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Implementation and Developments of Single Feed Design using Multiple U- Slotted Patch Antenna for Wireless Applications

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***Abstract*- Important factor for antenna design is that antenna must have small size and must be capable of working for different bands. This paper presents design and simulation of multiple u slot antenna for wireless applications. Design and simulation has been carried out using HFSS simulation software. In this dissertation, slots have been cut on side of patch so as to obtain better characteristics; initially patch of length 30 mm is taken and analyzed using coaxial feed at (1, 13, 0).U slots cut in patch is having length of 6 mm and two mm wide. Two straight arms are surrounding it with dimensions of 1x 8 mm^2. This u slot is repeated for four sides. . By cutting four u slots, antenna resonated at 4.6 GHz, 5.2 GHz and 7.4 GHz with return loss of -19.81 dB, -11.10 dB and -18.1 dB with bandwidth of 200 MHz, 100 MHz and 800 MHz. This antenna had good gain with maximum power in major lobe direction. This antenna can be used for defence and secure communication application, WLAN application, satellite, RADAR and different C band applications. Parametric analysis had been applied by varying substrate thickness, feed point, substrate, changing dimensions of patch. It is found that best results obtained using patch of dimensions 30 mm using FR-4 as substrate with thickness of 2.4 mm.**

Keywords: Microstrip, Slot antenna, U slot

1. INTRODUCTION

In the current scenario developments in wireless communication industries continue to derive requirement of small, compatible and affordable microstrip patch antennas. A patch antenna is a narrowband antenna with large beamwidth. It is fabricated by etching the antenna element pattern in metal trace which is bonded to an insulating dielectric substrate such as a printed circuit board with a continuous metal layer bonded to the opposite side of the substrate known as a ground plane. There are different shapes of microstrip antenna which are square, rectangular, circular and elliptical, but antenna can have any continuous shape. Instead of using a dielectric substrate, some antennas can be made of a metal patch mounted above a ground plane using dielectric spacers. They are often mounted on the exterior of aircraft and spacecraft or are incorporated into mobile radio communications devices. Microstrip antennas are best choice for wireless devices because of characteristics like low profile, low weight, ease of fabrication and low cost. Since it is common practice to combine several radios into one wireless and use single antenna. Microstrip antenna suffers from disadvantages like they have less bandwidth and gain. For obtaining multiband and wideband characteristics, different techniques have been used like cutting slot in patch, fractal geometry and DGS. In order to increase bandwidth DGS has been used. DGS may be realized by cutting shape from ground plane. Shape can be simple or complex. It is to be noted that within particular area of ground different DGS can produce different resonant frequencies and different bandwidth.

2. LITERATURE REVIEW

Lee et al.[1] proposed an ordinary patch antenna in the form of simple resonant circuit. This antenna had feature that its resonance frequency gets lowered by increasing number of slots without making change in capacitance. This antenna provided low cost solution which has been useful for applications of short range two way communications. The antenna is miniaturized to size. This antenna had bandwidth of 6.9%.

Nasimudin et al.[2] circular polarized slotted patch antenna for global navigation satellite system application. This antenna was having square ring with vias. Four square ring shaped slots were cut out onto square patch along diagonal sides and size reduction. This antenna had compact size of 60 X60 X 5 mm^3.

Sun et al.[3] proposed two pattern diversity antenna. This antenna was combination of monopole antenna and broadband microstrip patch antenna. Monopole antenna was having cup shaped patch with wires connected to ground. This Microstrip antenna was connected to ground by four metallic wires.

Dalia et al. [4] compact microstrip patch antennas using different spiral defected ground structure (DGS) were proposed. The proposed compact spiral DGS of microstrip patch antenna applications. It was found that the four arms spiral DGS of microstrip patch antenna with offset feed gives good performance

Babu et al. [5] a symmetric four slot patch antenna was proposed and a two element MIMO array was developed by using it. The developed antenna array resonates at tri-band of frequencies 3.8 GHz, 6.6 GHz and 7.6GHz with an improved impedance bandwidth of 20% and an average reduced mutual coupling of -40 dB.

Xu-bao et al. [6] a rectangular microstrip slot antenna fed by a microstrip line, which achieved a very bandwidth on a relatively thin substrate, was presented. The performance

was achieved by employing a combination of a rectangular slot in ground plane.

Ayman et al. [7] proposed a multi-band microstrip antenna based on slot loading technique. Incorporating up to seven slots in the conventional microstrip rectangular patch antenna maintained the multi-band. The frequency range 2-8 GHz which was appropriate for many applications such as WLAN, Mobile WiMAX, and WCDMA was considered.

