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Mutual Coupling Reduction in Microstrip Patch Antenna Array by simple I-Shaped DGS using Full Wave Electromagnetic Simulator

Lavesh Gupta[1], Mr. Mayank Joshi[2], Mr. Abhishek Tiwari[3]

[1]*M.Tech Scholar, Digital Communication, Marudhar Engineering College, Bikaner, Rajasthan, India, laveshgupta5@gmail.com, 9784622955*

[2]*Assistant Professor, Department of ECE, Marudhar Engineering College, Bikaner, Rajasthan, India, mayankjoshi2007@gmail.com, 7597512211*

[3]*Assistant Professor, Department of ECE, Marudhar Engineering College, Bikaner, Rajasthan, India, er.tiwari03@gmail.com, 7737742021*

Abstract— When a number of antennas are placed in an array formation, the mutual coupling between the array elements becomes a critical issue. The Microstrip Patch Antennas are useful in sending the onboard parameters to the ground, under different operating conditions. The main aim is to maintain the mutual coupling suppressing structure to the simplest form, while providing a great amount of reduction in the mutual coupling of patch antennas. The idea is to use a Defected Ground Structure (DGS), placed at the bottom of the substrate. It greatly reduces the mutual coupling between the antenna elements, thereby enhancing the antenna performance. The introduction of DGS does not affect other characteristics of the antenna array. The DGS and the normal patch antenna is simulated using CST (Computer Simulation Technology) antenna simulation software. Once an antenna design is finalized, their operational characteristics remains unchanged during the use.

Keywords*- Antenna Array, Mutual Coupling Reduction, Defected Ground Structure (DGS), Microstrip Patch Antenna*.

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I. INTRODUCTION

Patch antenna has been one of the most popular topics in the antenna field in the past two decades. It is used in aircrafts of high performances, spacecrafts, satellite and various missile applications, where the weight, size, cost, performance, ease of installation, and aerodynamic profile are constraints and the low cost antenna may be required.

At microwave frequency, microstrip is often used as transmission line because of its very good performance in transferring energy and microwave signals. The most important advantage of microstrip line is that it does not generate as much parasitic capacitances and inductance as lumped elements. Furthermore, as compared with another kind of transmission line, the stripline and microstrip are much easier and cheaper to fabricate and easy to connect to surface mounted components.

The most commonly used microstrip patch antenna has similar structure as microstrip line. On one side of the thin dielectric substrate layer, is an extremely thin layer of the conductor, which forms the radiating elements, and on the downwards side is the ground plane, which is also made of metallic material. The general shapes of the conductor are square, rectangle, triangles and circles for easy analysis and fabrication considerations. The operating frequency of microstrip antennas usually ranges from 1 GHz to 50 GHz. A single patch antenna provides a high directive gain. It is comparatively easier to put an array of patches on a single (large) substrate using lithographic techniques.

From a system stand point, antennas have historically been viewed as static and passive devices with time constant characteristics. Once an antenna design has been finalized, the operational characteristic of antenna array design remains unchanged during the use. The recent boom in wireless communication industry, especially in the field of cellular telephony and wireless data communication, has lead to the demand for multiband antennas. Reconfigurable multiband patch antennas are attractive for many military and other commercial applications where it is desirable to have single antenna that can be dynamically reconfigured to transmit and /or receive the multiple frequency bands. This common aperture antenna having the multiple frequency bands received considerable attention in the recent years for their great properties of adapting with change in the environmental and system requirements [1].

In this research paper, analysis of coupling between two microstrip patch antennas and the reduction of mutual coupling between microstrip patch antennas will be investigated using full wave electromagnetic simulator. To make the proposed antenna, two microstrip patches are incorporated in the same substrate. The antenna design is simulated using CST antenna simulation software. Different types of antenna parameters like return loss, radiation pattern, s_{11}, s_{21} and voltage standing wave ratio, etc are also simulated.

II. HYPOTHESIS FORMATION

In this proposed work , with the help of Hypothesis, we find out the solution to avoid confliction. We have to define certain queries related to the research work , to define our concept of research. Through this Hypothesis, we define the decision around which, the complete research has taken place. The various questions which arises from the research work are as follows [2]:

- What must be the size of the substrate, used to design two microstrip patch antennas.
- What must be the position of the patch antennas on the substrate.
- At which place, the defected ground structure be incorporated over the substrate.
- What is the probability of occurrence of any confliction.
- How the distance between the two patch antennas can be calculated.
- How the problem of impedance matching can be resolved.
- How can the confliction be resolved and which implementation method is used to find the solution of the defined problem.

