Micro-strip Crossed Monopole Antenna with Defected Ground Structure for Ultra Wideband Communication

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Abstract: In this paper a novel and compact ultra-wideband crossed monopole antenna with a defected ground structure which is feed by microstrip line is presented. The impedance bandwidth of a rectangular patch antenna is maintained over the entire ultra-wideband frequency range and the response is improved by introducing defections of suitable dimension in the ground plane. The crossed monopole shows the return loss of 10 dB over the entire ultra-wideband frequency range (3.1 – 10.6)GHz while maintaining a stable radiation pattern. The effects of the Defected Ground Structure on the performance of the antenna are investigated. The software used for antenna design and simulation is HFSS V17.2.

Index Terms - **Microstrip feed, Crossed Monopole, DGS, UWB.**

I. Introduction

Development in ultra wideband (UWB) communication in recent times has encouraged the researchers to design different ultra wideband antennas. The monopole antennas are widely used for UWB communications due to their attractive features such as wide bandwidth and simple structure [2 – 4]. In contrast, the microstrip antenna is preferred to the monopole antenna with ground plane perpendicular to the radiator because of its light weight, small size, low cost and ease of integration with printed circuit board. Various microstrip antennas of different shapes were designed earlier for this purpose [5 – 9]. This paper presents a simple, easy to fabricate microstrip crossed monopole antenna fed by microstrip line with defected ground structure. The crossed monopole perpendicular to the circular ground plane was used earlier for UWB applications [4]. The monopole antenna needs a perpendicular ground plane, resulting in the increasing of antenna volume and the inconvenience for integrating with monolithic microwave integrated circuits, whereas the printed monopole antenna avoids the perpendicular ground plane. Therefore, planar printed monopole antenna is more compact in structure and possesses advantages in the portable UWB applications [10]. In the present work this idea is implemented for the microstrip structure with defected ground structure. The inclusion of the cross plate increases the bandwidth of a narrow band rectangular patch antenna. The inclusion of defected ground structure improves the performance of antenna. The paper demonstrates a optimal design of this type of antenna that can achieve UWB performance. The UWB antenna is characterized by the impedance matching and stable radiation pattern over the bandwidth (3.1 – 10.6) GHz. The electromagnetic software HFSS V 17.2 is used for the simulation.

II. ANTENNA DESIGN

In this paper a rectangular crossed monopole antenna is designed for ultra-wideband communication. FR4 epoxy is used as substrate of dielectric constant4.1 and dielectric loss tangent of 0.02. The height of the substrate is 1mm. The dimensions of the patch and substrate are shown in Fig. 1. The dimensions of the cross plate i.e., L2*W2 are adjusted suitably so the antenna resonates throughout the ultra-wideband frequency range (3.1-10.6) GHz.

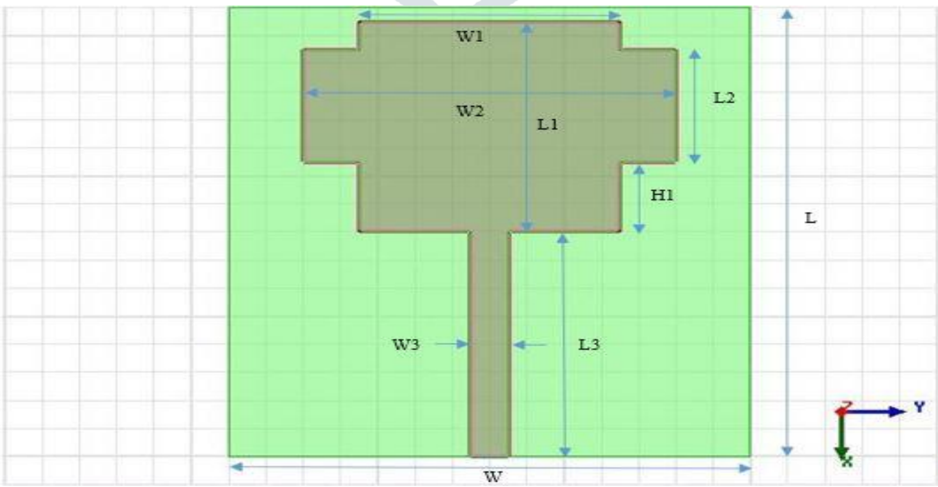


Fig. 1: Dimensions of patch and substrate.

The patch is feed by a microstrip line of dimensions L3*W3 which is base of the monopole antenna. The cross plate of dimensions L2*W2 are suitably chosen for stability throughout the ultra-wideband frequency range. The fig. 2 & fig. 3 shows the dimension of the two cases of ground plane with defected ground structure. The dimensions of the defected ground structure are varied and optimal values are chosen. The antenna should resonate at additional frequencies while maintaining its bandwidth over the ultra-wideband frequency range (3.1-10.6) GHz, so in order to achieve this we introduce defections in the ground plane.