Hotpan et al. [8] paper was purposed the mutual coupling between elements of a microstrip antenna design has been studied in an array configuration, both versus frequency and element spacing. A defected ground structure based on narrow, closely spaced rectangular slots has been proposed for mutual coupling reduction.

Koohestani et al. [9] a novel compact microstrip antenna, fed by a CPW, is presented for UWB applications. The microstrip patch consists of a U-shaped patch combined with two parasitic tuning stubs. The antenna has a minimized total size equal to 24×27×0.787 mm^3. The measured return loss indicates that the antenna exhibits UWB characteristics.

3. ANTENNA DESIGN

Microstrip antenna has been used for various applications like defense, airplane and military applications. But these antennas suffer from disadvantages of small bandwidth, gain and return loss. In order to improve antenna characteristics, different techniques have been used like use of fractal geometry, defected ground structure and slot cutting slot. In this dissertation, slots have been cut on side of patch so as to obtain better characteristics; initially patch of length 30 mm is taken and analyzed using coaxial feed at (1, 13, 0). FR-4 has been used as substrate with dielectric constant of 4.4 and loss tangent of 0.02. Design is modified by making a u slot so as to make similar to that of reference antenna. As there are certain draw backs of microstrip antenna, hence one will use such techniques. Details of antenna dimensions are made in table 1. These dimensions had been used to design antenna.

Table 1:Dimensions of Initiator Antenna

Variable	Value
Length of patch	30 mm
Width of patch	30mm
Length of ground	50 mm
Width of ground	50 mm
Thickness of substrate	2.4 mm
Feeding technique used	Coaxial Feeding Technique
Substrate used	FR-4
Dielectric constant	4.4
Loss tangent	0.02
Feed point	(1, 13, 0)
Feed Length Probe	5 mm

This antenna configuration is designed using HFSS simulation software. In this design configuration square patch is taken having dimensions of 30 mm. Ground plane is having dimensions of 50 mm. In order to design antenna, first substrate box is taken and it is assigned material FR-4 with dimensions of 50 mm square and thickness of 2.4 mm. Patch is drawn on top with dimensions of 30 mm and ground is made as square on bottom with dimensions of 50 mm. Feed to antenna is made by cutting slot on ground at feed point (1, 13, 0). Feed is made by having outer radius of 0.48 mm and inner radius of 0.24 mm. Feed to antenna is made by given excitation through port cap with dimensions same as outer cylinder and height of 0.24 mm. Entire antenna is given boundary as radiation boundary to find antenna parameters. Design of zeroth iteration has been shown in figure 1.

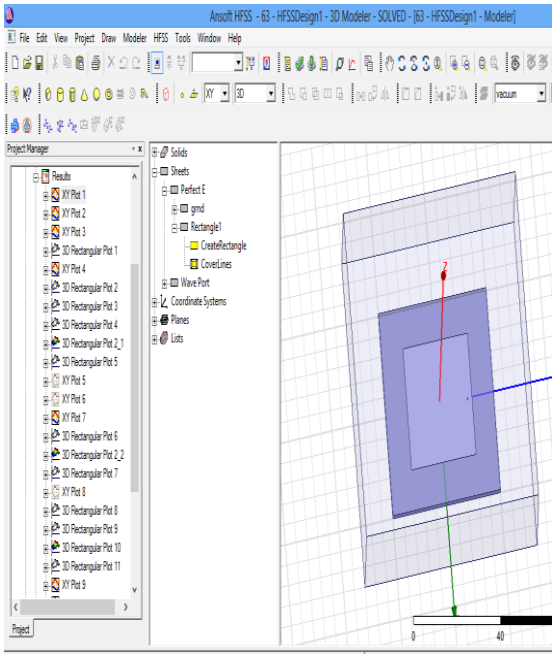


Figure 1:Initiator Antenna

After designing basic configuration, one may also get simple u slot to obtain better characteristics. In case of reference antenna one has patch of size 32X 30 mm^2. Instead of designing antenna with same dimensions as that of antenna one cut u slot in patch of size 30 mm. U slots cut in patch is having length of 6 mm and two mm wide. Two straight arms are surrounding it with dimensions of 1x 8 mm^2. This combine forms u slot patch. By applying u slot to patch characteristics shows improvement. This antenna has fed by coaxial feed at feed point (1, 13, 0). Geometry correspond to it is shown in figure 2.