Research Design

A complete solution of the research work has been obtained through the help of this research paper. The flowchart of my research follows [2]:

Selection of the Topic

↓

Collection of Information about Patch Antennas

↓

Topic Feasibility

↓

Prior Performed Researches

↓

Availability of Resources during the work

↓

Choosing an implementation method

↓

Implementation

Fig.1 Flow Chart of Proposed Work

III. MATERIALS & METHOD

In order to realize a compact structure at 2.4 GHZ, the dual polarized microstrip patch antennas are printed on an FR 4 substrate with a thickness of 1.60 mm and a dielectric permittivity of 4.4. The antenna has to be compact with maximum authorized surface area of 150*150 sq. mm.

Between the two microstrip patch antennas printed on a high permittivity substrate, the mutual coupling is high. So to improve the isolation between patch antennas, we incorporate the ground plane by the defected ground structure (DGS) [3]. The mutual coupling is suppressed at 2.4 GHZ. The patch is fed by a 50 ohms SMA connector by the use of impedance lines. Design optimization is done to achieve desired characteristics using CST antenna simulation software [4].

Fabrication Process:

The steps of this process includes [5]:

Import designed antenna using CST software

↓

Now take a copper sheet, clean it

↓

Cut copper sheet of required size and dip it into photo resist solution

↓

Place it in the oven for drying

↓

Use laser printer to take a print out of the desired antenna on transparent sheet

↓

Put the printed design on photosensitive side of copper sheet and expose it to the U.V. Expose Unit

↓

Dip copper sheet in the photo resist developer

↓

Put it in the etching unit containing Ferric Chloride solution and stir it, till the unwanted copper is etched up

↓

Now take it out from the etching solution & clean it

Fig.2 Flow Chart of Fabrication Process

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IV. MICROSTRIP PATCH ANTENNA

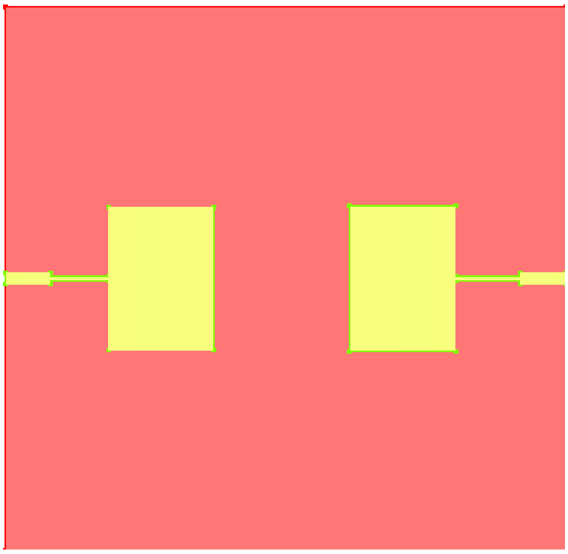

Fig.3 Patch Antenna Array [6]

A square dielectric substrate of 150*150 sq. mm. with permittivity (dielectric constant) of 4.4 and thickness of 1.60 mm. is taken. The patch dimensions are 28mm. * 40 mm. and the distance between both the antenna patches is fixed at 34 mm. from each other. The length of feed line is assumed as 10 mm. and its width is 3.05 mm. The impedance matching transformer, having an impedance of 70 ohms, is having a length of 17.52 mm. and a width of 1.66 mm. This transformer is used to match the impedances between the feed line and patch antenna.

The input feed line is connected to a 50 ohms connector. Both the feed lines are fed individually. The patch antenna element array has a ground plane, a dielectric substrate and two square antenna patches. In the simulation of the dual polarized microstrip patch antenna elements, the meshing of 20% has been performed. The analysis of coupling between two microstrip patch antennas and the reduction of mutual coupling between microstrip patch antennas will be investigated using full wave electromagnetic simulator [7]. To make the patch antenna, two microstrip patches are incorporated in the dielectric substrate. The antenna design is simulated using CST (Computer Simulation Technology) antenna simulation software. Different types of antenna parameters like return loss, radiation pattern, s_{11}, s_{21} and radiation efficiency, etc are simulated. FR-4 is the substrate, used to make the proposed antenna [8].

The antenna is simulated using CST antenna simulation software and its layout is as shown in the Fig.3. The Resonance Frequency of the antenna array is 2.4 GHZ with a return loss of both the patch antennas to be around -16 dB each. The negative value of return loss proves that this antenna is not having many losses, while transmitting the signals through the system.

