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Size Reduction with Multiband Operating Square Microstrip Patch Antenna Embedded with Defected Ground Structure

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Abstract: The focus of this work is to obtain a miniaturized microstrip patch antenna using defected ground structure (DGS) for S band and below for various low band applications. The antenna is also made to resonate in multiband frequencies. Initially the patch antenna is designed at 5 GHz which falls in C band design resonates at 4.48 GHz. The proposed DGS is integrated in the ground plane of the patch antenna for size reduction. However, process of size reduction is obtained by removing the ground plane of designed antenna and not changing the physical dimension of design. In order to improve the gain of this patch radiator, the DGS is further modified to retain its radiation properties. Finally, the resonance frequency of an initial microstrip antenna shifts from 4.48 GHz to various low band frequencies, with better performance miniaturization up to 86% with respect to conventional microstrip antenna is successfully obtained. A prototype of the antenna was fabricated with the Modified epoxy substrate. This technique is validated experimentally and measured results were in good agreement with simulated results, these antennas find their application in various ISM applications.

I. INTRODUCTION

Microstrip antennas are major choice for wireless devices since, they provide various properties, and several advantages. Some of the main advantages of microstrip antenna are that it has low fabrication cost, light weight, low volume, and low-profile configuration that plays an important role in wireless communication it finds a major application [1]. However, the microstrip patch antennas suffer from a number of disadvantages as patch length is around half a wavelength etc.

In recent years, the size reduction of antennas has become more and more important due to the increasing demand for small antennas, as there is a need for compact devices and multi-frequency. Many efforts have also been made in order to achieve the size reduction like using different feeding methods [2] or using a dielectric substrate of high permittivity [3], defected microstrip structure (DMS) [3], defected ground structure (DGS) [3], also combination of both DGS and DMS.

This paper mainly speaks about DGS which is an etched periodic or non-periodic cascaded configuration on the ground plane, which disturbs the shield current distribution in the ground plane because of the defect in the ground. Hence, it’s the intentionally created defect on the ground plane. The defect geometry is easy to implement and is basically embedded on the ground plane below the patch area. These features enable such structures to acquire a great relevance in microwave circuit design [4]. In particular, DGS is employed to enhance performance of microstrip antennas for different applications, for instance, cross polarization, mutual coupling reduction in antenna arrays and harmonic suppression. Moreover, DGS has been widely used in the development of miniaturized antennas and harmonic suppression [5].

DGS is used to design a miniaturized microstrip patch antenna and its parameters are compared with a conventional one. Initially the proposed typical square microstrip patch antenna designed at C band, resonates at 4.48 GHz. By embedding defect in ground plane, DGS effect is observed by shift in the resonance frequency from C band to S band keeping the physical volume of the antenna constant and making it shift its resonating frequencies, and hence the size reduction about more than 80% compared with the conventional one is carried out.

This size reduction significantly reduces the gain and degrades the antenna performance due to the increase in ohmic losses. This loss of gain and increase in performance is obtained by improving the DGS dimensions and maintain the DGS to be below the patch element on ground plane. Finally, we obtain the a square microstrip patch antenna to resonate from C band of frequency to S band and also in C band making it to provide multiband antenna, the gain loss is compensated with change in the structure of gain and the patch modification. [6]

A. 5 GHz Square Microstrip patch antenna

The proposed square microstrip patch antenna is shown in Fig. 1. In this design the substrate modified epoxy with dielectric constant $\varepsilon_r = 4.2$ was used due to its advantages. The substrate height was 0.16 cm and with loss tangent 0.002. The dimensions of the antenna were optimized by using Ansys HFSS simulation tool. On the top of the substrate, a square copper patch with dimension L_p = 1.8605 cm and W_p = 1.8605 cm was connected to 50Ω feed line with an edge feed method to provide the stability to the antenna and other parameters. The microstrip patch is feed with feed and quarter to provide proper impedance match in the design. [5] The simulation result of reference antenna is shown in Fig. 2. The polar radiation plots simulated at $\phi = 90^0$ and $\phi = 0^0$ are shown in Fig. 3. The design and simulation of the proposed antenna have been carried out. Fig. 2 shows S_{11} of the antenna without any DGS in ground plane resonates at frequency 4.48 GHz (C band) with the gain 4 dBi. Main objective of the work is size reduction without altering its physical dimension by embedding DGS which in turn improve the performance of antenna. [7]