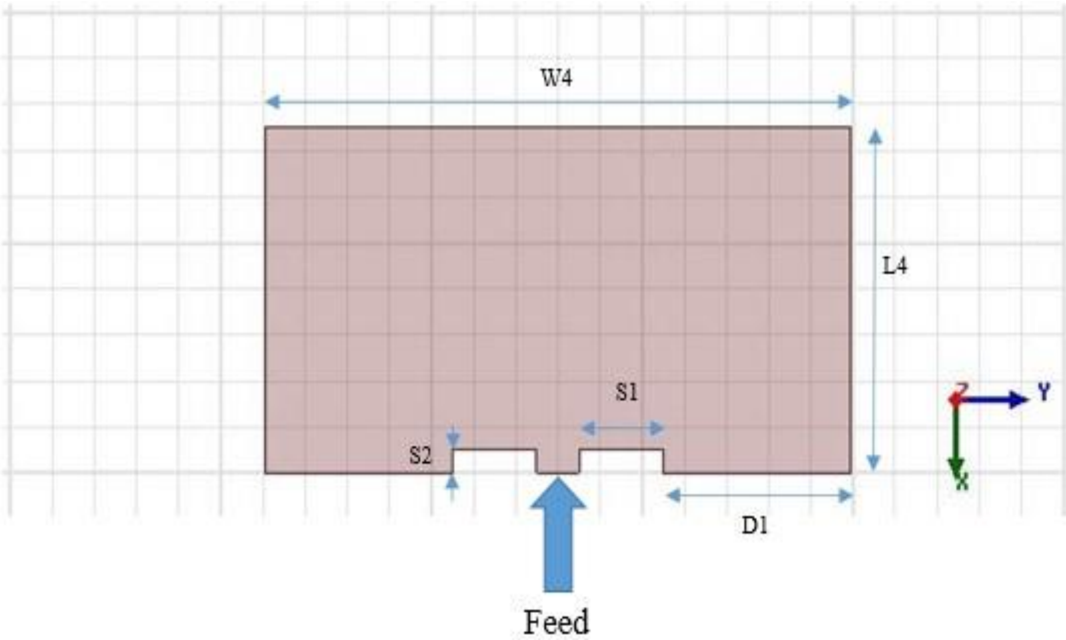


Fig. 2(a): Rectangular slot defected ground structure

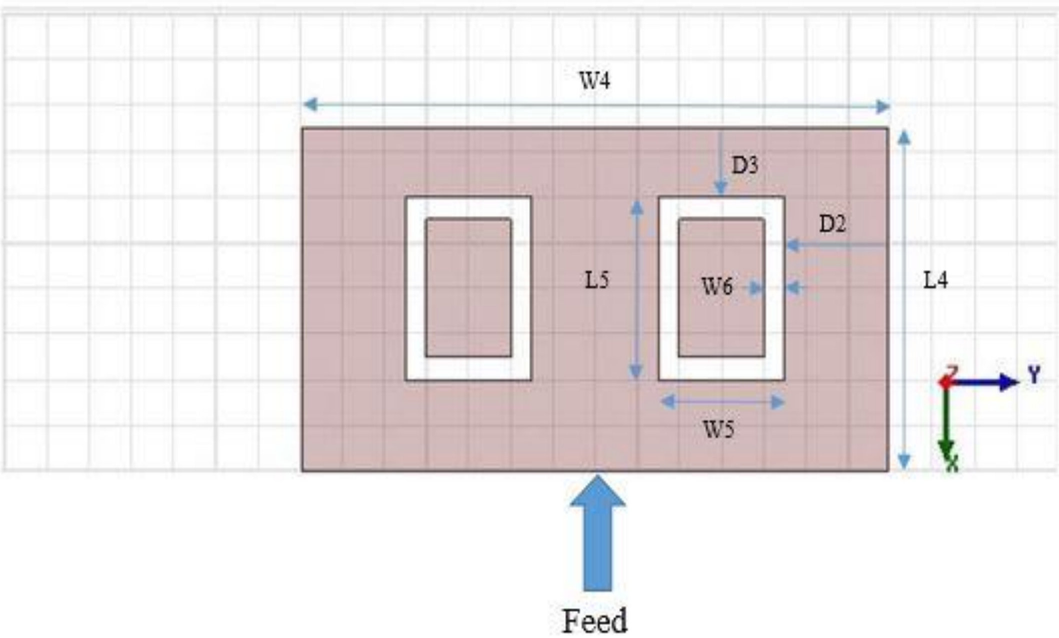


Fig. 2(b): Rectangular loop slots defected ground structure

The values of dimensions of antenna are tabulated in table. 1, the values shown are the optimized by performing parametric analyses and give best response of the antenna. The antenna configuration with ground plane as shown in fig. 2(a) has achieved a additional resonance frequency with increased return losses while slight shrink in the bandwidth while the antenna configuration with ground plane as shown in figure. 2(b) has also achieved additional resonance frequency with an increase in bandwidth and improved return losses. The defected ground structure is a very effective approach for increasing antenna performance especially while maintaining the bandwidth.

The dimensions of the ground plane L4*W4 are not varied for the two configurations of the antenna. The antenna is simple to fabricate since the design is simple and the dimensions are of the order of millimeters.

Parametric analysis is done for each and every dimensions of the defections in the ground plane to achieve best results in terms of return loss and VSWR, the dimensions of the ground plane are unaltered throughout the analysis.

Table 1: design parameters of the proposed antenna

S.No	Name of the parameter	Value(in mm)
1	L	32
2	W	28
3	L1	15
4	W1	14
5	L2	8
6	W2	20
7	L3	15
8	W3	2
9	H1	1
10	L4	15
11	W4	28
12	D1	9
13	S1	4
14	S2	1
15	D2	5
16	D3	3
17	L5	8
18	W5	6
19	W6	1

III. Simulated Results

The results are obtained by using ANSYS HFSS V.17.2. The results obtained after the introduction of defections in the ground plane are compared with conventional antenna.

A. Return loss

Return loss is the measure of reflected power to transmitted power given to the antenna. If the return loss is maintained at -10dB then 97% of the power is transmitted to the antenna.
The return loss of the conventional antenna and the proposed antenna with different defected ground structure are given in the below figure: Fig. 3, Fig. 4 and Fig. 5.

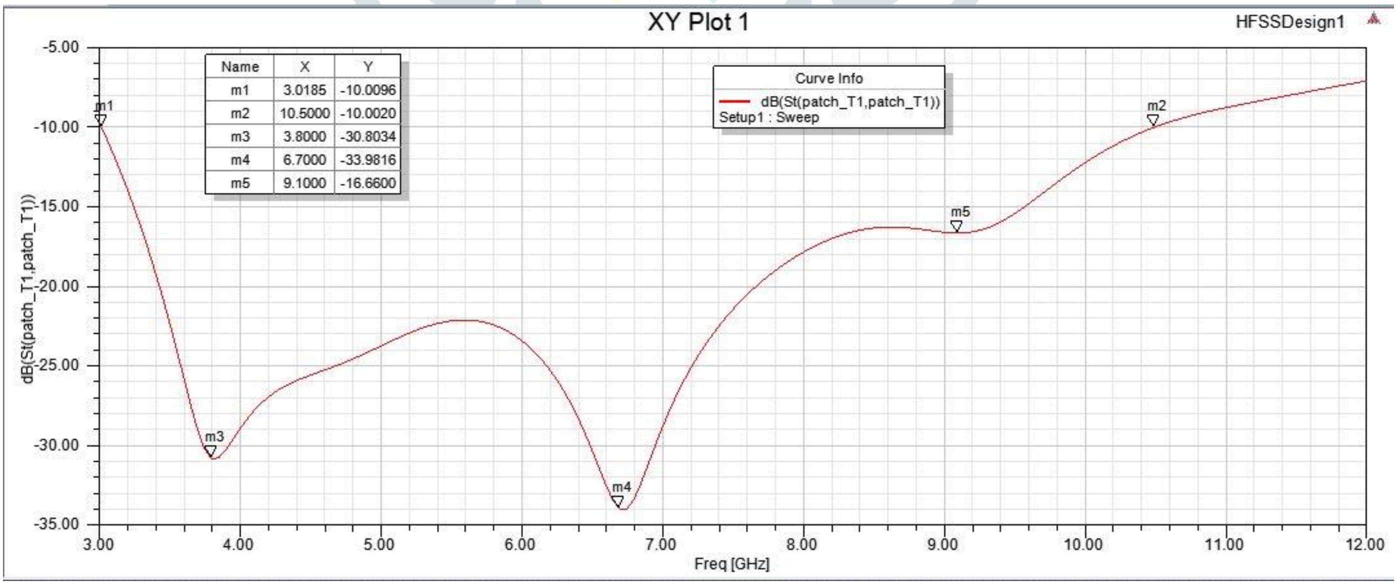


Fig. 3: Plot of Return loss of conventional antenna

The conventional antenna maintains -10dB return loss almost throughout the ultra-wideband frequency (3.1-10.6GHz). The antenna is resonating at three frequencies in this frequency range i.e. 3.8, 6.7, 9.1 GHz. Their respective return losses are as follows -30.8034 dB, -33.9816 dB, -16.6600 dB.