V. MUTUAL COULPING REDUCTION USING DGS:

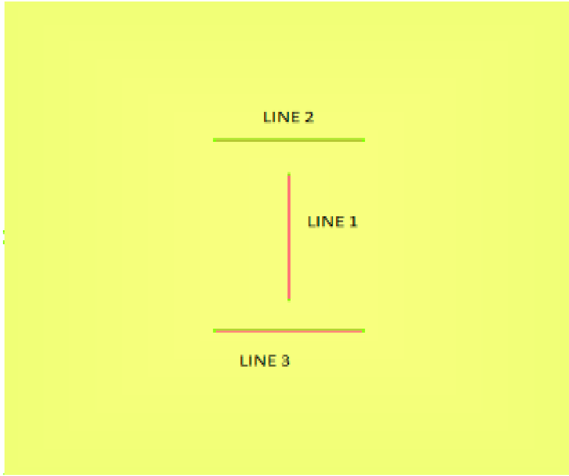

Fig.4 Defected Ground Plane

When two microstrip patch antennas are placed in front of each other, the performance degradation is shown by both the antennas. To avoid this performance degradation, a Defected Ground Structure can be placed at ground plane of substrate. This size is suitable to obtain gain between 6-9 dB [9].

In the present paper, the mutual coupling between the patch antennas is reduced by using the defected ground structure (DGS), in which the copper is etched or removed out from the back plane of the dielectric substrate, using the process of etching. In this DGS structure, three line patches are formed in the ground plane of substrate namely LINE 1, LINE 2 and LINE 3. The LINE 1 has a dimension of 1mm. * 40mm. On the other side, LINE 2 and LINE 3 are having equal dimensions of 40mm. * 1mm. When the DGS is applied, the mutual coupling has been reduced greatly. The two microstrip patch antenna elements have been simulated, realized and then measured [10].

VI. SIMULATION RESULTS & DISCUSSION

A). Return Loss:

The Return Loss of the simulated microstrip patch antenna and the antenna array are illustrated in the Fig.5, 6 and 7. When the DGS was not used, the return loss of each of the patch antennas was around -16 dB and the mutual coupling was around -21 dB. But, when the Defected Groud Structure (DGS), formed after the etching of copper, is placed at the ground plane on the dielectric substrate, it reduces the mutual coupling by upto -31 dB.

