC (Perfect Electrical Conductor) and air or vacuum can be used for the radiation box.

Firstly, the effect of varying length of partial ground plane on bandwidth of antenna is analyzed. Return loss gives us amount of power being reflected by the input port. For UWB antenna, return loss below -10 dB is considered to be quite efficient.Figure2 shows return loss v/s frequency curve at different length of ground plane.

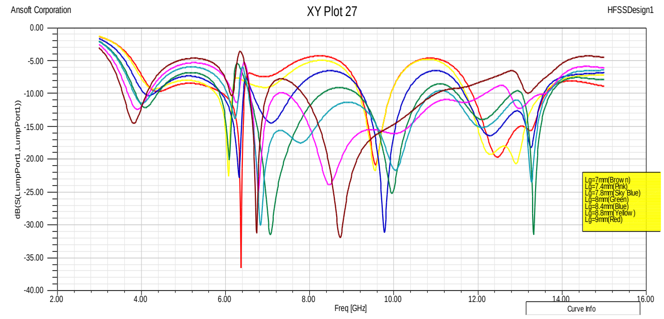

Figure 2:Return loss v/s frequency curve for varying length of ground plane

Table 2: Bandwidth at Different Length of Ground Plane

Length of Ground Plane	Frequency Range	Bandwidth	Fractional Bandwidth
7mm	7.8-11.01 GHz	3.21 GHz	44.58%
7.4mm	6.5-12.22GHz	5.72GHz	79.44%
7.8mm	6.5-13.6GHz	7.1GHz	98.6%
8mm	6.5-13.7GHz	7.2GHz	95%
8.4mm	9.2-10.33GHz	1.13GHz	15.69%
8.8mm	9.17-9.94GHz	0.77GHz	10.69%
9mm	9.22-9.92GHz	0.7GHz	9.72%

From the figure 2 and table 2 it is clear that optimum bandwidth is achieved when length of ground plane is 8mm.

Now, we see the effect of U-slot width on bandwidth of antenna. Figure 3 shows return loss v/s frequency curve at different width of ground plane.

The E-plane is defined as the plane containing the electric field vector and the directions of maximum radiation while the H-plane is the plane containing the magnetic field vector and the direction of maximum radiation. The x-z plane elevation plane with some particular azimuth angle φ is the principle E-plane. While for the x-y plane azimuth plane with some particular elevation angle θ is principle H-plane. Figure4 and figure 5 shows 2D E-plane radiation pattern at different frequencies within the band 4.1-14.1 GHz.