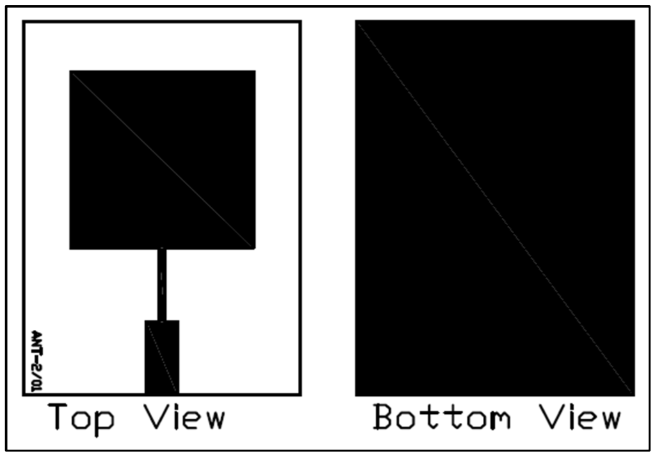

Fig 1: Dimensions of square microstrip patch antenna without DGS

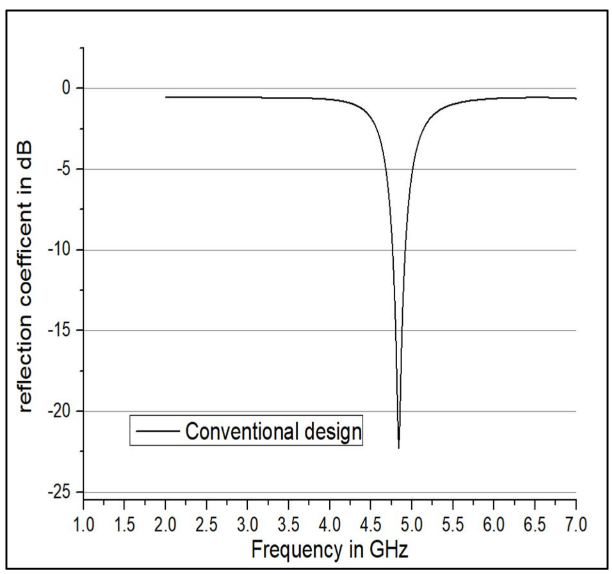

Fig 2: Return loss of conventional design of 5 GHz antenna

B. Embedding Defected Ground Structure on Ground Plane

The defected ground structure (DGS) and the Electromagnetic band gap structures (EBG) are the two different types of the generic structures mostly used for the design of compact and high-performance microwave components [8]. These structures are embedded to reject unwanted frequency and circuit size reduction since it creates a band stop effect due to disturbance in the current distribution on the ground plane. DGS is an etched lattice of proposed shape embedded on the ground plane. The performance of microstrip antennas and parameters are enhanced by introducing the defects in the ground plane [9].

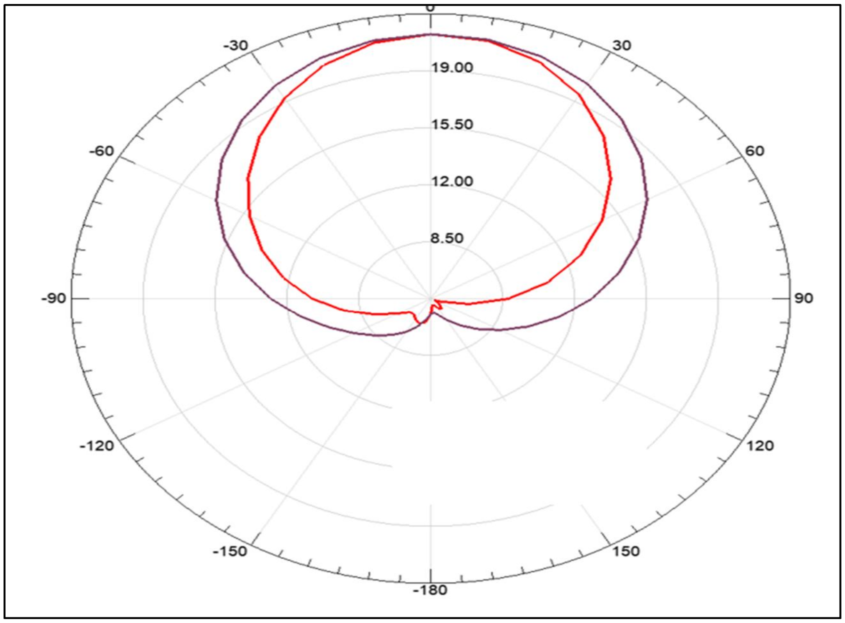

Fig 3: Radiation pattern of conventional design of 5 GHz antenna

The modification in the shape of the defect for obtaining better performance than that of conventional antenna. The DGS equivalent circuit consists of a parallel tuned circuit in series with the transmission line to which it is coupled as shown in Fig 4. The different shapes of DGS structure have the same role and same characteristics of slow wave effect and high impedance, band rejection, size reduction with the basic equivalent model [10].

