PERFORMANCE INVESTIGATION OF A NOVEL UWB ANTENNA INCORPORATED WITH DEFECTS IN THE GROUND STRUCTURE TO MINIATURIZE THE SIZE OF ANTENNA

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Abstract: In this paper a novel and compact ultra wide band antenna is proposed having modified hexagon shaped patch with slots etched on the patch and step size slots truncated in the ground plane for attaining wide impedance and minimal return loss characteristics. The proposed antenna is designed and stimulated using HFSS, which is a high frequency structure stimulator, based on Finite Element Method. The proposed antenna can operate from 3 GHz to 30 GHz for VSWR < 2. The minimal return loss characteristic of -15.40 db is obtained at 19 GHz and exhibits good radiation performance over the entire frequency range.

***Index Terms* –Antenna, Ultra wide band, WPAN, DGS, Wireless and Mobile Communication**

I. **Introduction**

The contemporaneous spurt of wireless applications and with high level of miniaturization, the world is already moving with 4G networks and very soon we will be entering into a world of 5G networks. With such revolution in wireless technology, seen within a short span of time, has definitely increased the interest in designing high performance antenna types for various applications. On February 14, 2002 FCC (Federal Communications Commission) has approved a band of 3.1GHz - 10.6GHz for UWB wireless communication technology applying to civil and personal communication system.

Over the last few years of research, it is evident now that a wide variety of proposed 'UWB' antennas, have proved as potential techniques for improving the spectrum efficiency of cellular radio systems. There are a growing number of applications, which involve the radiation or reception of electromagnetic signals over ultra-wide frequency bandwidth [1]. Therefore, the demand has swiftly raised, for compact and cheap antennas that can provide satisfactory performance in both time and frequency domains in the entire UWB Range. In addition, the trend in modern wireless communication systems, including UWB based systems, are to build on small, low-profile integrated circuits in order to be compatible with the portable electronic devices. This resulted in numerous studies on UWB microstrip antenna, which specifically focused on the optimization techniques for designing antennas radiating in the UWB Range [2] - [5].

In the planar structure, the antenna can be easily and conveniently printed onto a piece of printed circuit board which easily satisfies the requirements for small UWB antennas and can be used for portable applications. Due to this advantage, industry and academia have been putting enormous efforts on researches to study, design and develop planar antennas for UWB communication system.

Basically a printed antenna consists of a planar radiator and ground plane etched oppositely onto the dielectric substrate of the PCBs. The radiators can be fed by a microstrip line or coaxial cable depending upon the convenience. The electric currents in these antennas are distributed both on the radiating element and on the ground plane, and the radiation from the ground plane is unavoidable, which also need to be managed by doing modifications in the geometry. Therefore, the performance of the printed UWB antenna is considerably affected by the size and shape of the ground plane in terms of operating bandwidth, gain, directivity and radiation patterns.

Defected ground structure (DGS) has been widely used in the development of miniaturized antennas with satisfactory performance [6] - [9]. With DGS technique few defects are etched on the ground plane in periodic or non-periodic cascaded configuration. Defects in the ground structure facilitate the current distribution at the ground plane resulting in a controlled excitation and propagation of the electromagnetic waves through the substrate layer. The reason is that, DGS increases the electrical length than the conventional microstrip line for the same physical length. By using DGS, the equivalent inductive component of the microstrip line gets increased and it produces slow wave property [10].

Section II discusses the detail parameters calculation and geometrical model of the proposed antenna design. Section III describes the parametric study on improvised stable return loss by using modified hexagon shaped antenna. The conventional hexagon shape is modified by introducing defects in the radiator and by size reduction using the Defects in the ground structure. The simulated results of bandwidth, gain, and radiation pattern in tabular form will be discussed in Section IV. The last section will be conclusion that will conclude the entire research finding.