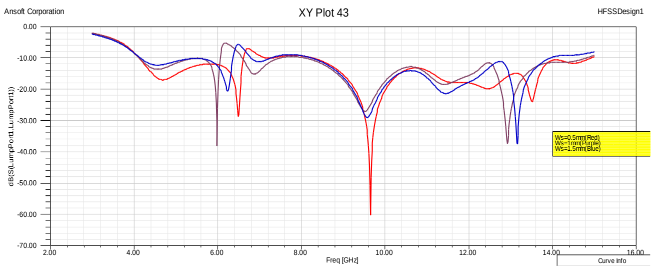

Figure 3: Return loss v/s frequency curve for varying width of U-slot

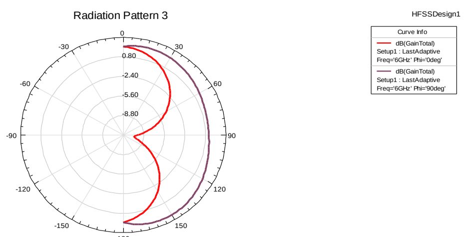

Figure 4: 2D E-plane Radiation Pattern at 6 GHz

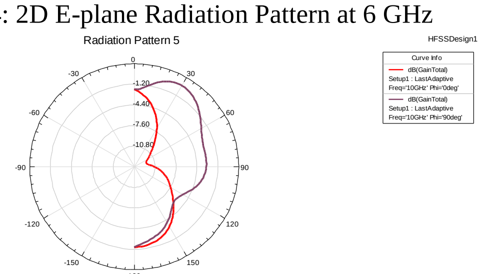

Figure 5: 2D E-plane Radiation Pattern at 10 GHz

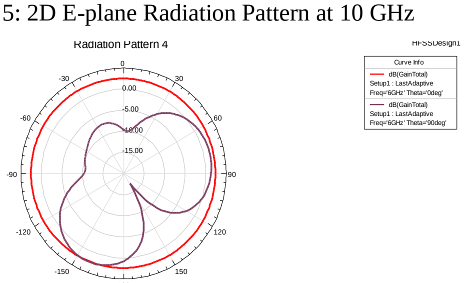

Figure 6: 2D H-plane Radiation Pattern at 6 GHz

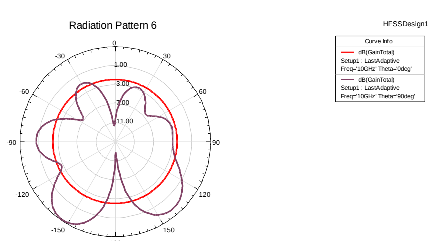

Figure 7: 2D H-plane Radiation Pattern at 10 GHz

Figure 6 and figure 7 shows 2D H-plane radiation pattern at different frequencies within the band 4.1-14.6 GHz.

Figure8 and figure 9 shows 3D radiation pattern at different frequencies within the band 4.1-14.6 GHz

Figure 8: 3D Radiation Pattern at 6 GHz

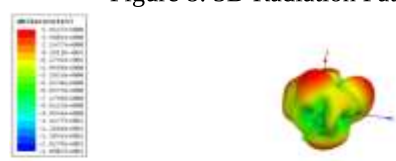

Figure 9: 3D Radiation Pattern at 12 GHz

V. ANTENNA DESIGN

This antenna is also designed by using ANSOFT HFSS (High Frequency Structural Simulator) [4]. Method of finite element solver is used. Rectangular patch is 11.964 mm wide and 16 mm long. Dielectric material of substrate is varying and it is 30 mm wide and 30 mm long and height of the substrate is 1.5 mm. We take different types of substrate such as glass, FR4 epoxy, copper, pec, mica and Bakelite. Feeder position is varied at 0 mm, 1.5mm, 2.5 mm and 3mm from the symmetrical position. Ground plane is partial providing good impedance match with width 30mm and varying length. At different lengths of partial ground plane i.e. 7mm, 8mm, 8.4mm, 8.8mm,9mm and 9.5mm, effect on antenna bandwidth is observed. Double T-stair shaped slot can also used to decrease the overall impedance. It provides higher return loss at a 8.8mm.

VI. RESULTS AND DISCUSSION

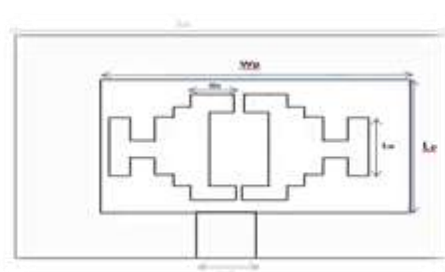

Figure 10: Design of Double T-Stair slot loaded Rectangle Patch Microstrip Antenna

Table 3: shows the dimension of various parameters of antenna.

S.No	Parameters	Dimensions	Material
1	Substrate	W_{sub}=30 mm L_{sub}=30 mm H_{sub}= 1.6mm	Varying
2	Rectangular patch	L_p= 16 mm W_p=11.964mm	Copper
3	Ground Plane	W_g= 16 mm L_g= varying	Copper
4	T-Stair Slot	L_{Hs}= Varying W_s= Varying	-
5	Feed line	W_f= 3.01mm L_f = 8 mm	Copper

VII. Results And Discussion

The antenna geometry is shown in fig10. Firstly, the effect of varying length of partial ground plane on bandwidth of antenna is analyzed. Return loss gives us amount of power being reflected by the input port. Figure11shows return loss v/s frequency curve at different length of ground plane.

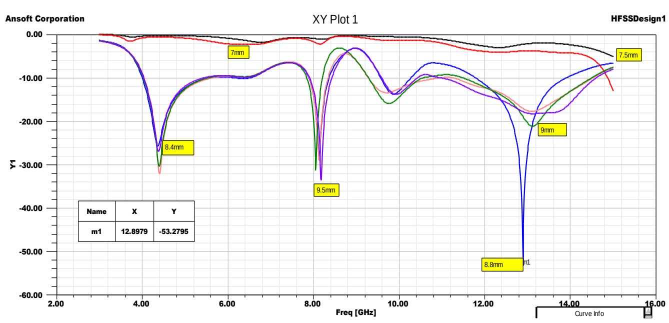

Figure 11:Return loss v/s frequency curve for varying length of T-Stair slot

Table 4: Bandwidth at Different Length of Ground Plane

Length of Ground Plane	Frequency Range	Bandwidth	Fractional Bandwidth
7mm	12- 14.01GHz	2.01 GHz	20%
8mm	8.0-12.15GHz	4.15 GHz	55%
8.4mm	4.5 - 8.22GHz	3.72 GHz	70%
8.8mm	4.5-12.89GHz	8.39GHz	97%
9.0mm	8.1-13.45GHz	5.35 GHz	65%
9.5mm	8.4 -12.8GHz	4.4 GHz	45%

From the figure 11 and table 4 it is clear that optimum bandwidth is achieved when length of ground plane is 8.8mm.