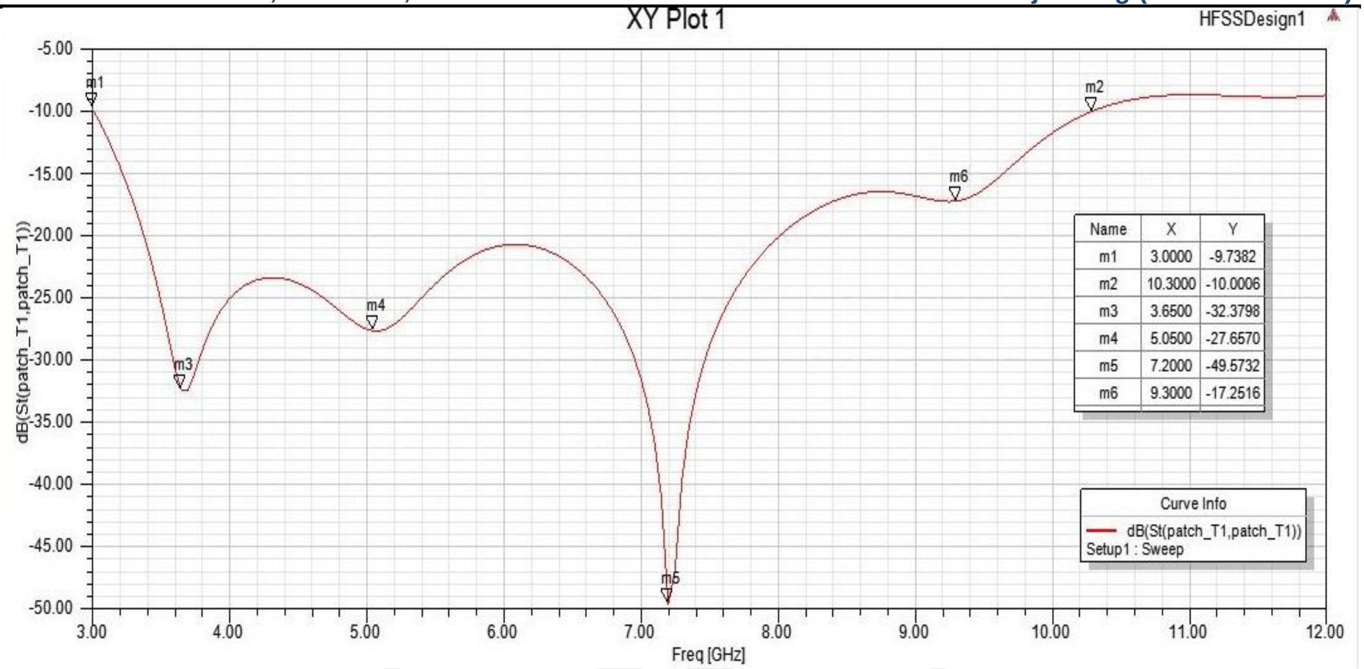


Fig. 4: Plot of return loss of rectangular slots defected ground structure

The antenna configuration with rectangular slot defections also achieved near ultra-wideband frequency range but a slight shrink in bandwidth is observed. The antenna is resonating at 3.65, 5.05, 7.2, 9.3 GHz. An additional resonant frequency is achieved by this defection and the respective return losses are -32.3793 dB, -27.6570 dB, -49.5735 dB and -17.2516 dB.

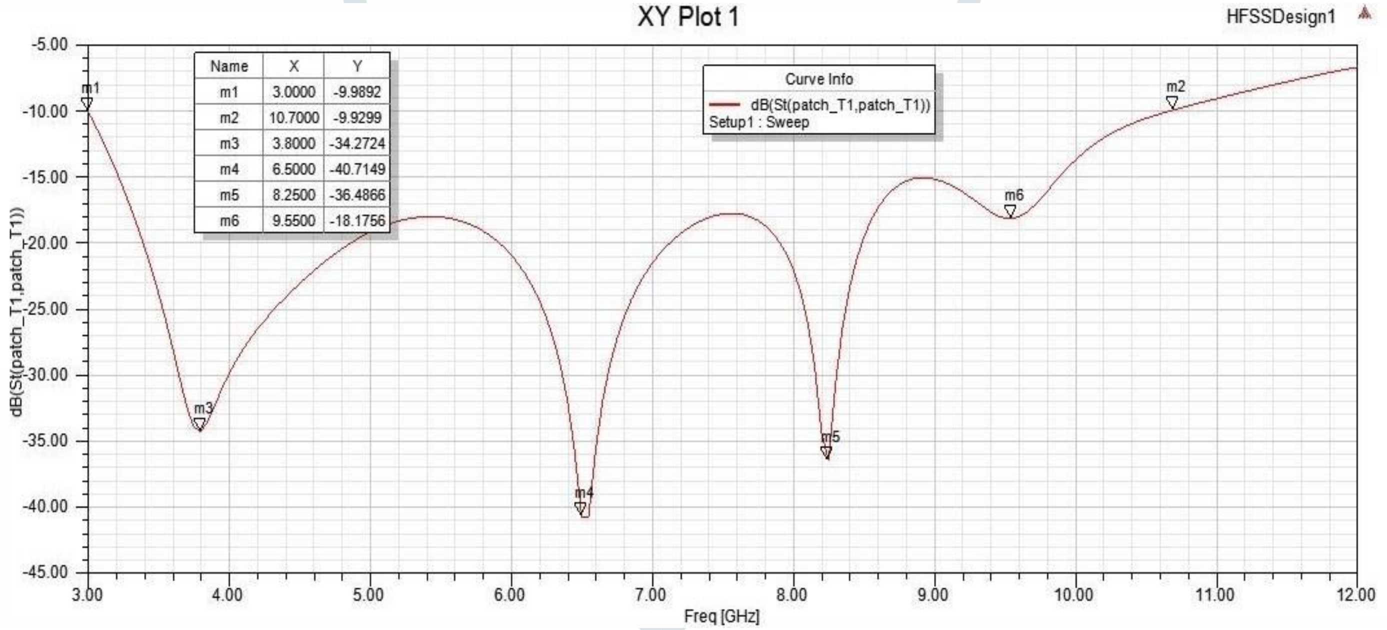


Fig. 5: Plot of return loss of rectangular loop slots defected ground structure

The antenna configuration with rectangular loop slot defections also achieved ultra-wideband frequency range with a slight expansion in bandwidth is observed. The antenna is resonating at 3.8, 6.5, 8.25, 9.55 GHz. An additional resonant frequency is achieved by this defection and the respective return losses are -34.2724 dB, -40.7149 dB, -36.4866 dB and -18.1756 dB.

B. Voltage Standing Wave Ratio

Voltage standing wave ratio is the ratio of transmitted wave to reflected wave in other words it's a function of reflection coefficient.

The VSWR of the conventional antenna and the proposed antenna with different defected ground structure are given in the below figure: Fig. 6, Fig. 7 and Fig. 8.