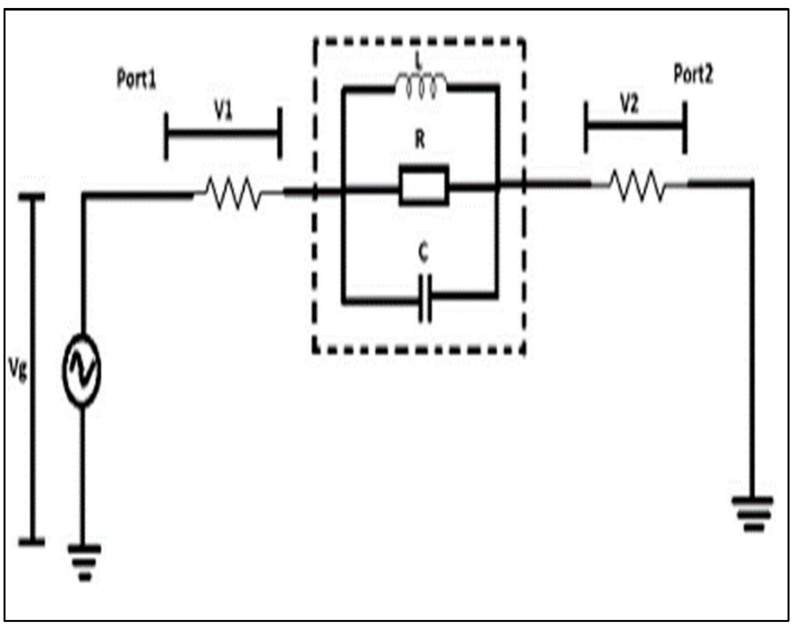

Fig 4: Basic equivalent circuit model of DGS

When DGS structure is embedded on the ground plane the current disturbance creates a disturbance in transmission line characteristics of the antenna, such as line capacitance and inductance. Its like adding the capacitance and inductance to conventional circuit by creating the slots, careful dimensions of slots as to be made since the slots created on the ground plane directly influence the input impedance and the current flow of the antenna [11] which helps the purpose of size reduction with respect to a conventional design, by making the antenna resonate in the lower band of frequencies.

C. Proposed antenna embedded with DGS

To obtain the shift in the frequency from C band to S band of frequency, different dimensions of Dumble shaped DGS shape is embedded on the ground plane of the antenna shown in Fig. 5.

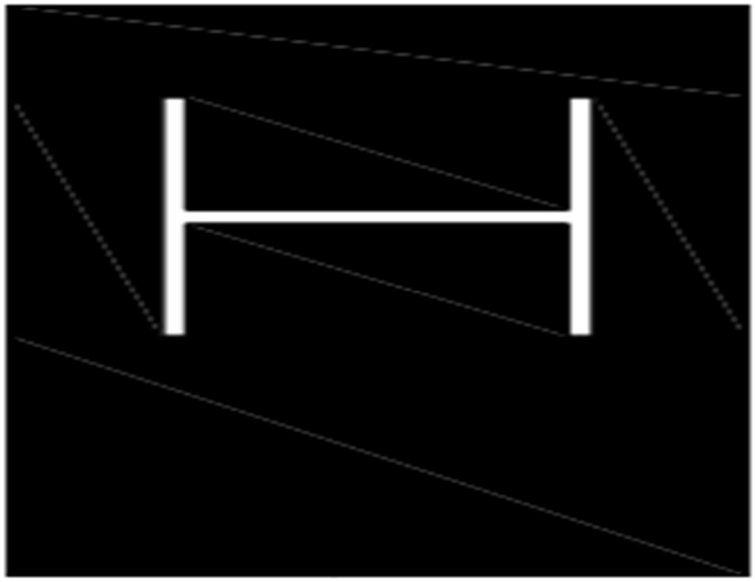

Fig 5: Dumble shaped defect embedded on ground plane

The detailed geometry of defect is given in Fig. 6, two different dimensions of defect is selected and simulated for enhancement in the parameter. The geometry of defect is varied with respect to a and b as shown in Fig 6. The effect of removing the resonating frequency is getting shifted range of 1.80 ~ 1.93 Ghz with gain enhancement after modification of shape of DGS embedded. with respect to the position of the DGS shape is generally placed on the ground plane but placing the defect exactly below the patch gives the enhancement in the parameters of the microstrip patch antenna. [12] [14]

