Performance Enhancement of Microstrip Planar Array Antenna With Triangular Shaped Defected Ground Structure

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Abstract - ***The goal of this paper is to use defected ground structure(DGS) in microstrip antennas at microwave frequencies. The DGS structures are introduced to improve the performance of planar array antenna in terms of return loss, gain, directivity and antenna efficiency. The array of two by two (2) planar array antenna with inset feed technique based on quarter wave impedance matching is designed and simulated using IE3D software. The proposed design consists of a triangular shaped DGS. The simulated results shows that the proposed array antenna has gain of 6.43dBi, directivity of 6.55dBi, antenna efficiency of 97.28 and return loss of -17.86dB at 2.5 GHz.***

Key Words: *Microstrip patch, Defected ground structures, Inset Feed, Mobile communication.*

1. INTRODUCTION

In today's world of wireless communication systems patch antennas play a very important role. There is always a very large demand for high performance, small size and low cost wireless communication systems. In order to meet these requirements, planar patch antenna is preferred because of their various advantages such as light weight, low volume, low cost and ease for fabrication [1]. Although the microstrip patch antenna has various advantages it also has various disadvantages which are low gain, narrow bandwidth, low efficiency, spurious radiation from feeds and surface excitation of waves, these disadvantages can be overcome by constructing patch antennas in array configuration, by using thick substrates and by using defected ground structures. Recently there has been increasing demand in the use of DGSs for performance enhancement of microstrip patch antennas and planar array antennas [5]. There are basically two types of structures which are used for the design of compact and high performance wireless communication systems named as defected ground structures (DGS) and electromagnetic band-gap structures (EBG) which is also known as photonic band-gap structures (PBG).DGS have more advantages compared to PNG such as 1) For EBG large area is needed to implement periodic patterns whereas DGS do not require large area for implementation of regular patterns. 2) DGS can be implemented easily and can be extended easily for large scale manufacturing without any difficulty in practical applications. DGSs are realized by simply etching off simple shape (called as defect) from the ground plane. Depending upon the shape and the dimensions of the defect, the current distribution in the ground plane is disturbed and resulting in a controlled excitation and propagation of electromagnetic waves through the substrate. The shape of the defect may be changed from a simple shape to complex one for better performance.

In this paper the design of single antenna, 2x2 array antenna and 2x2 array antenna with DGS structures with inset feeding method [3] is presented. The proposed array antenna is designed on FR4 laminate having dielectric constant of 3.48 and thickness of 0.762 mm respectively.

2. ANTENNA DESIGN

For obtaining high performance planar array antenna, the exact dimension of each patch element is very important. There is always a tradeoff between any two parameters in design and hence always a patch antenna is designed as per the requirement. The proposed antenna is designed by using transmission line model which is the most accurate method. Here design of single patch and 2 patch is shown below. Here the software used for simulating the patch antenna is IE3D. IE3D is an integral full-wave electromagnetic simulation and optimization packages for analysis and design of 3D and planner microwave circuits MMIC, RFIC, RFID, antennas ,digital circuits and high speed printed circuit broads(PCB).since its formal introduce in 1993 IEEE international Microwave Symposium(IEEE IMS 1993) ,IE3D has been adopted as industrial standard in planner and 3D electromagnetic simulation.

Table -1: Design Specification of Patch Antenna

Parameters	Dimensions
Substrate Type	FR-4
Dielectric constant	3.48
Centre Frequency	2.5 GHz
Patch Thickness	0.035 mm
Substrate Height	0.762 mm

2.1 Single Patch Antenna Design

The structure of the single element antenna is shown in Figure 1. The element is composed of patch, ground plane, substrate and the feeding line. The performance of planar patch antenna depends on their dimension that also influences the operating frequency, radiation efficiency, directivity, return loss and other parameters .The essential parameters for the design of a patch antenna are as follows:

1) Calculation of Patch Width (W)

$$W = \frac{c}{2f\sqrt{\frac{(\in r+1)}{2}}}$$

2) Calculation of Effective dielectric constant (ε_{reff}) :

$$\in reff = \frac{\in r+1}{2} + \frac{\in r-1}{2}[1+12\frac{h}{W}]^{\frac{1}{2}}$$

3) Calculation of extension Length (ΔL):

$$\Delta L = 0.412\frac{\left(\frac{W}{h}+0.264\right)(\in reff+0.3)}{(\in reff-0.3)(\frac{W}{h}+0.8)}$$

4) Calculation of Effective Length (L_{eff}) :

$$Leff = \frac{c}{2f\sqrt{\in reff}}$$

5) Calculation of Ground dimensions

i. Lg = 6h + L

ii. Wg = 6h + W.

Here on substituting values in above equation we get the value of W = 40mm, L=31.5 mm and the inset feed length of 27.85mm .The above values are used in designing and are used in the below Fig-1.