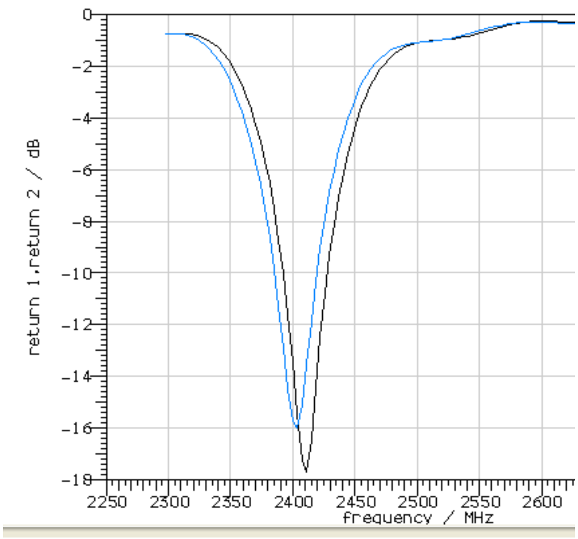

Fig.5 Return Loss- s_{11} *v/s Freq. for two Antennas [11]*

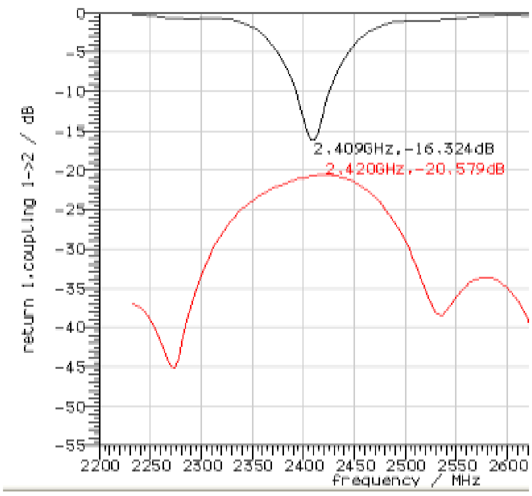

Fig.6 Return Loss- s_{11}, s_{21} *in absence of DGS [12]*

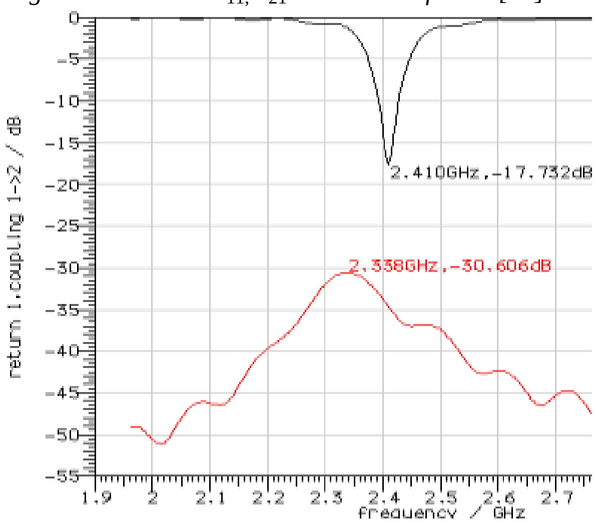

Fig.7 Return Loss- s_{11}, s_{21} *in presence of DGS*

B). Radiation Pattern:

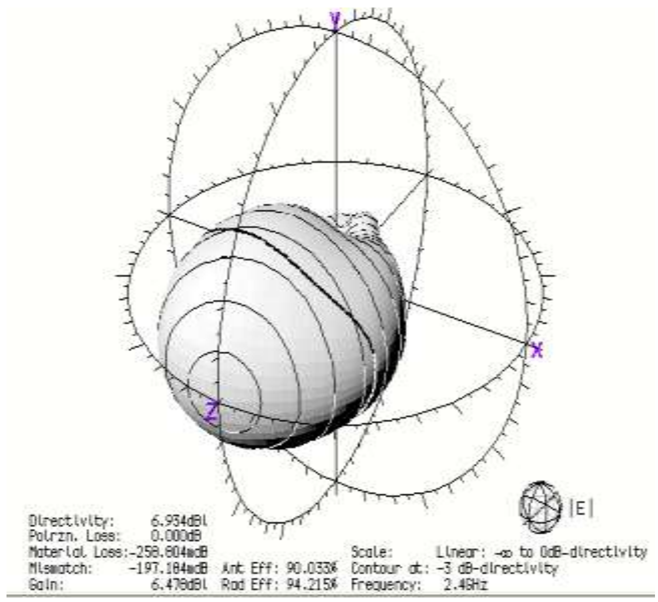

Fig.8 Radiation Pattern of Patch Antenna Array

C). Comparison of Mutual Coupling between two Microstrip Patch Antennas:

In the Fig.6 shown above, when there is no DGS present, the mutual coupling was high and following observations were obtained:

Observed Freq.	**Distance between two antennas**	**Mutual Coupling**
2.42 GHZ	34 mm.	-20.57 dB

Table1. Mutual Coupling in absence of DGS

When DGS is introduced in the Microstrip Patch Antenna Array system, the mutual coupling between patch elements is greatly reduced. The following observations are obtained in the presence of DGS which are shown in Fig.7:

Observed Freq.	**Distance between two antennas**	**Mutual Coupling**
2.34 GHZ	34 mm.	-30.6 dB

Table2. Mutual Coupling in presence of DGS

By comparing the results from both the tables above, it is clear that there is a reduction of about 10dB in the mutual coupling

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of the two patch antennas, when the DGS is present in the antenna array [13].

VII. CONCLUSION

The mutual coupling between the two microstrip patch antenna elements has been studied very carefully. We have observed that the proposed system is providing the solution to reduce the mutual coupling between the two microstrip patch antenna elements.

In this work, we are providing the prevention mechanism to reduce the interference among the patch antennas. A Defected Ground Structure (DGS) has been inserted into the ground plane, under the microstrip patch antenna elements, to reduce the coupling between them. In the radiation pattern of the Patch Antenna Array, the antenna efficiency of greater than 90% and the radiation efficiency of more than 94% has been achieved.

An I- shaped DGS structure is placed at the back of the dielectric substrate, at the ground plane and the mutual coupling has been successfully suppressed. After the placement of the DGS at the ground plane of the substrate, the mutual coupling has been greatly reduced. The proposed antenna array is made using CST Antenna Simulation Software.

VIII. FUTURE WORK

We have presented the work on the CST Antenna Simulation Software, to reduce the mutual coupling between the patch antenna array. The proposed work can be enhanced in many different ways:

- We can implement this approach on some other Simulation Software like HFSS, etc. and can increase the number of patch antenna elements used in antenna array. Also, the patch antennas can be fed up by a single power source, instead of feeding both the patch antennas individually.
- We can change the frequency of the patch elements as well as the shape of the DGS to enhance this work in a different way.
- We can use some other transmission line methods for fulfilling the concept of impedance matching between the feed line and the patch antenna elements.

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