The conventional antenna has maintained a VSWR between 1 and 2 throughout the ultra-wideband frequency range (3.1-10.6 GHz) and the respective VSWR at the resonating frequencies are 1.0594, 1.0408 and 1.3476

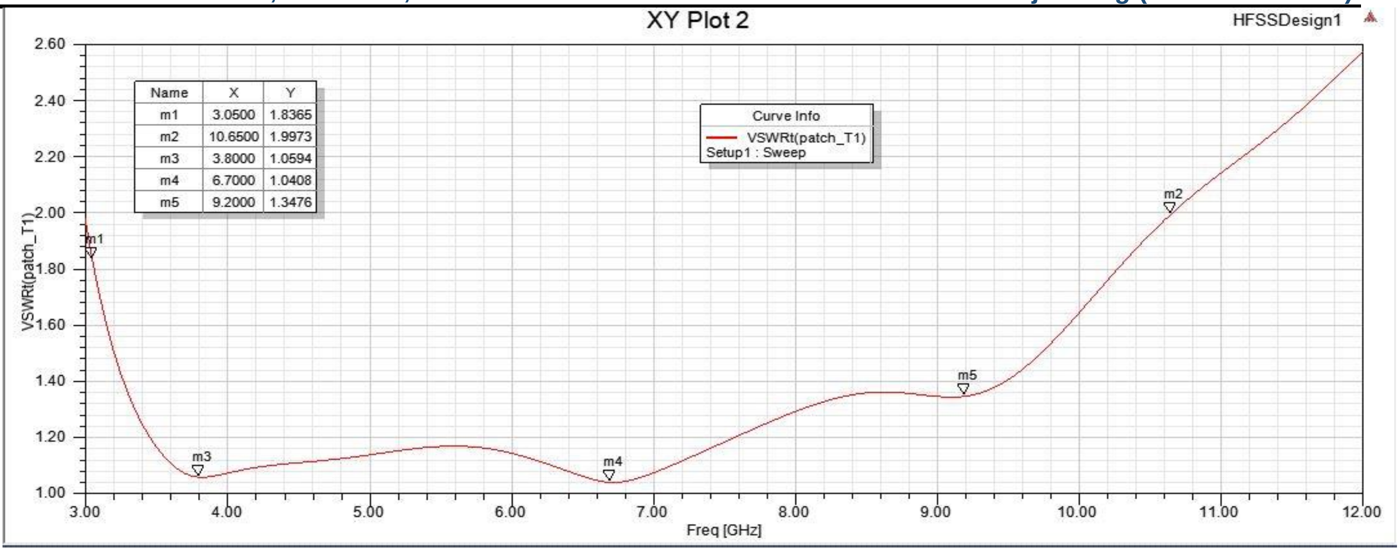


Fig. 6: Plot of VSWR of conventional antenna

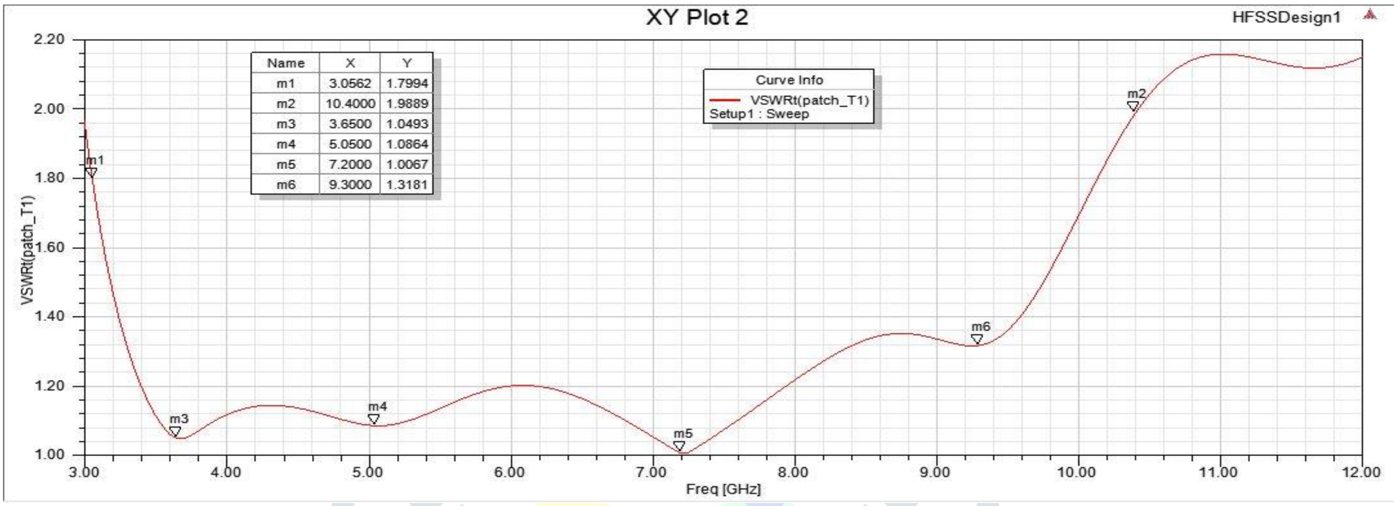


Fig. 7: Plot of Return loss of rectangular slots defected ground structure

The antenna is resonating at 3.65, 5.05, 7.2, 9.3 GHz. An additional resonant frequency is achieved by this defection and the respective VSWR are 1.0493, 1.0864, 1.0067 and 1.3181.