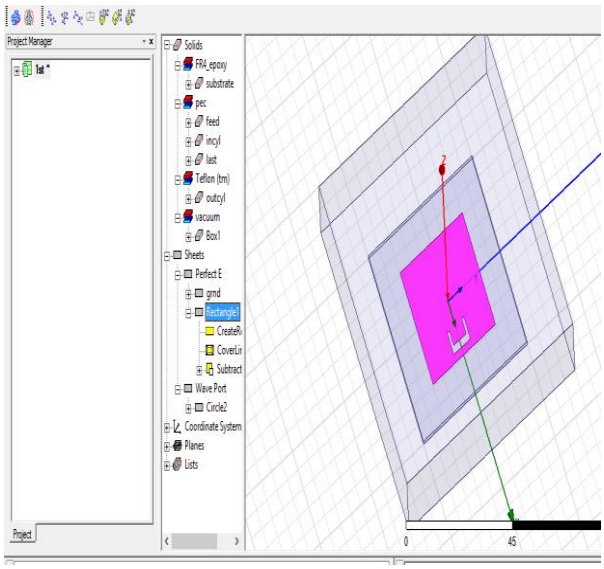


Figure 2:U slot cut Patch Antenna.

Here one u slot can be made. Variations can be done in terms of antenna parameters. Length of limbs can be vary to obtain better results. Also one can increase width of limbs. Further parametric analysis can be applied in terms of length of patch, width. Second iteration is applied by increasing number of slots up to two as shown in figure 3.

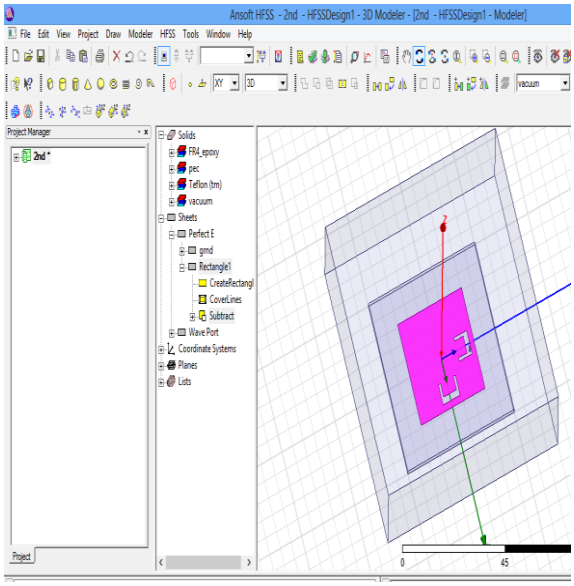


Figure 3:Two U Slot Antenna

Proceeding in same way, third iteration is applied by cutting u slot. In this iteration, number of u slots have increased to three. By increasing number of slots, geometry as shown in figure 4 is obtained.

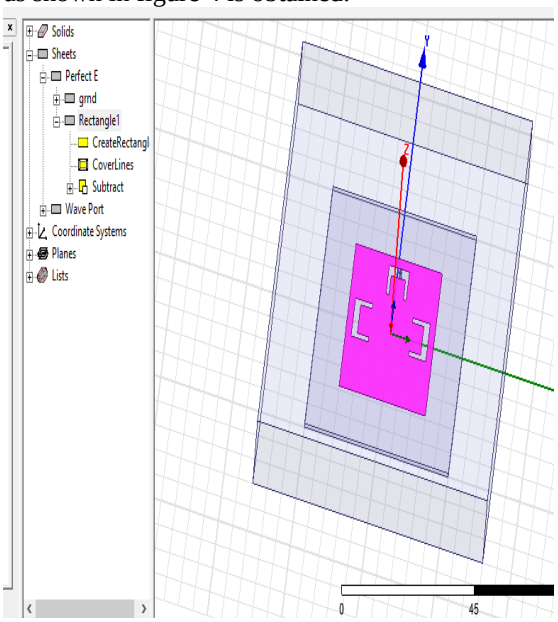


Figure 4:Three U slot cut Patch Antenna.

Final iteration is applied by increasing number of slots upto four. These slots have all same dimensions. Slots have been cut in form of ring. It is found that as number of slots increases, characteristics of antenna improves in terms of return loss, bandwidth and gain. Geometry of four u slot antenna has been shown in figure 5.