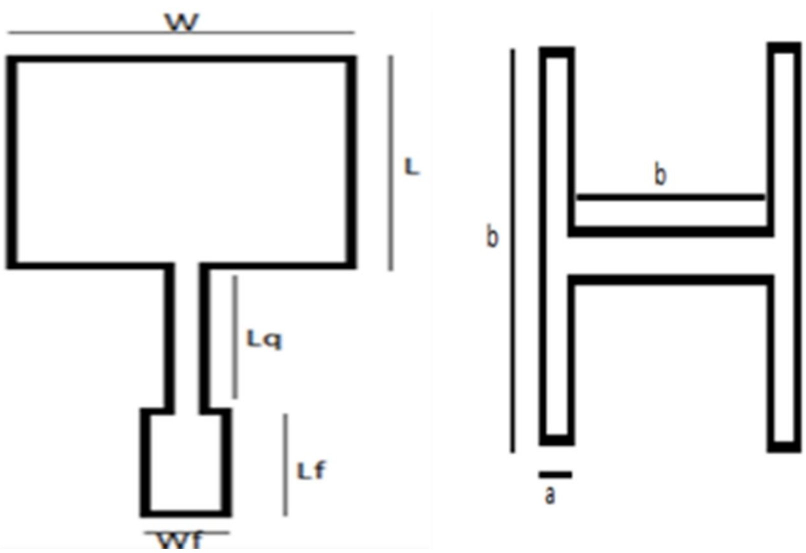

Fig 6: Geometry of defect embedded on ground plane

Table 1 shows the various DGS dimensions with resonating frequency comparison with respect to conventional design of the 5 GHz patch antenna, table provide the various band of frequencies at which it is resonating with respect to its reflection coefficient. It's observed that the antenn-1 to antenna-3 all are providing a multiband operation, frequency range varying from 1.80 GHz to 10.46 Ghz each with minimum gain of more than that of 4 dBi, these antennae have frequencies from lower ISM band to higher band of operation within the dimensions of 5 GHz patch antenna.

Table 1: DGS dimensions and its reflection coefficient showing multiband operation

Antennas	Dimension in cm		F_r in GHz	RL in dB
	A	B		
Conventional	-	-	4.485	-21.9
Antenna-1	0.1~0.2	1.6605~ 1.4605	1.880	-19.441
			8.563	-12.133
			10.460	-16.430
Antenna-2	0.1	1.6605	1.810	-17.913
			7.160	-13.616
			8.068	-17.484
			8.673	-26.767
			10.515	-19.032
Antenna-3	0.05~0.1	1.6605~ 1.4605	1.935	-21.142
			7.160	-15.706
			8.370	-11.586
			10.323	-11.459

D. Fabrication and measurement of proposed antenna

The design of proposed antenna with and without DGS embedded was fabricated using modified epoxy as a substrate as it's is easily available for fabrication at low cost, other substrate can be tested for the better performance of the antenna. The substrate used has the thickness of 0.16 cm with relative dielectric constant of 4.2 Fig. 7 shows the fabricated antenna top view with its dimensions measured, modification of DGS is carried out on the ground plane.

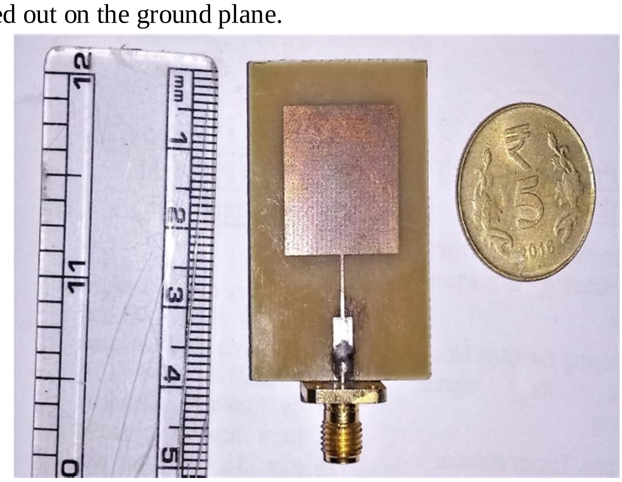

Fig 7: Fabricated antenna conventional of 5 GHz.