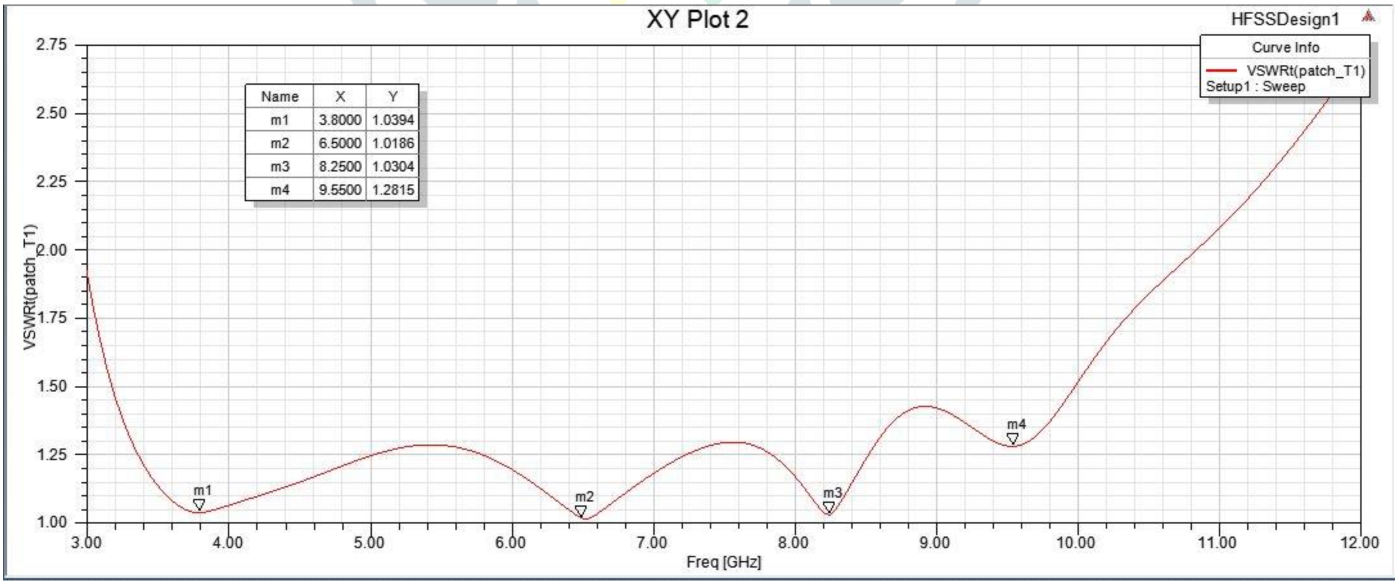
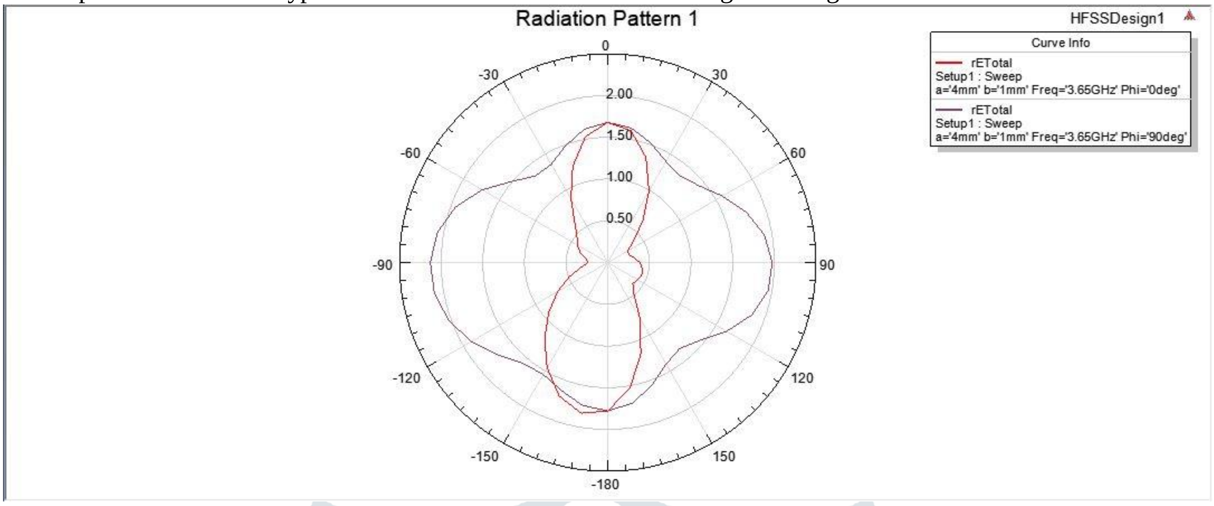


Fig. 8: Plot of VSWR of rectangular loop slots defected ground structure

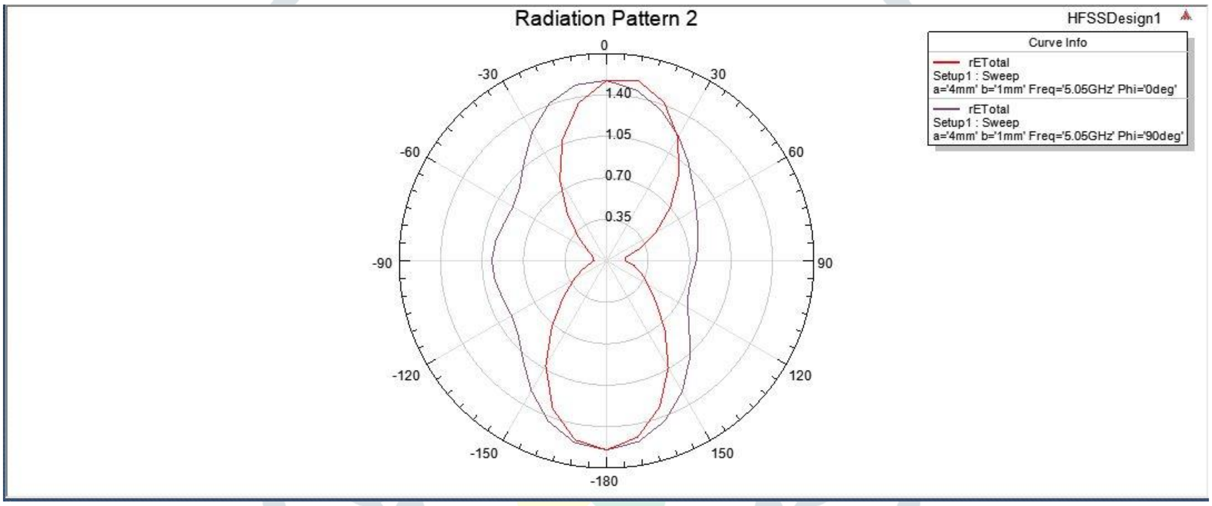
The antenna is resonating at 3.8, 6.5, 8.25, 9.55 GHz. An additional resonant frequency is achieved by this defection and the respective VSWR are 1.0394, 1.0186, 1.0304 and 1.2815.

C. Radiation Pattern

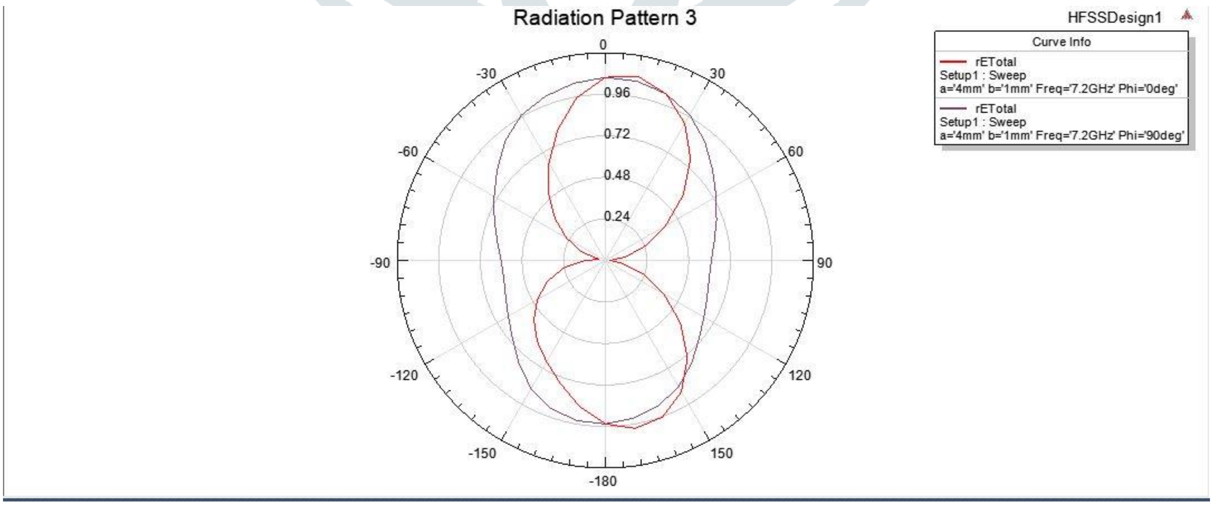
Radiation pattern is function of directional strength of power outflow radiated from the antenna.
The radiation pattern for the two types of defections are shown below in Fig.9 and Fig.10



