A Broadband U-slot Loaded Cylindrical Disk Microstrip Patch Antenna

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ABSTRACT
In this paper first we design V-shaped slot loaded and cylindrical slot loaded microstrip patch antenna fed by a microstrip line (50Ω) and analyze its performance. The proposed antenna is designed 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, and length of cylindrical slot and ground plane variation on antenna bandwidth is analyzed**.** This antenna design gives impedance bandwidth of 10 GHz operating over a frequency range of 3.5 to 14.1 GHz with VSWR < 2. These characteristics make the designed antenna suitable for various ultra wideband applications.

Keywords
Microstrip Antenna, Dielectric Constant, Cylindrical Slot, Ultra Wideband Antenna.

1. INTRODUCTION
Consider the term "ultra wideband" (UWB) as a relatively new term to describe a technology, which had been known since the early 1960's. The old definition was referring to "carrier-free", "baseband", or "impulse" technology. The fundamental concept is to develop, transmit and receive an extremely short duration burst of radio frequency (RF) energy, like a short pulse. The pulse typically has duration of a few tens of picoseconds to a few nanoseconds. These pulses represent one to only a few cycles of an RF carrier wave; therefore, as for resultant waveforms, extremely broadband signals can be achieved. Often it is difficult to determine the actual RF center frequency for an extremely short pulse; thus, the term "carrier-free" comes in. The amount of power transmitted is a few milliwatts, which, when coupled with the spectral spread, produces very low spectral power densities. The Federal Communication Commission (FCC) specifies that between 3.1 and 10.6 GHz, the emission limits should be less than -41.3 dBm/MHz, or 75 nW/MHz. The total power between these limits is a mere 0.5 mW.

The entire paper has been partitioned into five 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 beendiscussed. In V, conclusions and future scope of the paper work has been presented.

2. LITERATURE REVIEW
N. P. Yadav*et al.,* [1], proposed "A Broadband U-slot loaded circular disk patch Antenna". In this paper, size of the substrate is 70mm*60 mm and use RT/Duriod 5870 substrate with dielectric constant $\in_r$= 2.2 and thickness between ground and fed patch (h) = 1.575 mm. Here, we use radius of fed disk path (R) = 10.65 mm and length of U-slot (L_s) = 11.0 mm. In this paper, patch antenna is simulated on IE3D software and also experimentally. Experimental results shows return loss is less than -10 dB for the range 3.8 GHz to 12 GHz. Its E and H-plane patterns are stable over the UWB frequency range.

Mulgi.et al., [2], 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. Then three slots loaded at different positions in microstrip antennas. Triple band operation can be achieved by keeping the distance between two slots 0.2 and 0.3 cm. Therefore, due to slot loading, we get multi resonant peaks achieved and bandwidth also increases by an amount of 15.05%.

Dubey.et al., [3], proposed compact rectangular L-shaped slot microstrip antenna for UWB applications.A 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 length, slot width 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 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.

3. ANTENNA DESIGN
In this paper, V shape and cylindrical slot loaded microstrip patch antenna is designed by using ANSOFT HFSS (High Frequency Structural Simulator)[4]. Method of finite element solver is used. First of all we specify, following three input parameters which is decided by the designer according to specifications

ε_r = Dielectric constant of the substrate

h = Thickness of the substrate

f_0 = Resonant frequency

After deciding the values of these parameters the value of width and length of microstrip antenna will be determined. In order to get ultra wide bandwidth in microstrip antenna feeding point is 2.5mm away from the symmetrical position of radiator. For an efficient radiator, a practical width that leads to good radiation efficiencies is

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

Figure 1 and Figure 2 shows the design of different types of microstrip patch antenna i.e. V Shape slot microstrip patch antenna and cylindrical slot loaded microstrip patch antenna respectively.

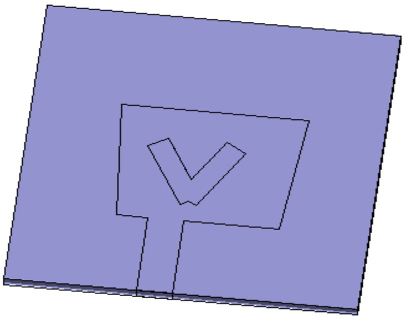

Figure 1: Design of V Shape Slot Loaded Microstrip patch Antenna

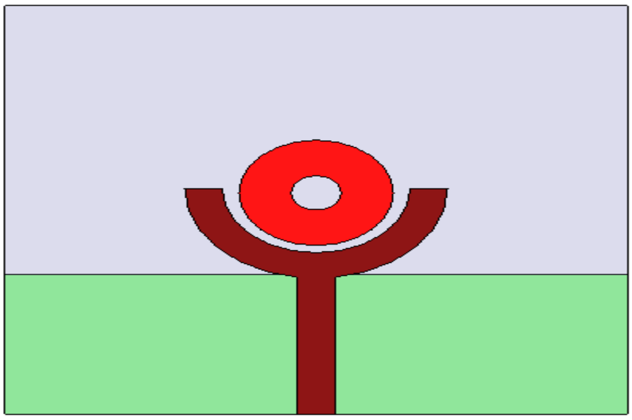

Figure 2: Design of Cylindrical Slot Loaded Microstrip Patch Antenna

The actual length of the patch can now be determined as follow

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

Where,

L_{eff}= Effective length of the patch.