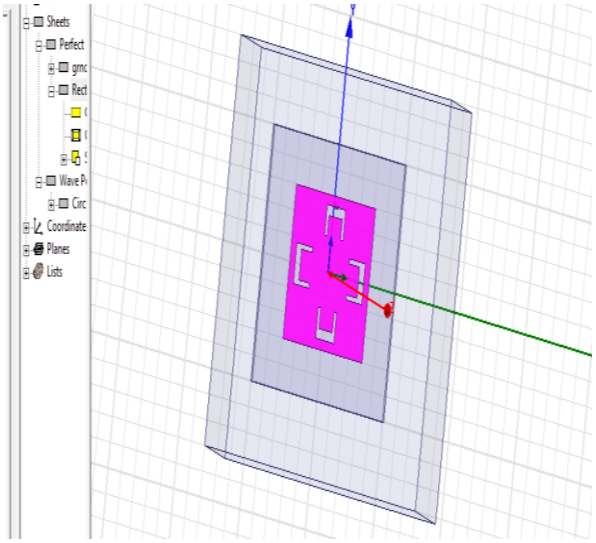


Figure 5:Four U slot Antenna

From these iterations, it is found that final iteration is produced from first iteration, by cutting of slots. Three slots have been cut out to form u slot antenna. By increasing number of slots, two three, four u slot antenna have been obtained. Parametric analysis has been carried out in order to have that antenna which gives best result.

4. RESULTS AND DISCUSSION

Four U structure ring is obtained by Return loss versus frequency for different designs are shown in figure 6. From these characteristics, it is found that characteristics of antenna improved by increasing number of cuts. Zeroth iteration show square patch antenna. Geometry correspond to it is shown in figure 1 and return loss has been shown in figure 6 by pink line. U slot have been made by connecting three rectangles.

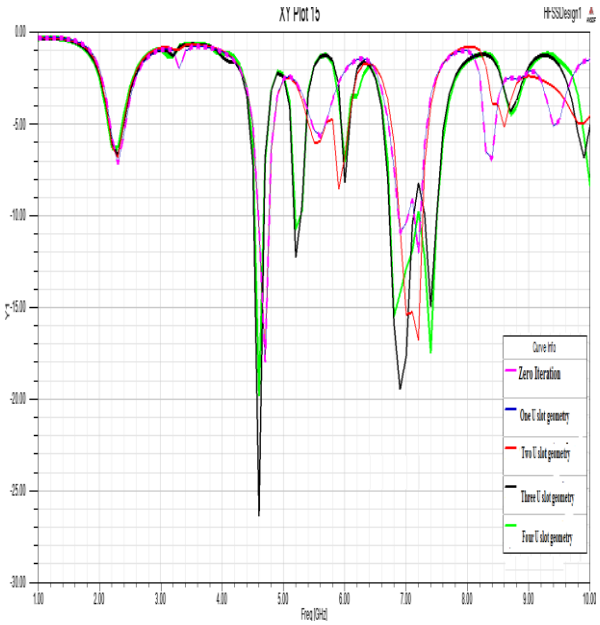
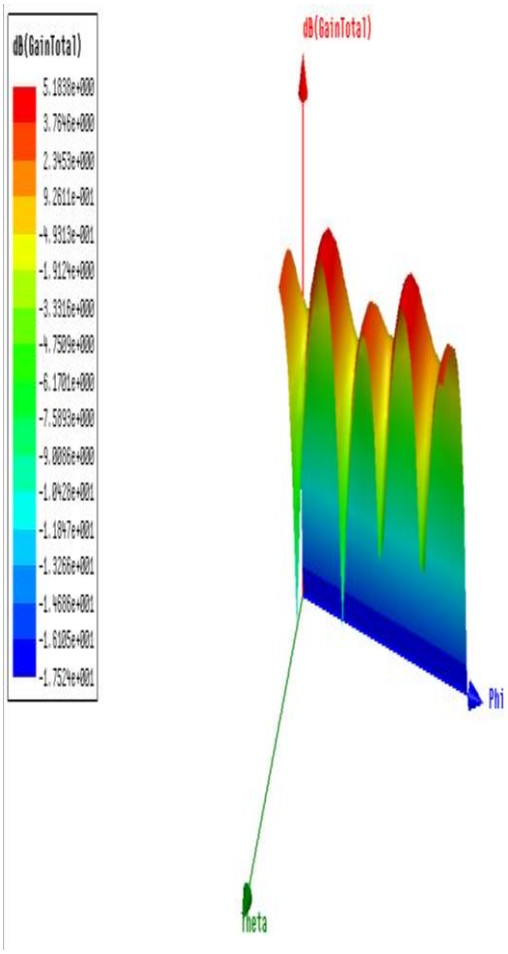
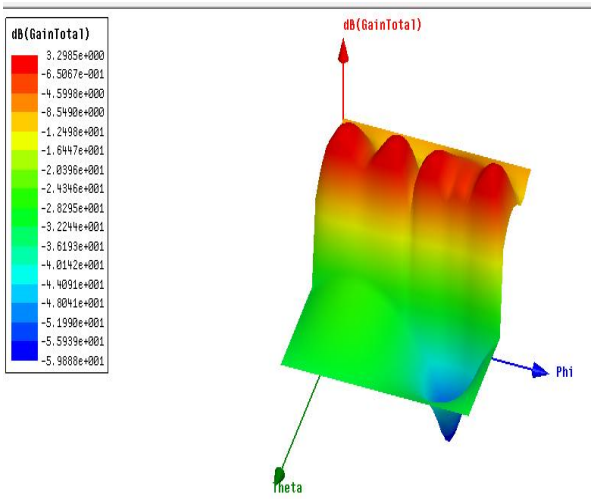