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In order to measure the practical readings such as return loss, radiation pattern, VSWR has been taken using vector network analyzer ZVK with frequency range of 10 MHz to 40 GHz, thus the S_{11} parameter was measured and compared with simulated results Fig 8, Fig 11, Fig 13 shows the S_{11} parameter of the proposed antennas with different dimensions of same DGS structure. Fig 8 is graphs of S_{11} parameter we find that the band width of antenna-1 vary 137 MHz to 165 MHz for 3 different frequencies in antenna as its resonating multiband frequencies, gain of antenna is also better than that of conventional design as the modification and placing of DGS below the patch provide reduction in loss of gain. Fig 9 gives the radiation patter of the antenna-1 shown.

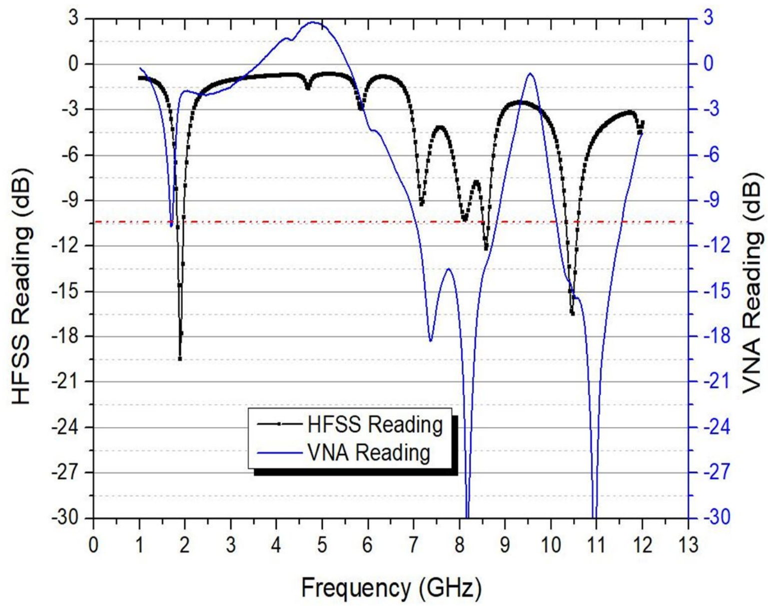

Fig 8: S_{11} Return loss of Antenn-1

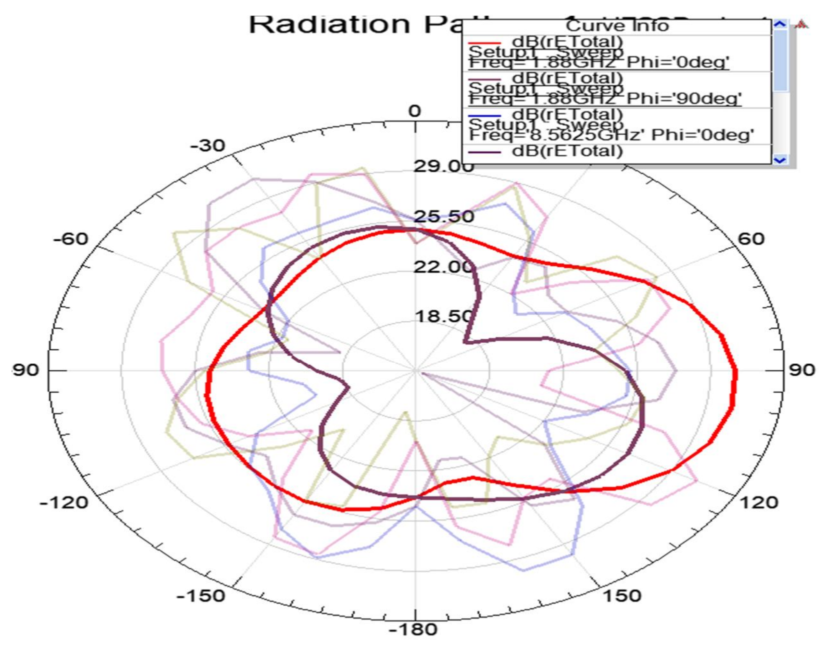

Fig 9: Radiation pattern of Antenna-1

In Fig 10 the dimension of the DGS is equal with respect to a and b parameter of measurement this design is considered to be better among the proposed antennas, since it resonated at four different frequencies from 1.810 GHz to 10.5 GHz as provided in that table

1 bandwidth of this antenna with respect to the frequencies is ranging from 137 MHz to 357 GHz gain of the antenna at the respective frequencies is found to be better than conventional gain without DGS. Fig 11 gives the radiation pattern of the antenna-2 we can observe that radiation pattern is almost omni directional in case of antenna-2.