II. Antenna Design and Geometry

Figure 1 shows the design geometry of the proposed modified hexagonal shaped UWB microstrip antenna loaded with Defect Ground Structure. The shape of the patch is modified to hexagonal shape fed by stepped microstrip line on one side of a dielectric substrate of 2.2. Mathematical calculations are done to calculate the optimum values of width and length of the proposed antenna by taking fo = 4.5 GHZ and c = 3 x 10^8 m/s.

$$W = \frac{}{2f_o\sqrt{(Er+1)/2}} \quad \text{(i)}$$

$$L = \frac{}{\sqrt{2fo\ Eeff}} - 0.824\ h\ (Eeff + 0.3)\ (w/h + 0.264)/\ (Eeff - 0.258)\ (w/h + 0.8) \quad \text{(ii)}$$

After computing the dimensions, the optimum values of the antenna geometry have a length of L=22 mm and the width of W=26 mm. The excitation is launched through a 50 Ohm microstrip feed line, which has the stepped feed line length of 6 mm and feed line width of 1.5 mm as shown in Figure 1.

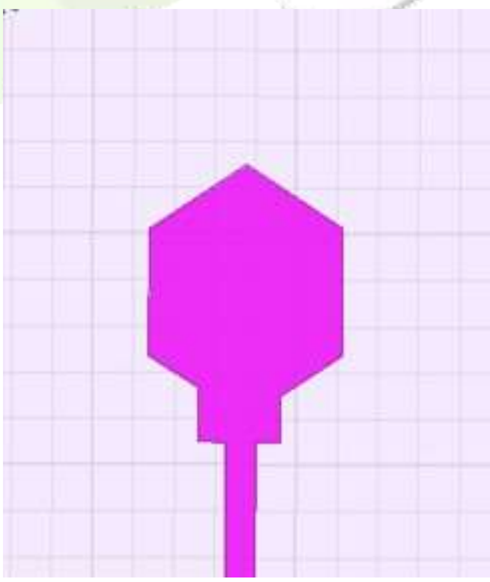

Figure 1: Simple prototype modified hexagon shaped microstrip patch antenna

III. MODIFIED HEXAGONAL SHAPED MICROSTRIP ANTENNA WITH DEFECTED GROUND STRUCTURE

The proposed antenna design is a novel UWB antenna which shows improvement in radiation performance over the entire frequency range. By adding the stepped blocks in the feed line and by introducing slots in the radiator, as shown in Figure 2, the return loss maintains below -15dB in the UWB range. DGS technique is applied on this antenna in order to improve the stable radiation pattern thus decreasing the size of the antenna as shown in Figure 3.

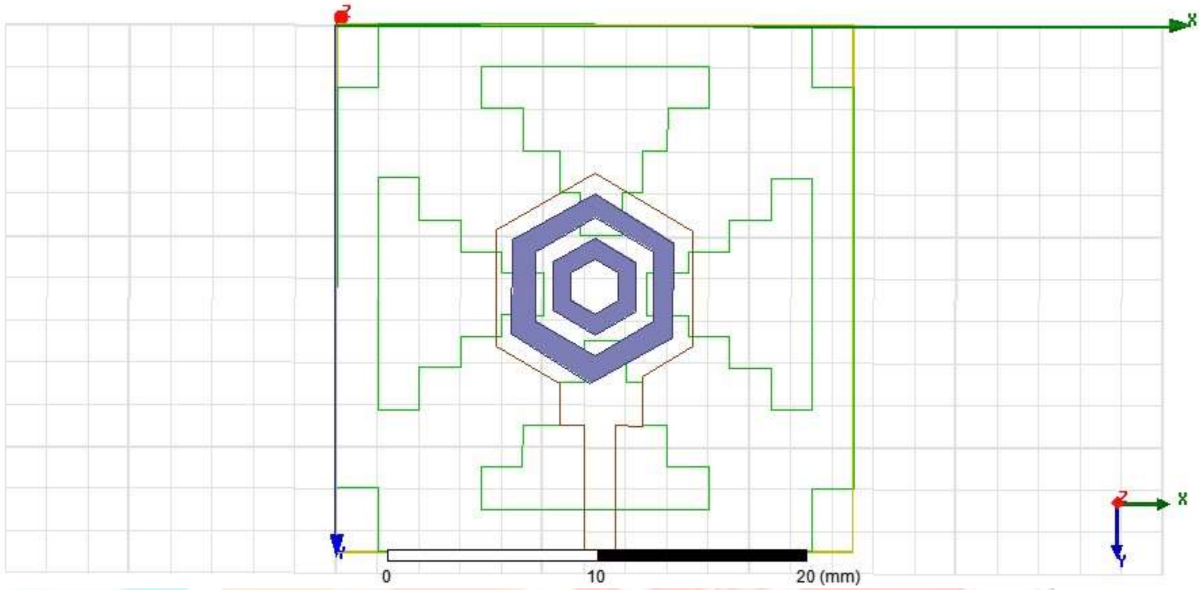

Figure 2: Simple prototype modified hexagon shaped microstrip patch antenna with slots in the radiator