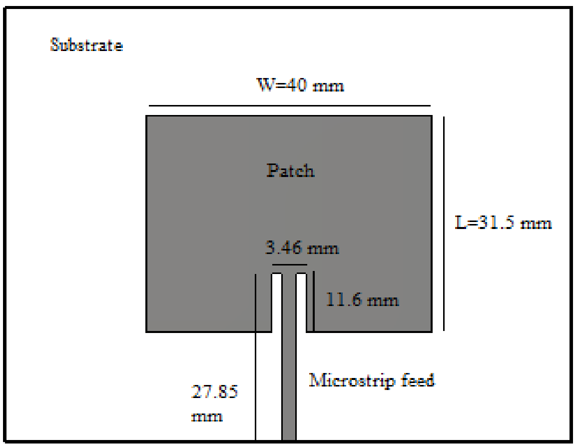

Fig -1: Top view of proposed single patch antenna

2.2 2×2 Planar Array Antenna Design

The planar array antenna is designed using 4 rectangular patches arranged in 2x2 formation, thus the corporate feeding network is chosen to feed all patches. The array antenna consists of a branching network of two-way power dividers. Quarter-wavelength transformers (70 Ω) are used to match the 100 Ω lines to the 50 Ω lines. After some parametrical study, separation between patches is set to be 0.6 of wavelength to avoid grating lobes. Figure 2 shows the design of 2x2 planar array antenna with the corporate feeding network. The dimension of each planar patch antenna is calculated using equation of width and length of patch which is similar to the single patch antenna. The length of substrate is 124mm and width of substrate is 152mm respectively.

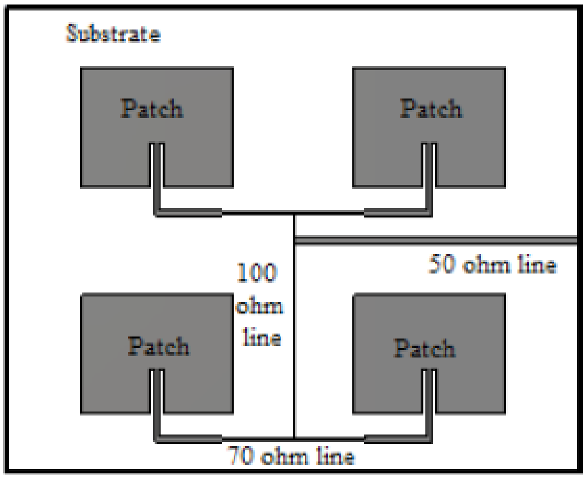

Fig -2: Proposed 2×2 Planar Array Antenna

2.3 2×2 Planar Array Antenna Design With DGS

Fig-3 shows the 2x2 planar array antenna design with DGS structure on the ground plane. The main goal of using DGSs in the ground plane is to reduce the antenna size and to enhance the performance in terms of gain, directivity, return loss, radiation pattern and voltage standing wave ratio. DGSs are realized by simply etching off simple shape (called as defect) from the ground plane. Depending upon the shape and the dimensions of the defect, the current distribution in the ground plane is disturbed and resulting in a controlled excitation and propagation of EM waves through the substrate. The shape of the defect may be changed from a simple shape to the complex one for the better performance.

Here triangular shaped DGS is used in the ground plane and the results are obtained. Fig-4 shows the schematic diagram of the triangular shaped DGS. Here the shape of DGS does not follow any specific rule in the geometry design. Various geometries have been tried and the results of it are obtained and the best results are used as final values.

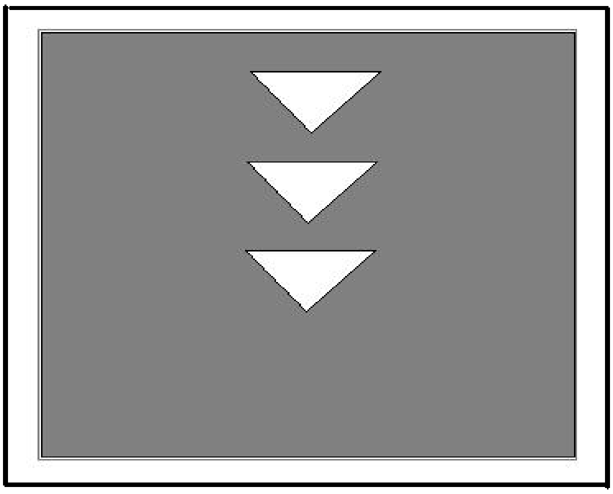

Fig -3: Triangular shaped DGS in ground plane

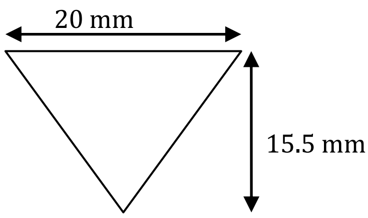

Fig -4: Triangular shaped DGS schematic diagram

3. RESULTS AND DISCUSSION

Here comparison of single patch with I-shaped dgs and 2×2 array with triangular DGS are shown in the below figure. Also the results are compared with only single patch without Defected ground structures. Here parameters under consideration are return loss, antenna efficiency, gain and directivity. Here Fig-5 and 6 shows the return loss of single patch with I-shaped DGS and 2×2 array with triangular DGS which has values -12.74dB and -17.86dB respectively.