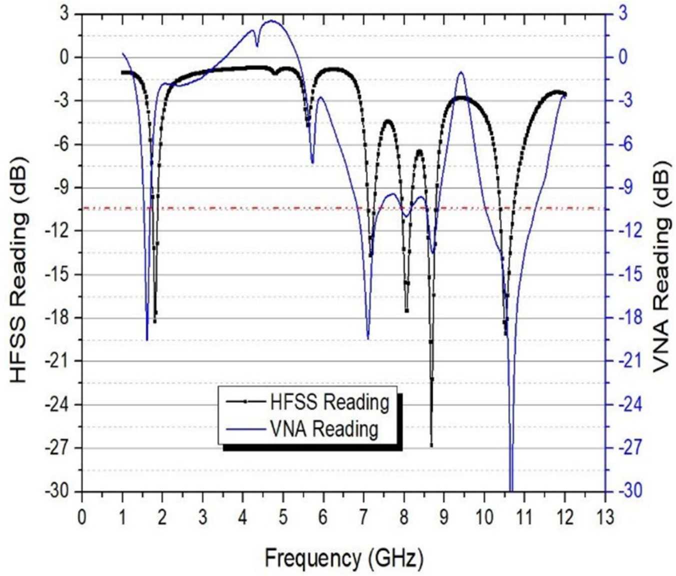

Fig 10: S_{11} parameter of Antenna-2

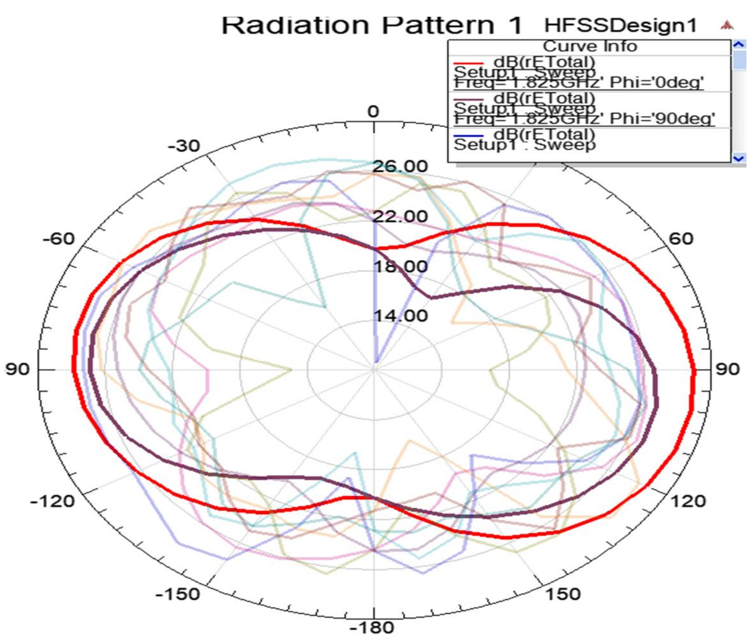

Fig 11: Radiation pattern of antenna -2

Further variation in the dimension of the DGS provided in the antenna-3 gives a multiband operation of frequencies which is shown in the Fig 12 with band width varying from 165 MHz to 385 MHz we can observe that antenna embedded with DGS is providing better bandwidth in compared to conventional design for 5 GHz. Antenna-3 is providing four frequencies as given in the table-1 making antenna multiband with considerable gain. Fig 13 give the radiation pattern of the antenna-3 which is not good as that of antenna-2 but provides a higher bandwidth and operate at multiband frequencies. [13]