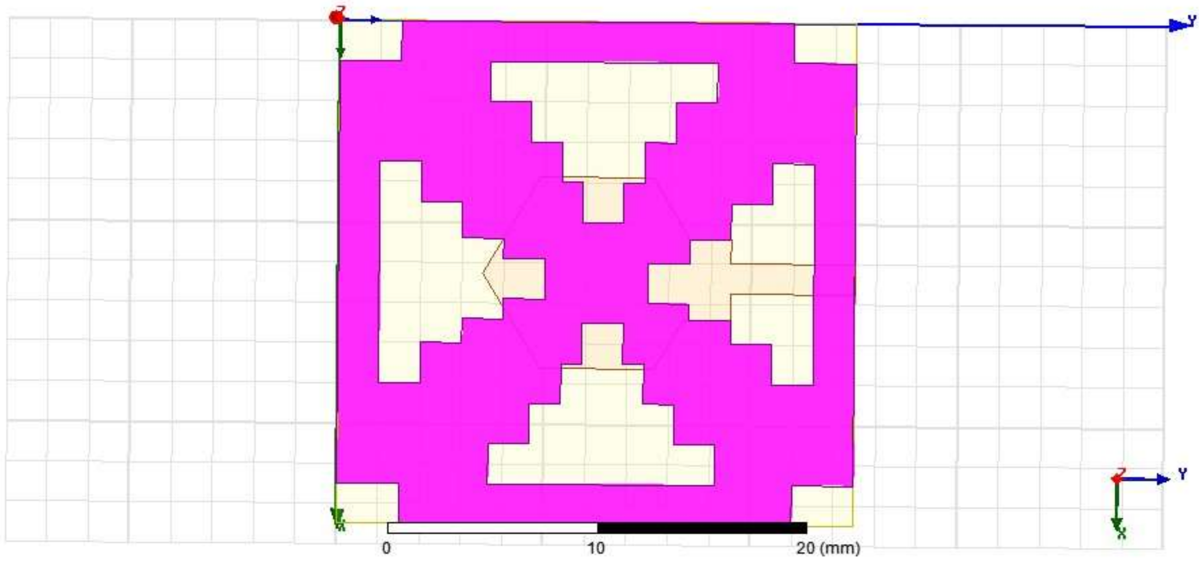

Figure 3: Simple prototype modified hexagon shaped microstrip patch antenna with Defected Ground Structure

IV. SIMULATION AND RESULTS

The results of the prototype antenna design are stimulated using High Frequency Structure Simulator (Ansoft HFSS). Parameters like return loss and radiation pattern are calculated and results are plotted using HFSS which is based on the Finite Element Method (FEM). Table 1.1 presents the calculated value of antenna parameters for the proposed prototype antenna.

Table 1.1 Antenna Parameters value

Quantity	Value

Max U	5.36596e-005(W/sr)
Peak Gain	0.0128357
Radiated Power	0.0527478(W)
Incident Power	9.91574e-008(W)
Peak Directivity	0.0127839
Peak Realized Gain	6800.52
Accepted Power	0.0525349(W)
Radiation Efficiency	1.00405

In this section, three parameters were considered for obtaining optimum results which are dimensions of the radiating patch, number of slots in the radiator and size reduction using the DGS. The parametric study was simulated with HFSS Simulation Software. Keeping other parameters constant only one parameter was changed at a time to get best results.

A. Dimensions of the Radiating Patch

Many designs were simulated and compared with each other and finally the proposed design was chosen with satisfactory results. After computing the dimensions, the optimum values of the antenna geometry have a length of L=22 mm and the width of W=26 mm. The excitation is launched through a 50 ohm microstrip feed line, which has the stepped feed line length of 6 mm and feed line width of 1.5 mm. These parameters were finalized after simulating the results number of times and final result with the proposed dimensions are shown in Figure 4.