Now, we see the effect of T-Stair slot width on bandwidth of antenna. Figure 12 shows return loss v/s frequency curve at different width of ground plane.

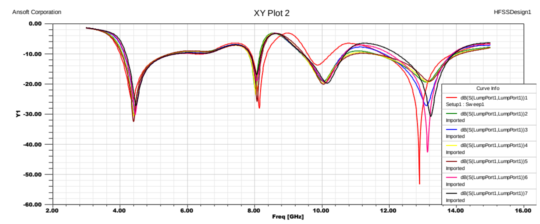

Figure 12: Return loss v/s frequency curve for varying width of T-Stair slot

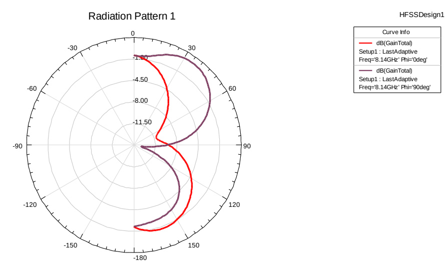

Figure 13: 2D E-plane Radiation Pattern at 8.2 GHz

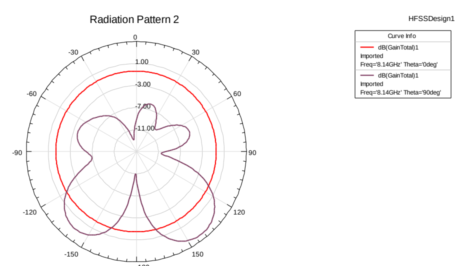

Figure 14: 2D H-plane Radiation Pattern at 8.2 GHz

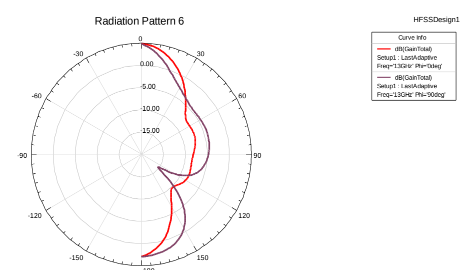

Figure 15: 2D E-plane Radiation Pattern at 13 GHz

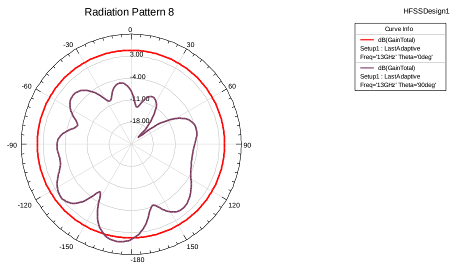

Figure 16: 2D H-plane Radiation Pattern at 13 GHz

Figure 17 shows 3D radiation pattern at different frequencies within the band 4.1-14.6 GHz.

Figure 17: 3D Radiation Pattern at 13 GHz

VIII. COMPARISON

In this section, Firstly the Broadband double U slot antenna presented with the FR-4 epoxy substrate and thickness of 12mm and got return loss bandwidth of 1%. Second the broadband double T-Stair slot antenna presented with the same substrate and thickness 7mm and got return loss bandwidth of 0.22%.

Table 5: Comparison between U- Shaped slot and T-Stair slot antenna

S.No	Antenna type parameters	U-Shaped slot	T-Stair Slot
1	Bandwidth	95%	97%
2	Frequency Range	6.5-12.7GHz	4.5-12.89GHz

IX. CONCLUSION

Two aspects of microstrip antenna have been studied. The first aspect is the design of U slot antenna having ground plane length 8mm, U-slot width 1mm, feeding position 2.5 mm from symmetrical position, substrate material is FR-4 epoxy, length of U-slot is 12mm then we get bandwidth (S11<-10 dB) 10.5 GHz (4.1-14.6 GHz)and provides a fractional bandwidth of 95% & 10.5% while the design of T-stair slot antenna having ground plane length 8.8mm, width is 1.5mm, feeding position is 3mm from symmetrical position , substrate material is FR-4 epoxy, length of T-stair slot is 9mm then we get bandwidth (S11<-10db) of 10.5GHz (4.1-14.6 GHz) and provides a fractional bandwidth of 55% & 97%. Both the antennas are suitable for designing purpose.

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