ΔL = Extended electrical length

Effective length of the patch is simply given by

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

Here ε_{reff} Effective dielectric constant. For low frequencies the effective dielectric constant is essentially constant.

4. RESULTS AND DISCUSSION

Both designs are simulated on HFSS software. In HFSS, V shape, cylindrical patch and partial ground plane are made up of PEC (Perfect Electrical Conductor) and air or vacuum can be used for the radiation box. Return loss gives us an amount of power being reflected by the input port. For UWB antenna, return loss below -10dB is considered to be quite efficient. For this antenna design return loss is less than -10dB in frequency range 5.11-9.34GHz.

Figure 3 and Figure 4 shows return loss v/s frequency curve of V shape antenna for a particular length of ground plane respectively.

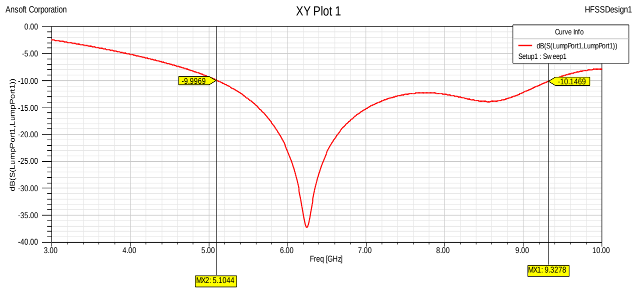

Figure 3: Variation of Return loss (S11) vs. Frequency of V Shape

Figure 4 Shows Voltage Standing Wave Ratio (VSWR) plot vs. Frequency in GHz. VSWR is simply the ratio of peak amplitude of standing wave ratio. VSWR below 2 is considered well for an antenna. For this design, VSWR is less than 2 from 5.11- 9.34GHz.

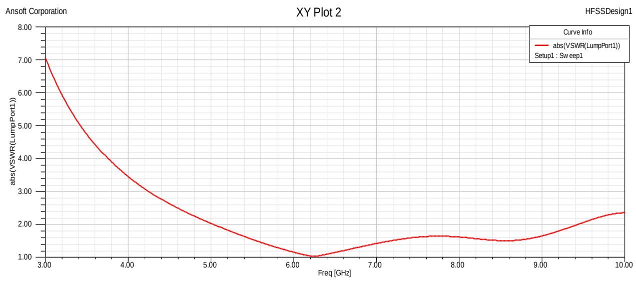

Figure 4: VSWR v/s frequency curve of V Shape

Figure 5 return loss v/s frequency curve of cylindrical slot antenna at particular length of ground plane respectively i.e. from 3.11- 6.39GHz.

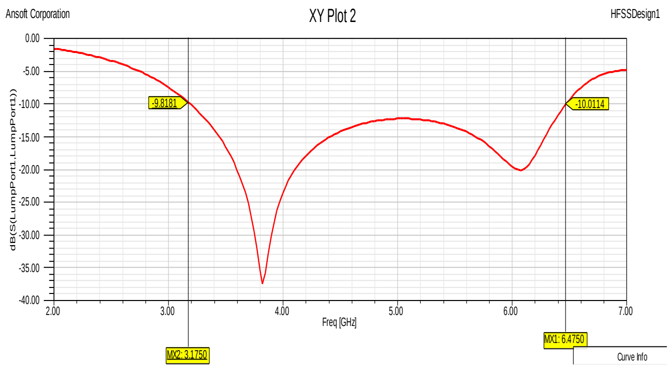

Figure 5: Return loss v/s frequency curve w.r.t length of Cylindrical slot

Figure 6 shows the VSWR v/s frequency curve for varying length of Cylindrical Shape . At all frequencies the VSWR remain below 2 which makes the respective system quite efficient.