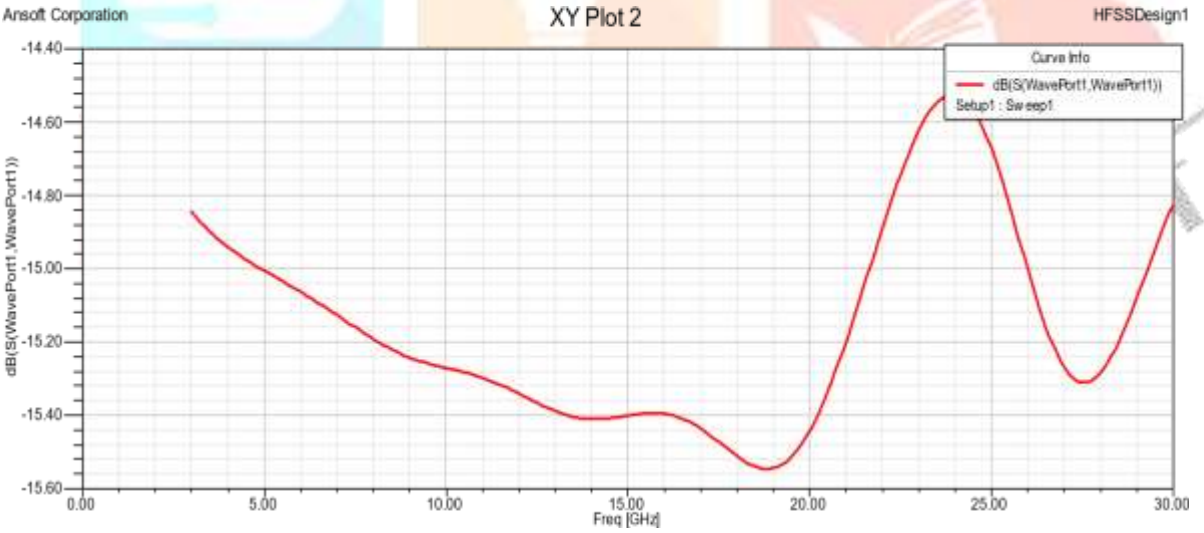

Figure 4: Simulated results of modified hexagon shaped microstrip antenna with L = 22mm & W = 26mm

The geometry of the radiator was varied number of times by stimulating the results using HFSS to get the final graph with optimized parameters. Further the length and width of the feed line were optimized for satisfactory return loss results as shown in Figure 5.