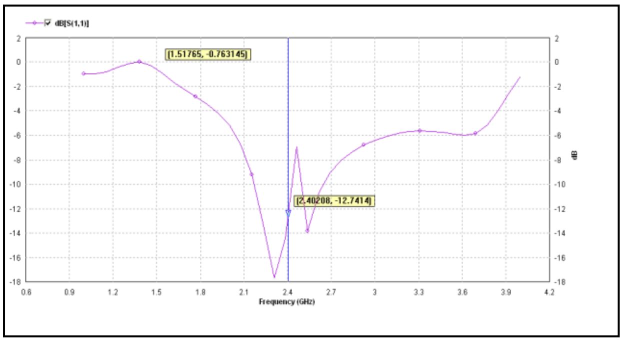

Fig-5 Return loss of single patch with I-shaped DGS

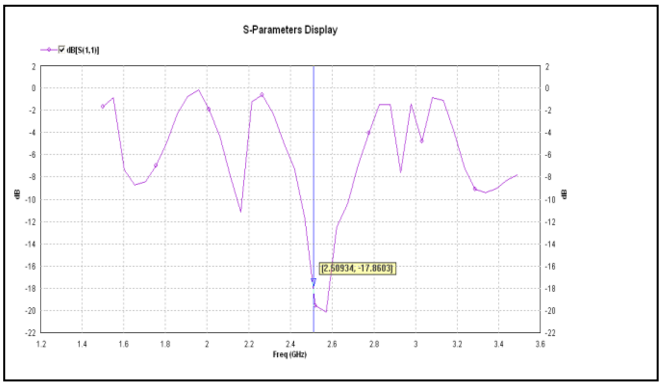

Fig-6 Return loss of 2×2 array with triangular DGS

Here Fig-7 and 8 shows the gain of single patch with I-shaped DGS and 2×2 array with triangular DGS which has values 5.01dB and 6.43 dB respectively.

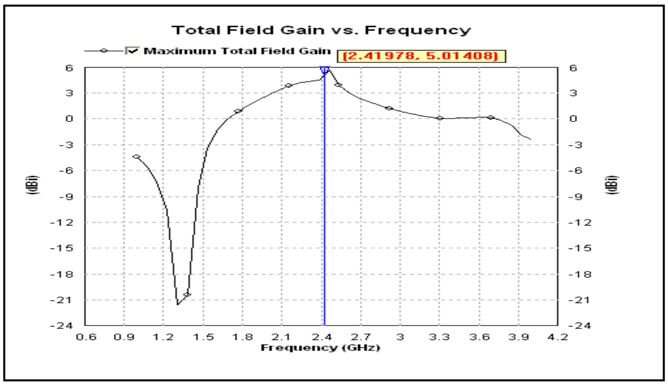

Fig-7 Gain of single patch with I-shaped DGS

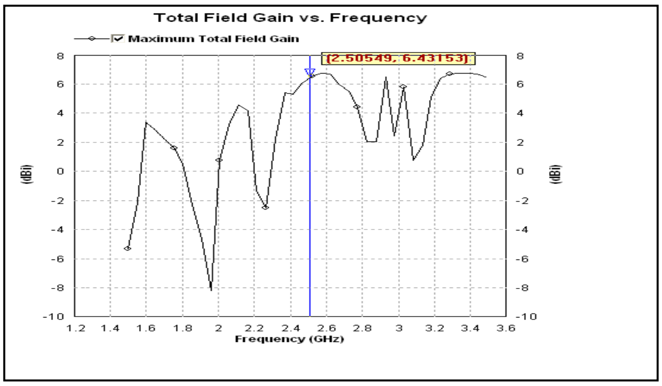

Fig-8 Gain of 2×2 array with triangular DGS

Here Fig-9 and Fig-10 shows the directivity of single patch with I-shaped DGS and 2×2 array with triangular DGS which has values 5.37dB and 6.55dB respectively. Both gain and directivity are related to each other and are in turn related which gives antenna efficiency. If gain and directivity both have equal values then antenna efficiency turns out to be 100%. Hence values of directivity and gain should be as near as possible.