Figure 6: Return Loss Vs. Frequency for Multi U Slot Antenna

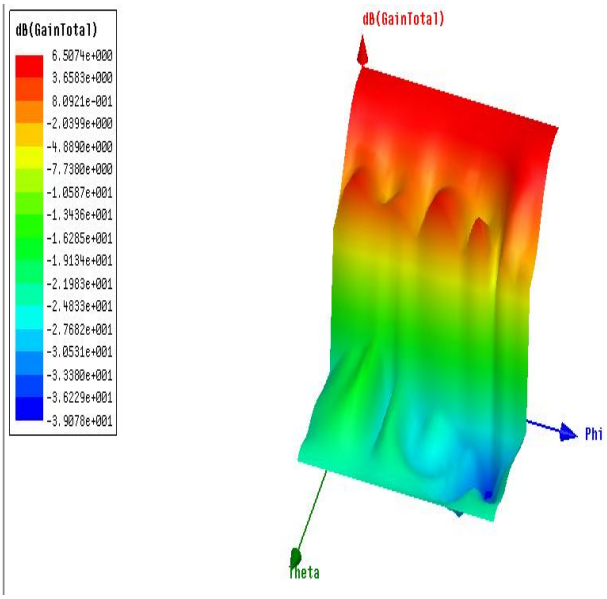
Antenna with 30 mm patch resonates at 4.7 GHz, 6.9 GHz and 7.2 GHz with return loss of -17.9 dB, -11.10 dB and -12.10 dB. This antenna had bandwidth of 170 MHz, 70 MHz and 120 MHz at corresponding frequencies. By applying first iteration which means cutting single u slot, antenna resonates at 4.7 GHz, 6.9 GHz and 7.2 GHz with return loss of -18 dB, -10.95 dB and -13.10 dB. This antenna had bandwidth of 180 MHz, 60 MHz and 140 MHz at corresponding frequencies. By increasing number of slots up to two, antenna resonates at 4.7 GHz and 7.2 GHz with return loss of -17.6 dB and -16.7 dB. This antenna had bandwidth of 200 MHz and 300 MHz at corresponding frequencies. When third u slot is cut out, number of bands increased to four. This antenna resonated at 4.6 GHz, 5.2 GHz, 6.9 GHz and 7.4 GHz with return loss of -26.34 dB, -12.29 dB, -19.47 and -14.98 dB. This antenna had bandwidth of 150 MHz, 100 MHz, 400 MHz and 200 MHz at resonant frequencies. By cutting four u slots, antenna resonated at 4.6 GHz, 5.2 GHz and 7.4 GHz with return loss of -19.81 dB, -11.10 dB and -18.1 dB with bandwidth of 200 MHz, 100 MHz and 800 MHz. Return loss versus frequency for different u slot cuts have been shown in figure 6 and characteristics for various configurations have been shown in table 5.1. Gain of antenna corresponding to antenna as shown in figure 4.4 at 4.6 GHz, 5.2 GHz and 7.4 GHz has been shown in figure 7a), 7(b) and 7(c).



(a)



(b)



(c)

Figure 7: Radiation Pattern of Multi U slot Antenna at (a)4.6 GHz, (b) 5.2 GHz (c) 7.4 GHz

Characteristics of antenna for various antenna configurations corresponding to different slot configurations have been mentioned in table 2.