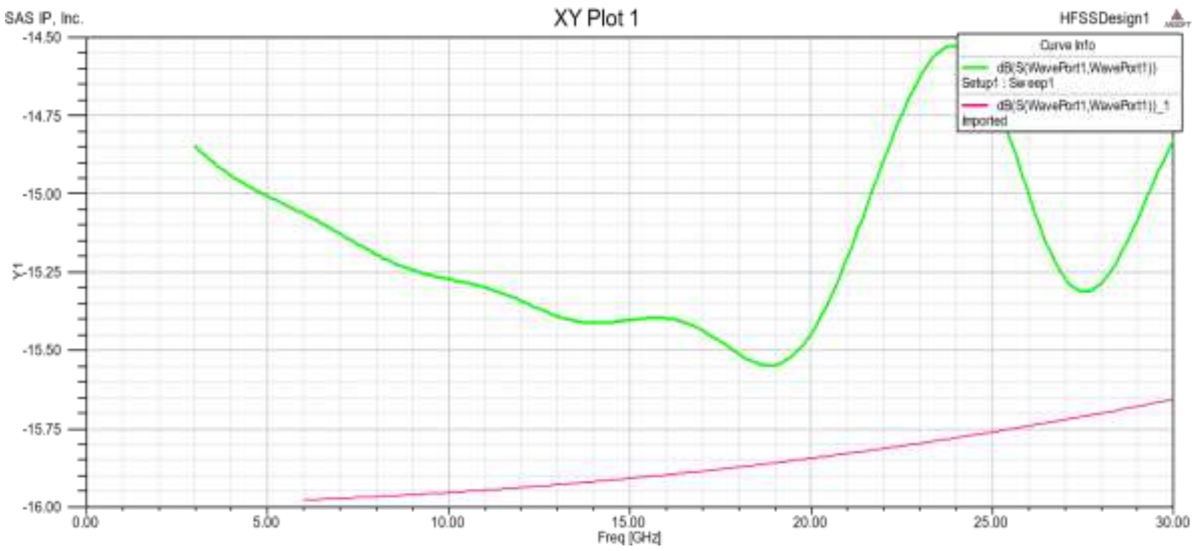

Figure 5: Comparison graph of the stimulated results with changes in the length of the feed line

B. Number of slots in the Radiator

After examining the results of modified hexagon shaped antenna, further a slot was cut in the radiating patch. The single hexagon shape slot in the radiator does not affect much on the return loss. The design was then stimulated in HFSS with three slots in the radiator because it gave the best result. Figure 6 shows the S11 parameter with slots in the shape of radiator. The slots are three in numbers. These numbers are increased 1 by 1 of each run. The result shows magnitude of return loss S11 and the bandwidths were slightly affected. Increasing number of slots improves the magnitude of return loss, however it saturates above three. Three slots were chosen to maintain the return loss below -14.50 dB within the entire UWB frequency range.

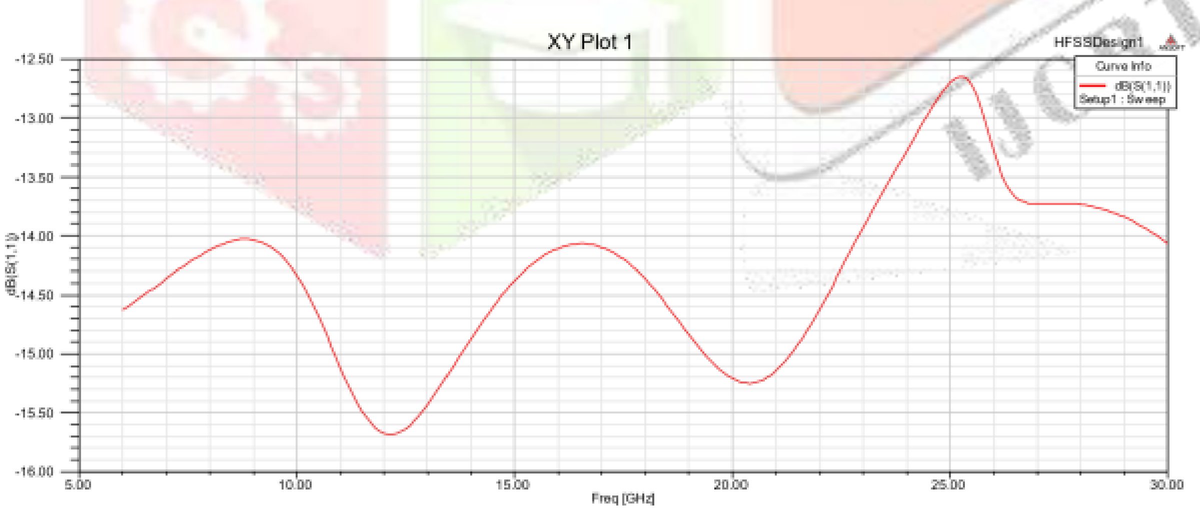

Figure 6: Simulated results of modified hexagon shaped microstrip antenna with three slots in the radiator

C. Antenna size reduction using the DGS

Defects in the ground structure were incorporated to improve the radiation performance of antenna and to miniaturize the size as shown in Figure 7. This size reduction decrease at first run is 10% and 20% of the others run.