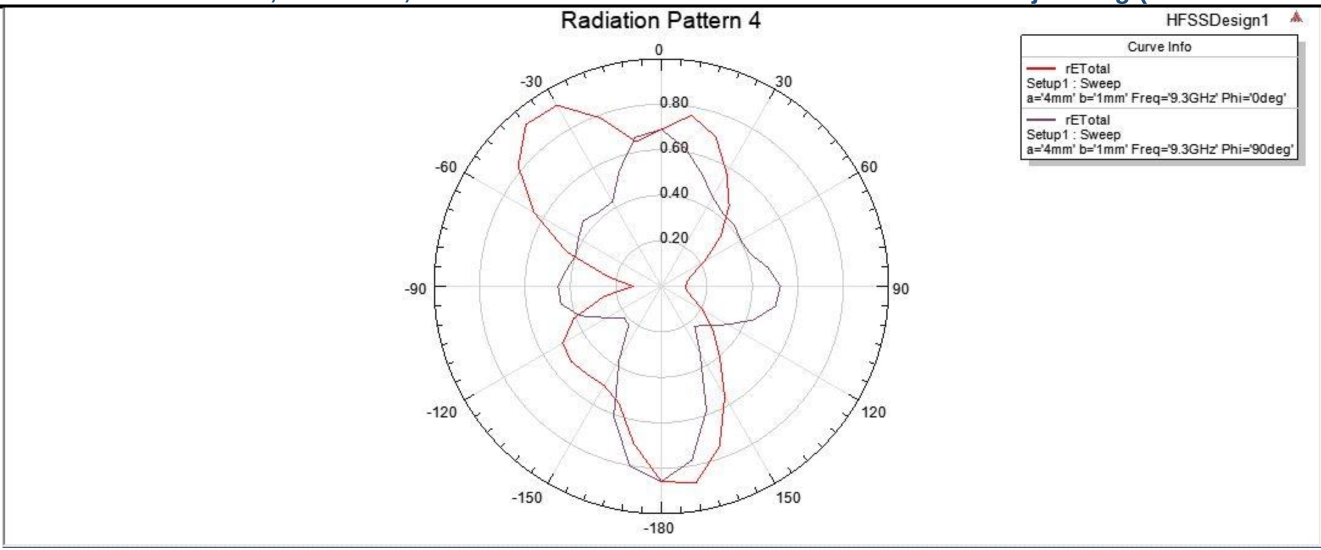
(a).radiation pattern at 3.65 GHz



(b).radiation pattern at 5.05 GHz



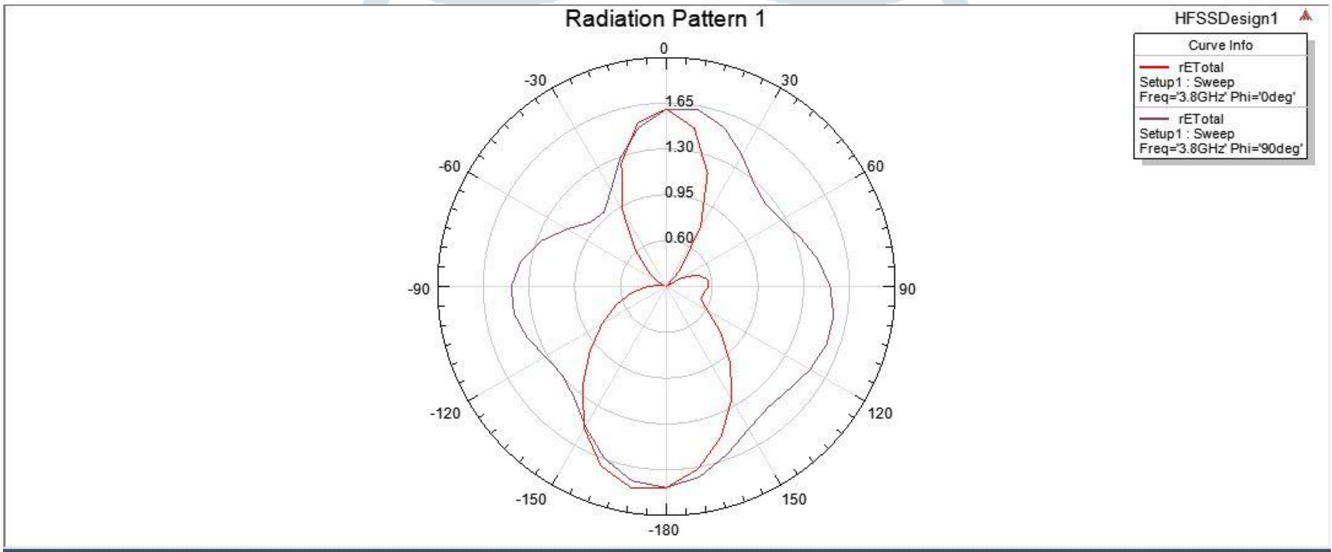
(c).radiation pattern at 7.2 GHz



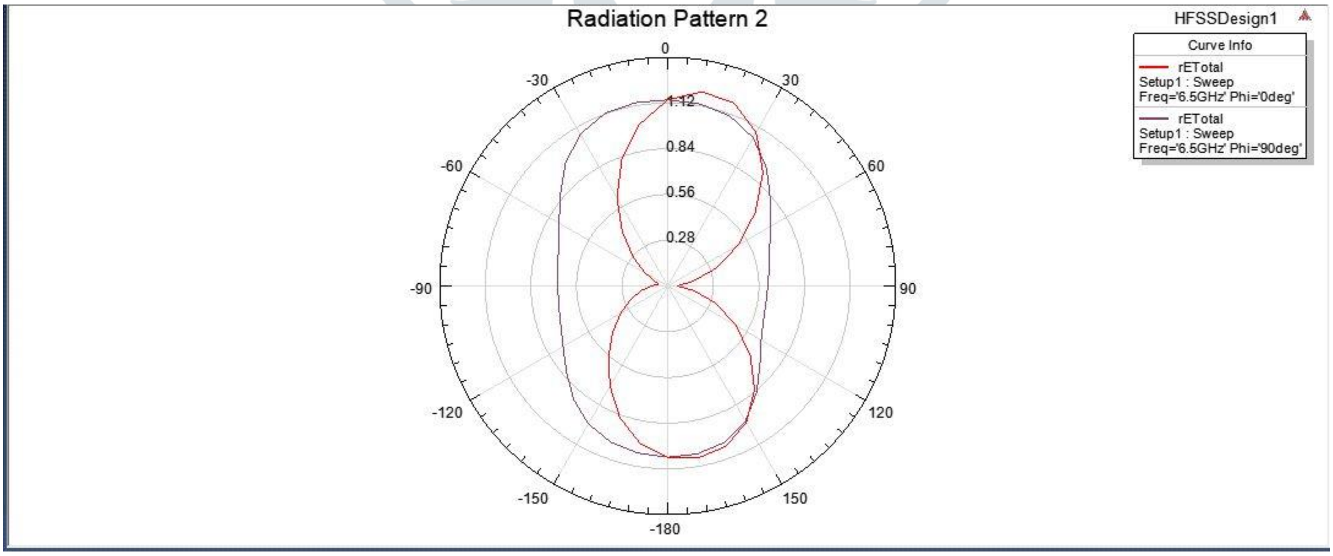
(d).radiation pattern at 9.3 GHz

Fig.9: radiation pattern of rectangular slot defected ground structure

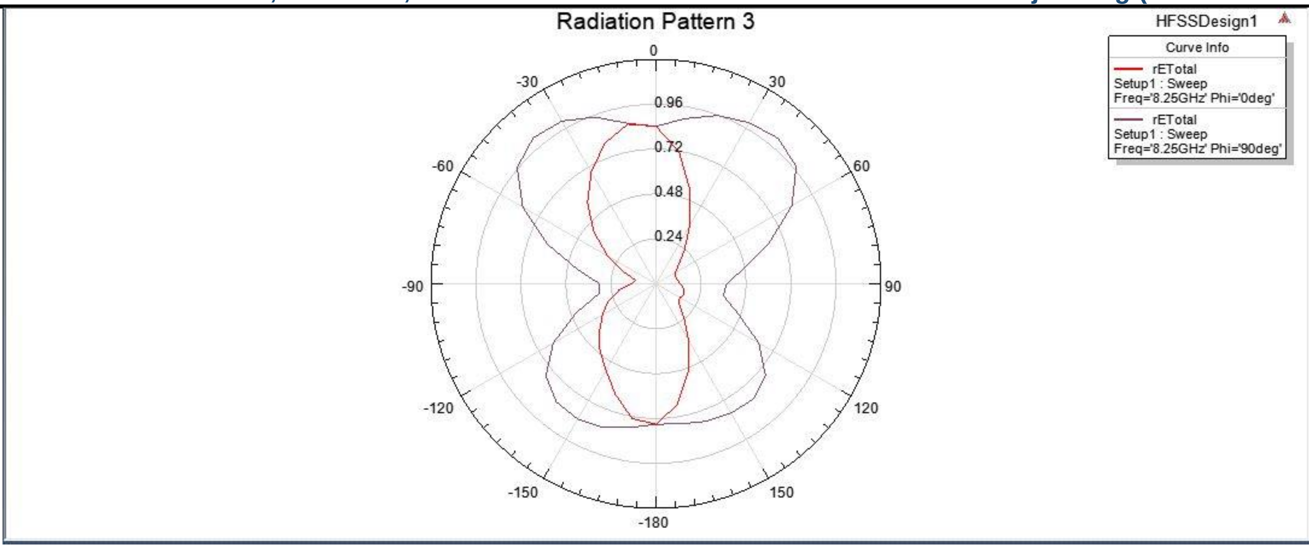
This antenna has a near omnidirectional radiation pattern for the first three resonating frequencies while the fourth resonating frequency has a bidirectional radiation pattern in positive and negative x-axis direction.