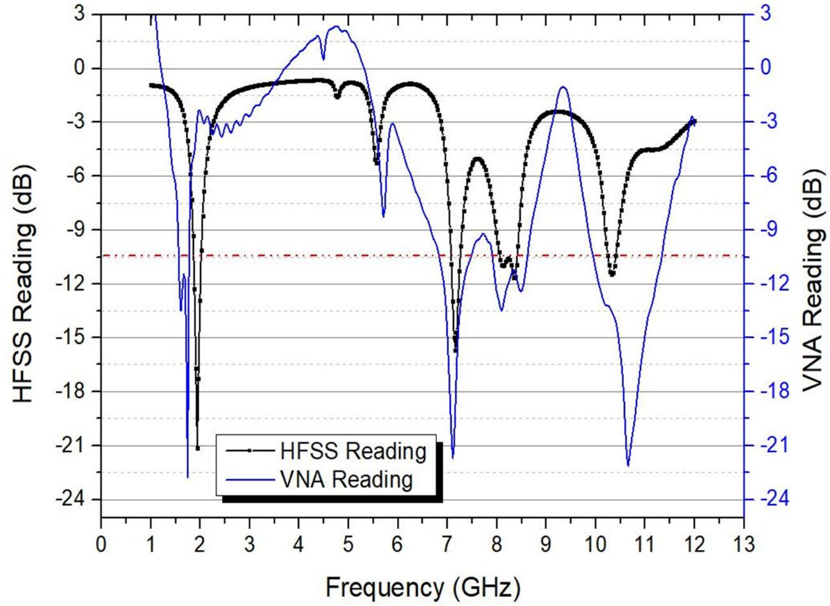

Fig 12: S_{11} parameter of antenna-3

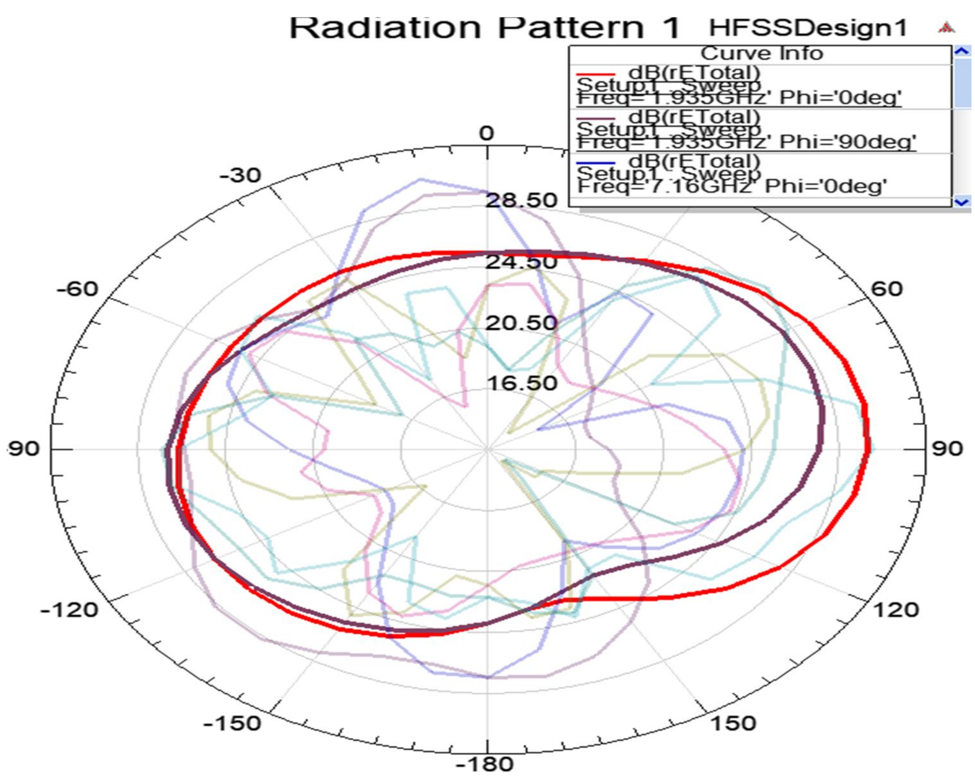

Fig 13: Radiation pattern of antenna-3

Table-2 gives the comparative analysis of the overall size reduction with respect to conventional design of antenna without DGS embedded. it is observed that all three proposed antennas provide a size reduction of > 85% which gives us the miniaturization of antennas and also provide a multiband operation in each antenna.

Table 2: Size comparison table with conventional design

Antenna	Convectional patch size without DGS at f= 5GHz	Patch size at F_r	Size reduction in %
Antenna-1	3.461 cm^2	24.502 cm^2	85.87
Antenna-2	3.461 cm^2	26.419 cm^2	86.89
Antenna-3	3.461 cm^2	23.136 cm^2	85.04

II. CONCLUSION

The size reduction and miniaturization process used by embedding DGS on the ground plane and not disturbing the antenna dimensions for which it’s is originally designed is a promising method of size reduction method that provides antennas in multiband operation and parameter enhancement of a conventional microstrip patch antenna. We have achieved a considerable shift of frequency of design to lower i.e. from 5 GHz to 1.88 GHz resonating at -19.4 dB for lower frequency and at 10.5 GHz at -16.5 dB proposed antenna is resonating in multiband without degrading the performance of antenna. Proposed antennas give overall size reduction of up to 85% as frequency shifts from 5 GHz designed frequency to 1.8 GHz with DGS. Proposed DGS shape with various modification is able to get the over all size reduction of 85 % when compared to conventional. all proposed antennas find their applications from lower band to higher band since antennas are resonating in both lower and higher band with considerable gain, antenna can be used for both ISM application to WIFI and other broadband applications.