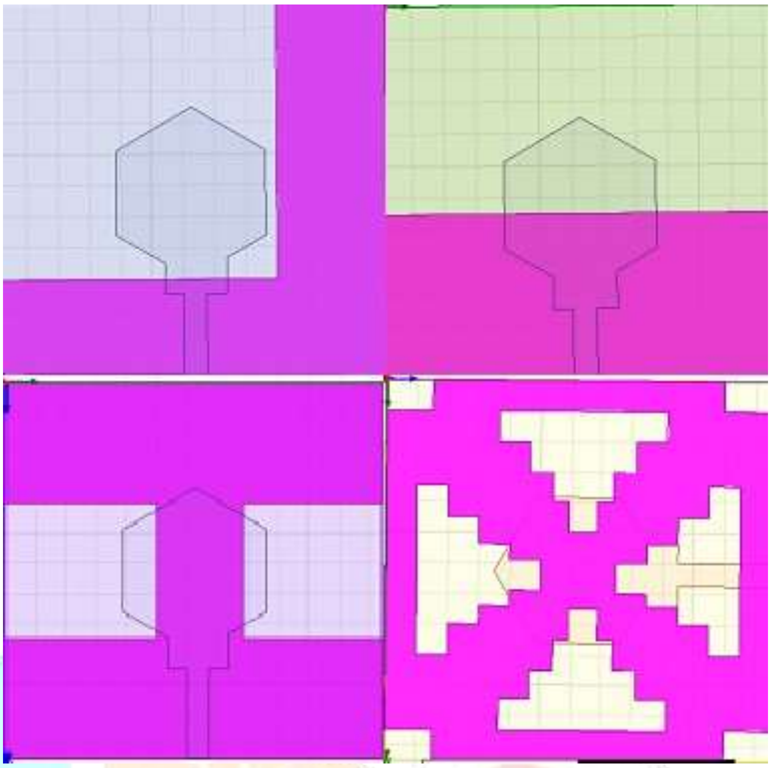

Figure 7: Defects in the ground structure

Figure 8 shows the comparative S11 parameters graph of the design when the size of the antenna with DGS was reduced from 10% to 60% of its original figure. The result affects the magnitude of return loss graph because reducing the size of the ground, reduces the electrical length of the antenna. In order to maintain the same electrical length like before, the DGS was added with some modifications as done in the geometry. The reduced size of 25% return loss was chosen which give higher and stable return loss in the entire UWB frequency range.

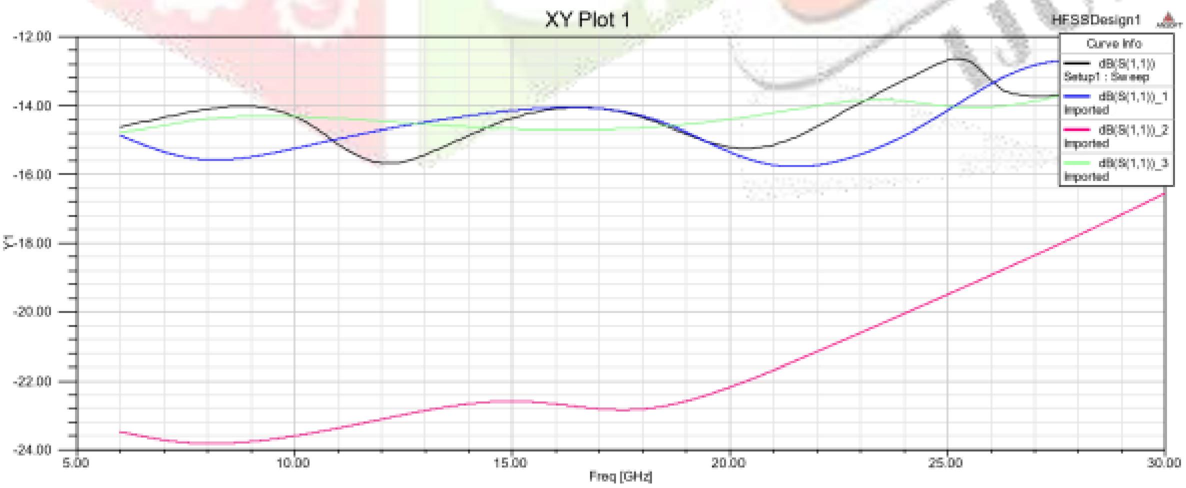

Figure 8: Comparison graph of the stimulated results with different defects in the ground structure

Due to the modified geometry in the ground plane, the field of electric and magnetic is mostly confined under the microstrip line. By introducing the Defects in the ground structure, the return patch of current is fully disturbed therefore the performance of the return loss can be tune. No doubt, by adding the DGS shape, the return loss was improved than the return loss without DGS but decreased at the high frequency as shown in Figure 9.