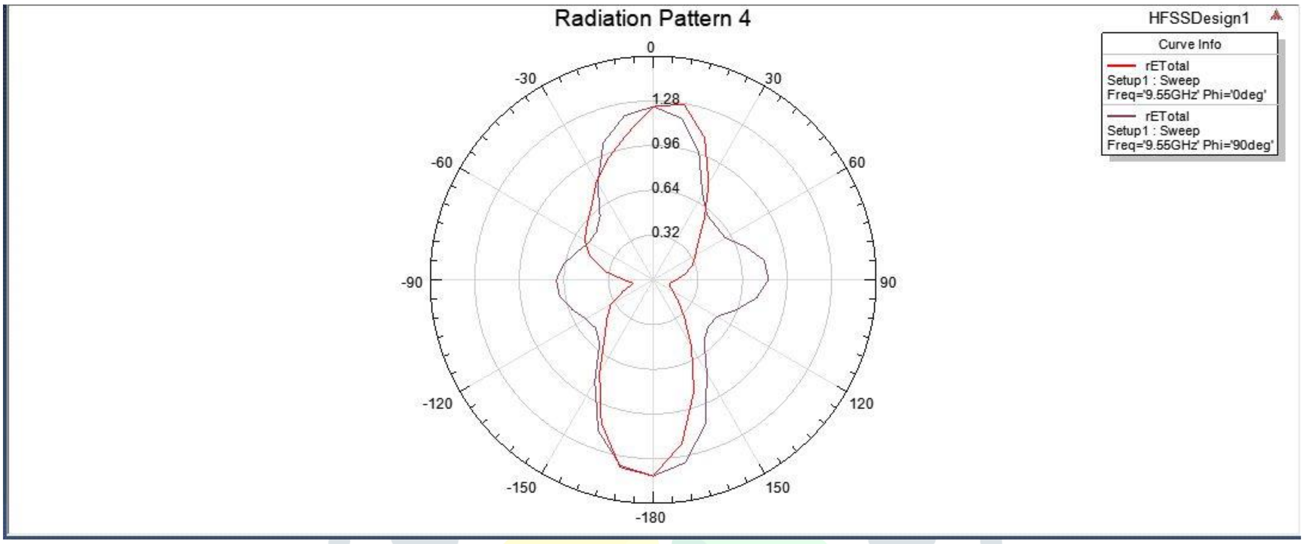
(a).radiation pattern at 3.8 GHz



(b).radiation pattern at 6.5 GHz



(c).radiation pattern at 8.25 GHz



(d).radiation pattern at 9.55 GHz

Fig.10: radiation pattern of rectangular loop slot defected ground structure

This antenna has a near omnidirectional radiation pattern for the first two resonating frequencies while the fourth resonating frequency has a bidirectional radiation pattern in positive and negative x-axis direction and the third resonating frequency has bidirectional radiation patter but with side lobe pattern.