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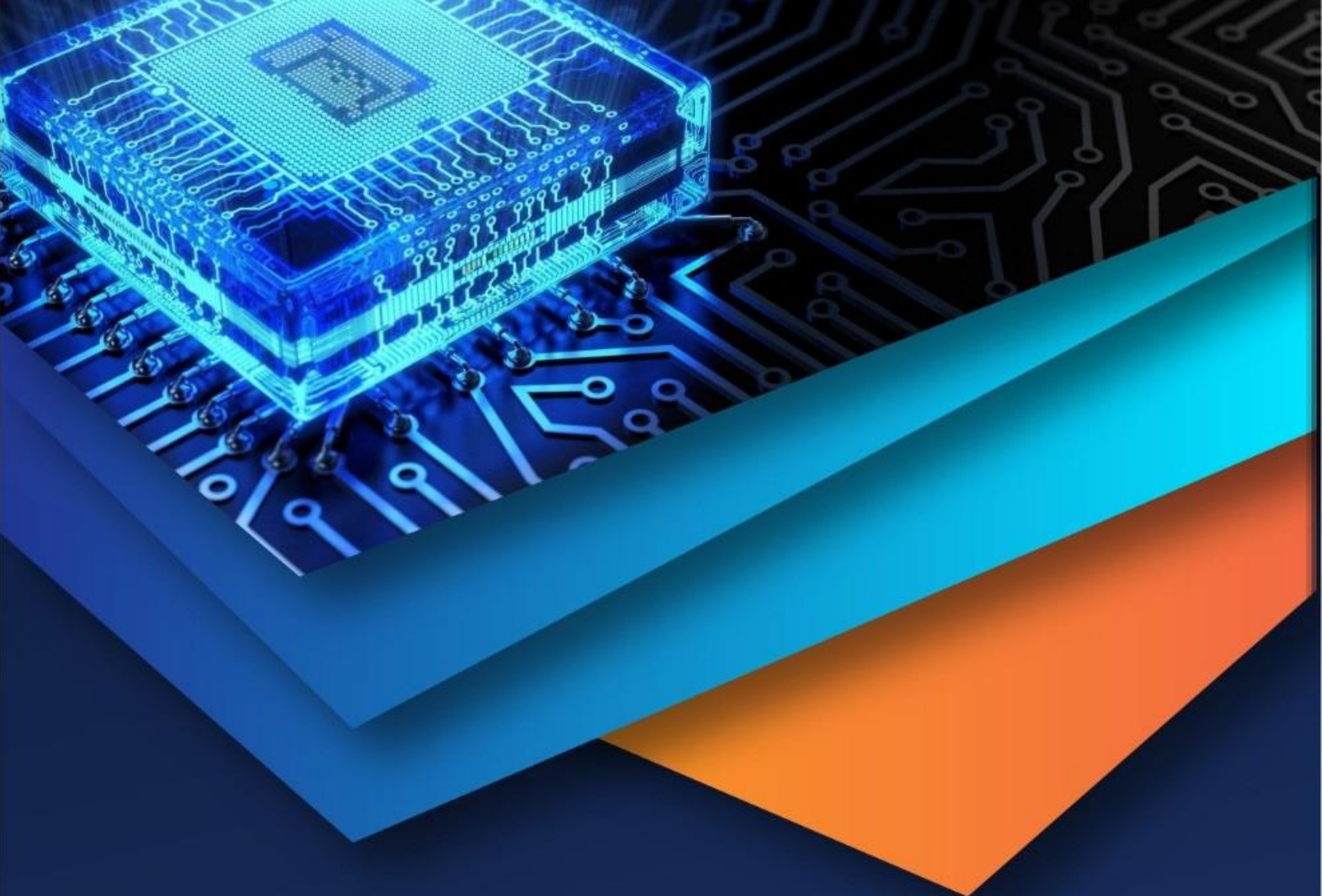

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