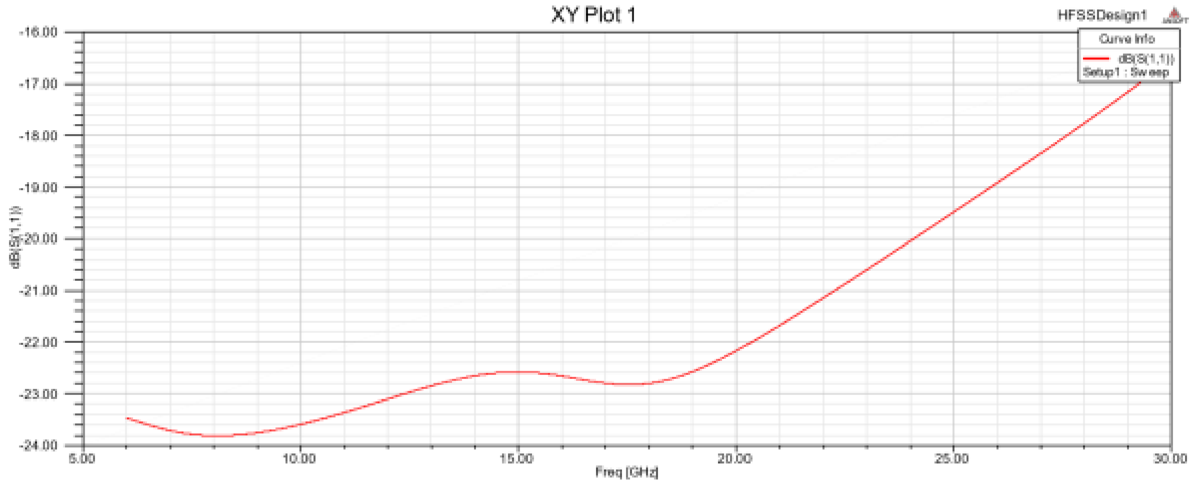

Figure 9: Stimulated results of the modified hexagon shaped proposed antenna incorporated with DGS

D. Radiation Pattern and Electric Field

The radiation pattern, electric field and current distribution of the final shape of the proposed antenna at the centre frequency is shown in Figures 10 to 12. It is evident from the figures that the proposed antenna performance is satisfactory as per the requirement of antennas radiating in the UWB range. As the requirement of specified application for Ultra wide band antenna, the proposed antenna exhibits the return loss property with good gain. The electric field distribution defines the excitement of fundamental modes within the specified UWB range of antenna. The radiation pattern of the proposed antenna in the research finding is well suited for Wireless Personal Area Network Application due to its attributed moderately good gain for short range communication.