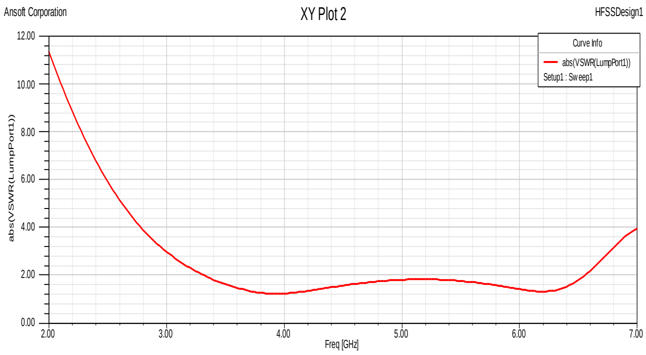

Figure 6: VSWR v/s frequency curve for varying length of Cylindrical

From the figure 7 and table 1 it is clear that optimum bandwidth is achieved when length of ground plane is 16.4 mm.

Table 1: Bandwidth at Different Length of Ground Plane

Length of ground plane	Frequency Range	Bandwidth (GHz)	Fractional Bandwidth (%)
16.4mm	3.14-6.17	3.03	70.8
17.4mm	3.4-6.5	3.1	64.58
18.4mm	5.8-6.5	0.7	11.38
19.4mm	6-6.6	0.6	9.5

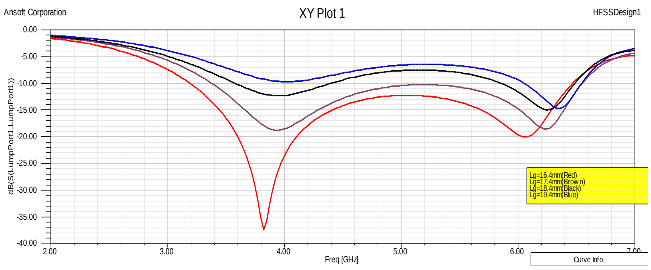

Figure 7: Return loss v/s frequency curve for varying length of ground plane

Figure 8 shows return loss v/s frequency curve for varying dielectric constant in GHz. Dielectric constant is simply a quantity measuring the ability of a substance to store electrical energy in an electric field. From the figure 8 and table 2 it is clear that optimum bandwidth is achieved when dielectric constant is 4.4 mm.

Table 2: Bandwidth at Different Dielectric Constant

Dielectric Constant	Frequency Range	Bandwidth (GHz)	Fractional Bandwidth (%)
2.2	4-7.5	3.5	60.86
4.4	3.1-6.5	3.4	70.84
4.8	3.2-6.4	3.2	66.67
5.5	3-6	3	65.6

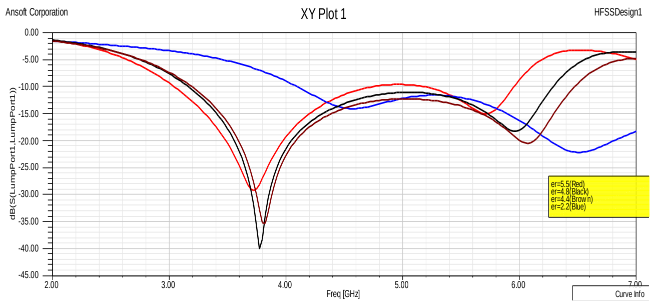

Figure 8: Return loss v/s frequency curve for varying Dielectric Constant

Figure 9 and Figure 10 shows 2D E-plane radiation pattern of V-Shaped slot loaded antenna at different frequencies with in the band 4.1-14.1 GHz.

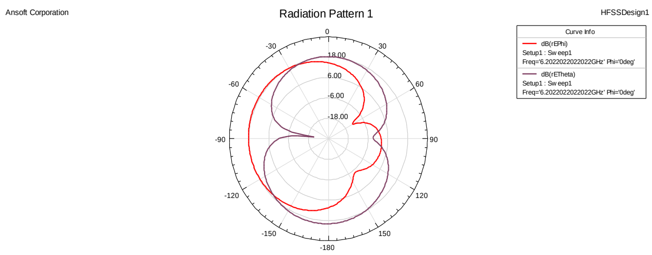

Figure 9: V Shape 2D E plane Radiation Pattern at 6 GHz

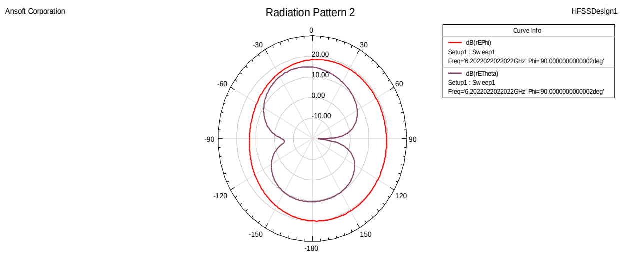

Figure 10: V Shape 2D H Plane Radiation Pattern at 6 GHz

Figure 11 and Figure 12 shows 2D E-plane and Figure 13 and Figure 14 shows H-planeradiation pattern of Cylindrical slot antenna respectively at different frequencies i.e. 3.9 GHz and 6.2GHz with in the band of 4.1-14.1 GHz.