D. Current Distribution

The current distribution across the patch and the ground plane are shown in the below figures: Fig. 11 and Fig. 12

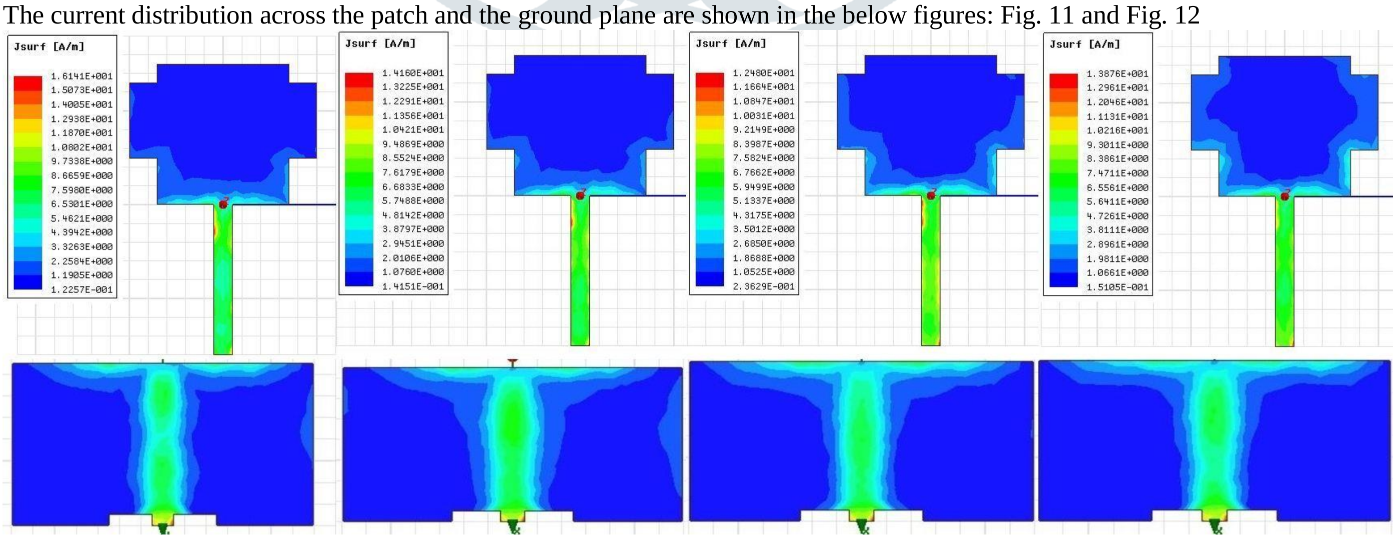


Fig.11: Current distribution of rectangular loop slot defected ground structure

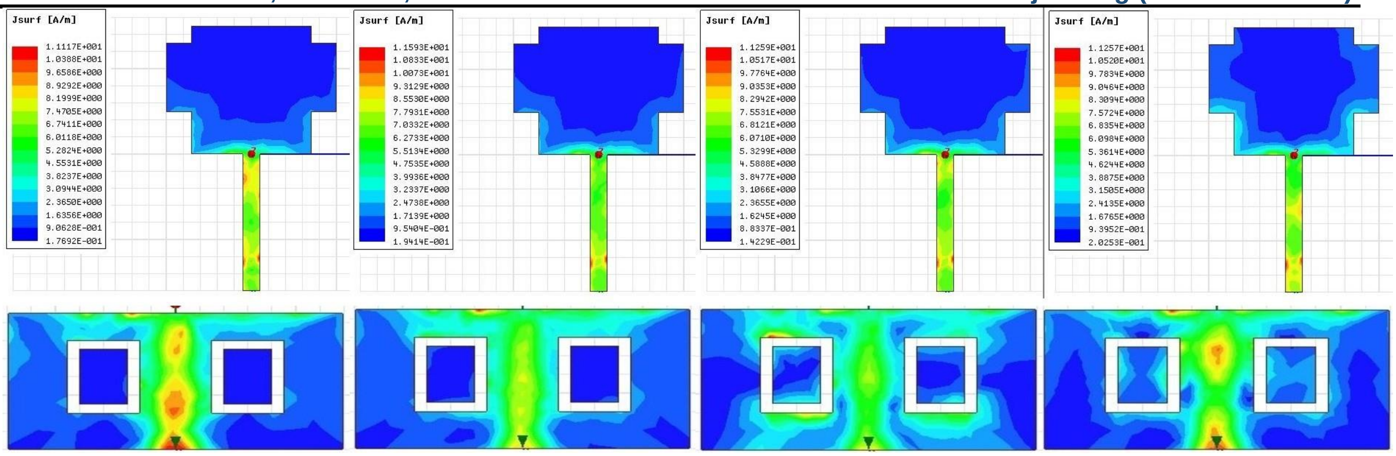


Fig.12: Current distribution of rectangular loop slot defected ground structure

Current distribution in patch and ground for both the antenna configuration are shown above and we can observe that current distribution is more spread out in the second case.

IV. DISCUSSION

The plot of return loss shows that the monopole antenna is resonating throughout the ultra-wideband frequency range (3.1-10.6GHz). The introduction of defections in the ground plane have improved the performance of the antenna in terms of return loss, VSWR and an additional resonating frequency for each antenna configuration. The improvement can be observed in every resonating frequency in return loss and VSWR for both the antenna configurations. Fig. 11-12 shows the current distribution in the patch and ground plane for the two configurations of the antenna. The current distribution is mainly concentrated in the portion of ground plane which is nearer to the patch and in and around the defections. In the patch the current distribution is concentrated in the feed line and lower end of the patch. As the response move towards the higher resonating frequencies the current distribution in the side cross-arms increase in the patch. This antenna exhibits near bidirectional radiation pattern for majority of resonating frequency and traditional monopole pattern for the remaining cases for both **φ**=0° and **φ**=90°.

Table 2: Simulated results of conventional antenna, rectangular slot DGS, Rectangular loop slot DGS

S.NO	**Name of the parameter**	**Conventional Antenna**	**Rectangular slot DGS**	**Rectangular loop slot DGS**
1	Resonating Frequencies	3.8 GHz, 6.7 GHz, 9.1 GHz	3.65 GHz, 5.05GHz, 7.2 GHz, 9.3 GHz	3.8 GHz, 6.5 GHz, 8.25 GHz, 9.55 GHz
2	Return loss	-30.8034 dB, -33.9816 dB, -16.6600 dB	-32.3798 dB, -27.6570 dB, -49.5732 dB, -17.2516 dB	-34.2724 dB, -40.7149 dB, -36.4866 dB, -18.1756 dB
3	VSWR	1.05, 1.04 and 1.33	1.0493, 1.0864, 1.0067 and 1.3181	1.0394, 1.0186, 1.0304 and 1.2815
4	Bandwidth	7.49 GHz (3.01-10.5GHz)	7.3 GHz (3.0-10.3GHz)	7.7 GHz (3.0-10.7GHz)

V. CONCLUSION

The presents a microstrip cross monopole antenna with defected ground structure as an ultra-wideband antenna. The plots of return loss and VSWR shows the antenna is resonating on the entire ultra-wideband frequency range with multiple resonating frequencies in each antenna configurations. Even though the bandwidth has diminished slightly for the first configuration, high return loss which is achieved which overshadow it. In the second configuration the bandwidth is enhanced and desirable return loss is achieved for all the resonating frequencies. Further an array of these antenna configuration can be used to achieve high gain and directivity. Due to its compact size and simple structure it's easy to fabricate and measure the results.

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