Figure 10: Radiation Pattern

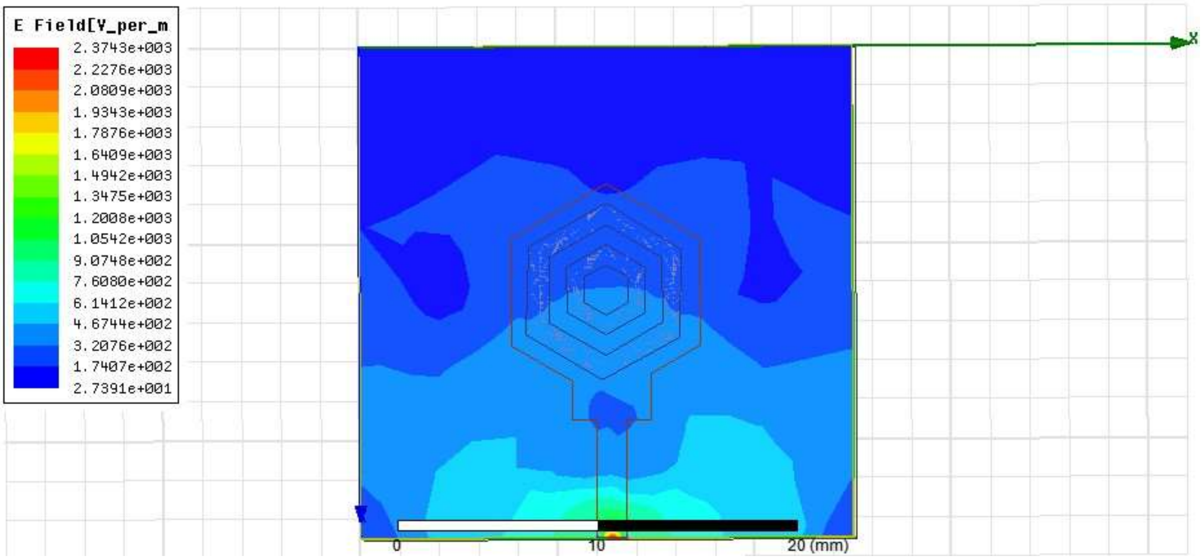

Figure 11: Stimulated results of E Field Distribution

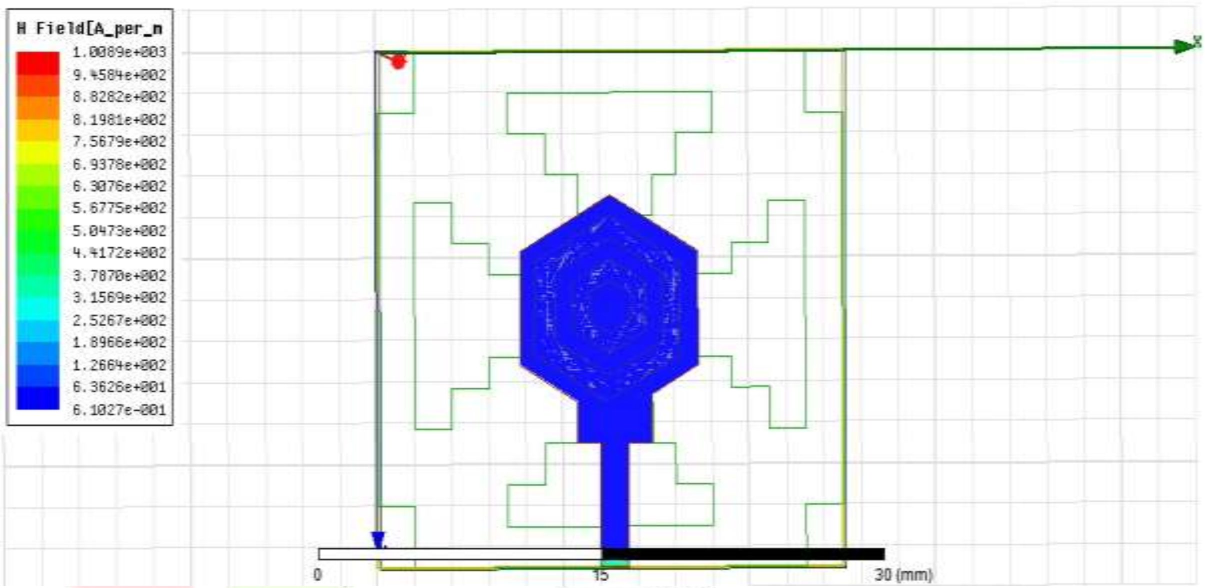

Figure 12: Stimulated results of H Field Distribution

V. Conclusion

The particular research finding propose a novel modified hexagon shaped patch antenna designed with slots etched on the patch and step size slots truncated in the ground plane for attaining wide impedance and minimal return loss characteristics. Defects introduced in the ground structure reduce the surface wave and fosters high impedance bandwidth with considerable gain performance for the operating range from 6 GHz to 30 GHz. Three variations of the antenna design by doing different parametric evaluation such as changing the dimensions of the geometry, introducing slots in the radiator and incorporating DGS in the design are considered. Reduction in the size by introducing slots is utilized for enhancing the bandwidth. Results of return losses found after simulating the proposed design a number of times is found satisfactory below -10 dB with VSWR analyzed below 2. The minimal return loss characteristic of -23.80 db in the UWB range. The proposed antenna exhibits good radiation performance over the entire frequency range.

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