Table 2: Antenna Characteristics of Different U slot Configurations

Iteration Number	Resonance Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)
0th Iteration	4.7	-17.9	170
	6.9	-11.10	70
	7.2	-12.10	120
1st Iteration	4.7	-18	180
	6.9	-10.95	60
	7.2	-13.10	140
2nd Iteration	4.7	-17.6	200
	7.2	-16.7	300
3rd iteration	4.6	-26.34	150
	5.2	-12.29	100
	6.9	-19.47	400
	7.4	-14.98	200
4th Iteration	4.6	-19.81	200
	5.2	-11.10	100
	7.4	-18.1	800

When a transmitter is connected to an antenna by a feed, the impedance of the feed line and antenna must exactly match for maximum energy transfer from the feed line to the antenna. However, when the antenna and feed line do not have matched impedances, part of the electrical energy cannot be transferred from the feed line to the antenna. VSWR of antenna as shown in figure 5 is shown in figure 8.

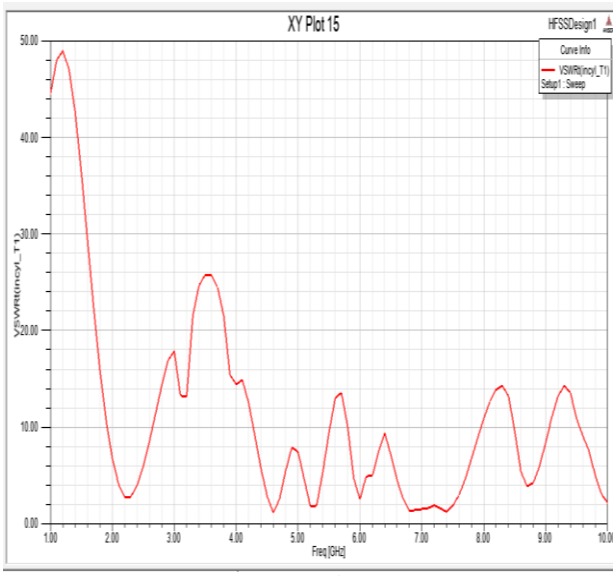


Figure 8: VSWR Versus Frequency for U Slot Microstrip Antenna

Smith chart was invented by P.H Smith of Bell Laboratories in 1939. It is most useful tool for high frequency circuit applications. Smith chart of double wang shaped antenna is shown in figure 9.

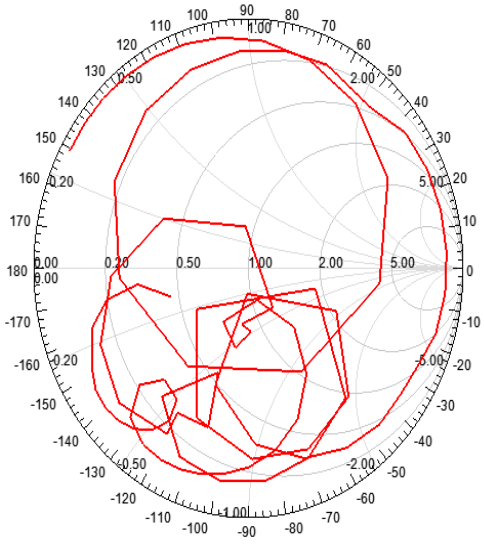


Figure 9: Smith Chart for U slot Microstrip Patch Antenna

It is best method of representing complex impedance with respect to coefficients defined by the reflection coefficient. For analyzing impedance, admittance and for solving transmission line problems, Smith chart is an important tool. From above analysis, it is clear that as number of cuts increase, characteristics of antenna improved. Further characteristics can improve by use of DGS.

5. CONCLUSION

Multi u slot antenna that were applied but best results were obtained with antenna with horizontal dumbbell DGS. Design and simulations are carried out using HFSS simulation software. Slots have been cut on side of patch so as to obtain better characteristics; initially patch of length 30 mm is taken and analyzed using coaxial feed at (1, 13, 0).U slots cut in patch is having length of 6 mm and two mm wide. Two straight arms are surrounding it with dimensions of 1x 8 mm^2. This u slot is repeated for four sides. . By cutting four u slots, antenna resonated at 4.6 GHz, 5.2 GHz and 7.4 GHz with return loss of -19.81 dB, -11.10 dB and -18.1 dB with bandwidth of 200 MHz, 100 MHz and 800 MHz This antenna had good gain with maximum power in major lobe direction. This antenna can be used for defence and secure communication application, WLAN application, satellite, RADAR and different C band applications.

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