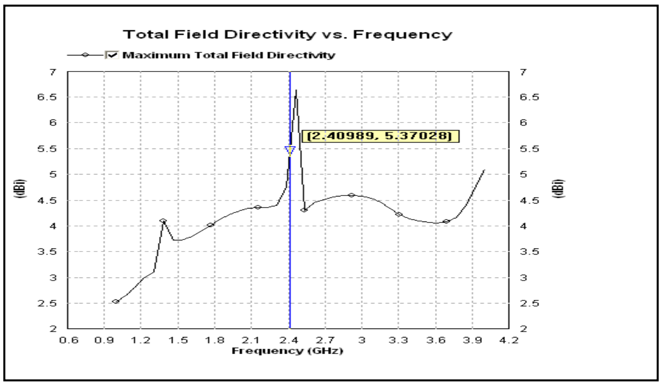

Fig -9 Directivity of single patch with I-shaped DGS

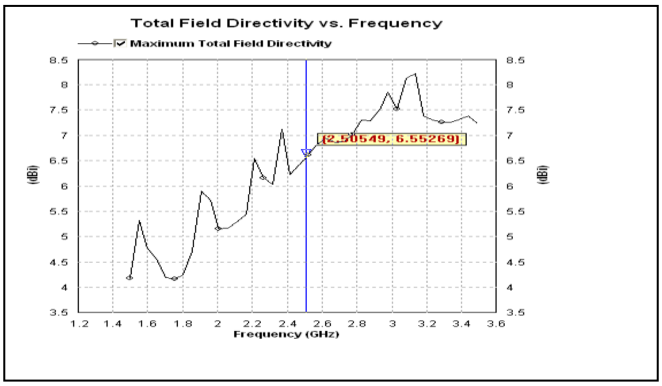

Fig-10 Directivity of 2×2 array with triangular DGS

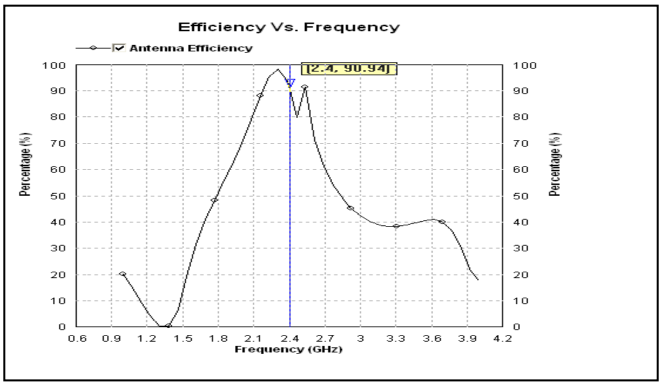

Fig -11 Efficiency of single patch with I-shaped DGS

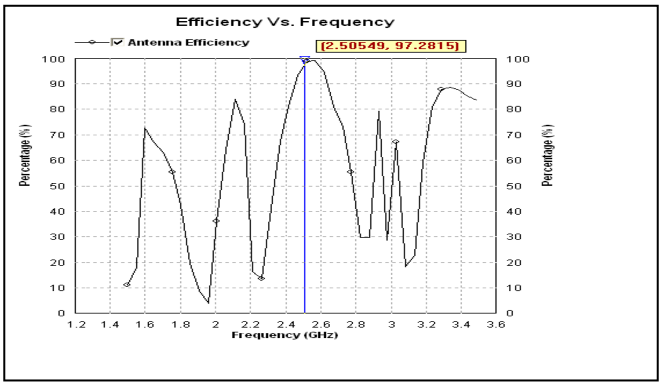

Fig-12 Efficiency of 2×2 array with triangular DGS

Here Fig-11 and Fig-12 shows the efficiency of single patch with I-shaped DGS and 2×2 array with triangular DGS which has values 90.94% and 97.28% respectively.

Table -2: Summary of outcomes

Parameters	Single patch without DGS	Single patch with I-shaped DGS	2×2 array with triangular DGS
S_{11}(dB)	-17.2	-12.74	-17.86
Gain(dBi)	4.1	5.01	6.43
Directivity(dBi)	4.27	5.37	6.55
Antenna Efficiency	97.23	90.94	97.28

4. CONCLUSIONS

A 2x2 planar array antenna with and without DGS structures has been designed, simulated and compared with the single patch antenna. It has been shown that the proposed 2x2 planar array antenna with triangular DGS structures has outperformed the single patch antenna and also single patch antenna with I-shaped DGS structures in terms of directivity, gain, return loss and efficiency. The simulation results have shown that the 2x2 planar array antenna with triangular DGS has gain of 6.43dB, directivity of 6.55dBi and the return loss of -17.86dB and efficiency of 97.28 % at center frequency of 2.5 GHz.

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BIOGRAPHIES

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