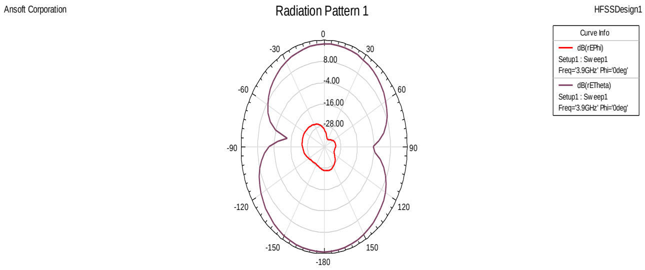

Figure 11: Cylindrical 2D E-Plane Radiation Pattern at 3.9 GHz

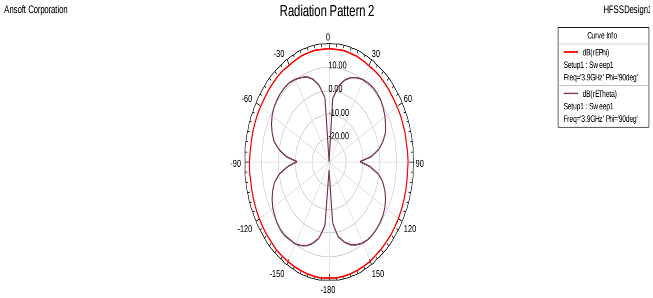

Figure 12: Cylindrical 2D H-Plane Radiation Pattern at 3.9 GHz

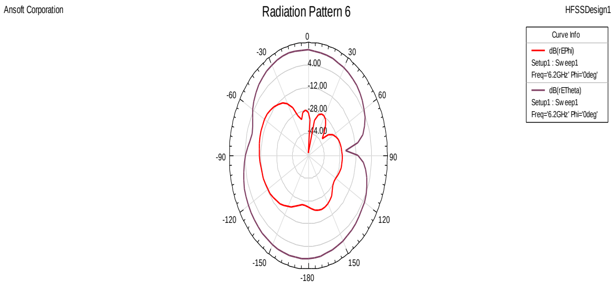

Figure 13: Cylindrical 2D E-Plane Radiation Pattern at 6.2 GHz

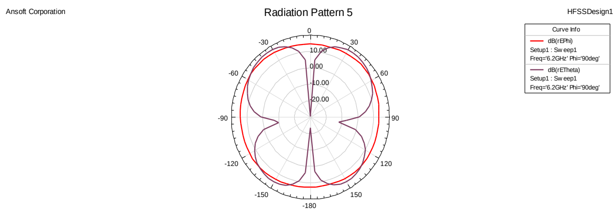

Figure 14: Cylindrical 2D H-Plane Radiation Pattern at 6.2 GHz

Figure 12 and Figure 13 shows 3D radiation pattern at different frequencies within the band 4.1-14.1 GHz

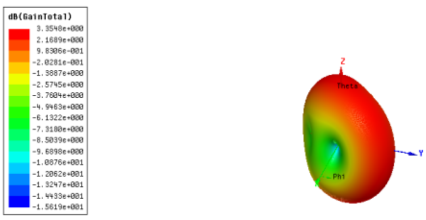

Figure 15: V Shape 3D Radiation Pattern at 6 GHz

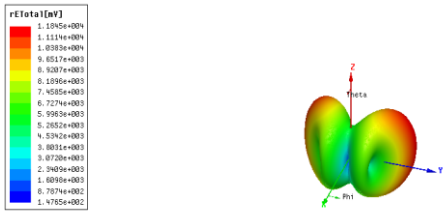

Figure 16: Cylindrical Shape 3D Radiation Pattern at 6.2 GHz

5. CONCLUSION

It is observed that V Shaped slot and Cylindrical Shape slot microstrip antenna provided optimum bandwidth when length of partial ground plane is 16.4mm (3.14-6.17 GHz i.e. 3.03 GHz), and feeding position is 3mm from symmetrical position.Finally, we saw the effect of varying dielectric material on bandwidth and got optimum bandwidth by using FR-4 epoxy substrate In the end, we design an antenna having ground plane length 16.4 mm, U-slot width 2.5 mm, feeding position 3 mm from symmetrical position, substrate material is FR-4 epoxy, then we get bandwidth (S11<-10 dB) 3.5 GHz (3.1-6.5 GHz). The proposed design of the antenna can be used for a variety of UWB applications including high speed data transfers, wireless connectivity between UWB-enabled devices and a variety of medical applications.

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