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Deduction in Mutual Coupling Across Two Microstrip Patch Antenna Elements using a Compact DGS Structure through CST Antenna Simulator

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Abstract

If two or more antennas are present in an antenna array, the mutual coupling between them becomes a major issue to deal with. At microwave frequency, microstrip is often used as transmission line because of its very good performance in transferring energy and microwave signals. 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. Our motive is to maintain the mutual coupling suppressing structure to the simplest form. We thus use a Defected Ground Structure (DGS), which greatly reduces the mutual coupling between the antenna elements, thereby enhancing the performance of antenna array. The introduction of DGS in the system is not affecting the characteristics of antenna array. The Simulation is done using CST (Computer Simulation Technology) antenna simulation software. 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.

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

I. INTRODUCTION

When a number of antennas are placed in an array formation, the mutual coupling between the array elements has to be taken into account. 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 array is simulated using CST (Computer Simulation Technology) antenna simulation software. Once an antenna design has been finalized, the operational characteristics of the antenna system remains unchanged during the use.

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

The most commonly used microstrip patch antenna has similar structure as that of a microstrip line. The general shapes of the conductor are taken as square, rectangle, triangles and circles for the 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.

In this research paper, the analysis of coupling between the two microstrip patch antennas and the reduction of mutual coupling between the microstrip patch antennas will be investigated using CST (Computer Simulation Technology) Antenna Simulation Software [1].

To make the proposed antenna, two microstrip patches are incorporated in the same substrate. The antenna design is simulated using CST antenna simulation software. The different types of antenna parameters like return loss, radiation pattern, radiation efficiency, antenna efficiency, s_{11} and s_{21}, etc are also simulated through the help of CST Antenna Simulation Software.

II. DESIGNING OF 2.4 GHZ PATCH ANTENNA

For designing, we start with conventional patch antenna and calculate its length and width at a resonant frequency of 2.4 GHZ. Hence, the designed values are obtained as follows:

- Width of both input feed lines = 3.05 mm.
- Length of both input feed lines = 12 mm.
- Width of both the impedance matching quarter wave transformers (Tx-1 and Tx-2) = 1 mm.

- Length of both the impedance matching quarter wave transformers = 17.52 mm.
- Width of both microstrip patch antennas = 40 mm.
- Length of both microstrip patch antennas = 28.2 mm.

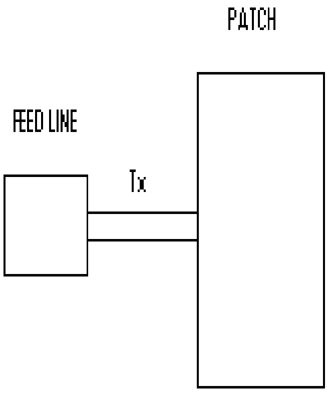

Fig.1 Compact Structure of a Patch Antenna [2]

The length and width of feed lines, patch antennas and quarter wave transformers are given above. Now, to design the proposed antenna, we also need to know the coordinates of feed lines, patch antennas and quarter wave transformers. The respective coordinates of the feed lines, patches and impedance matching quarter wave transformers are given in the following table:

Coordinates of Array Elements.	Feed Line-1	Tx-1	Patch-1	Feed Line-2	Tx-2	Patch-2
(X) - coordinate	0	10	27.52	138	120.48	92.28
(Y) - coordinate	73.47	74.5	55.1	73.47	74.5	55

Table1. Coordinates of Microstrip Patch Elements [3]

III. MICROSTRIP PATCH ANTENNA ARRAY

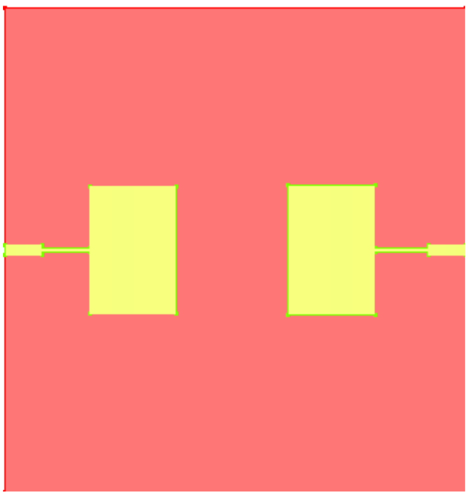

Fig.2 Microstrip Patch Antenna Array [4]

The square shaped dielectric substrate of size 150*150 sq. mm. is taken having a permittivity (dielectric constant) of 4.4 and thickness of 1.60 mm. The dimensions of both the patches are 28.2 mm. * 40 mm. and distance between both the patch antennas is 34 mm.

The optimized length of feed line is 12 mm. and its width is 3.05 mm. The impedance matching transformer has an impedance of about 70 ohms. Its length is 17.52 mm. and optimized width is 1.0 mm. The work of this impedance matching quarter wave transformer is to match the impedances between the feed lines and the microstrip patch antenna elements.

The feed line is attached to a 50 ohms connector. Both the feed lines are fed individually. The patch element array has a ground plane, a dielectric substrate and two rectangular antenna patches. In the simulation of microstrip patch antennas, the meshing of 20% has been done. The coupling analysis between two patch antennas and deduction of mutual coupling between microstrip patch antennas will be properly investigated through the help of Full Wave Electromagnetic Simulator [5].

To make the patch antenna, two microstrip patches are incorporated in the dielectric substrate. The antenna design is simulated using Computer Simulation Technology (CST) antenna simulation software. The various antenna parameters are simulated like return loss, radiation pattern, antenna efficiency, s_{11}, s_{21} and radiation efficiency.

The Resonance Frequency of antenna array is 2.4 GHZ. Both the patch antenna elements have a return loss of around -16dB each. FR-4 is the dielectric substrate, used in the manufacturing of the proposed microstrip patch antenna array structure. The negative value of return loss clearly indicates that this antenna does not have many losses, while transmission of signals through the array system [6].

IV. DEDUCTION IN MUTUAL COULPING BY DGS

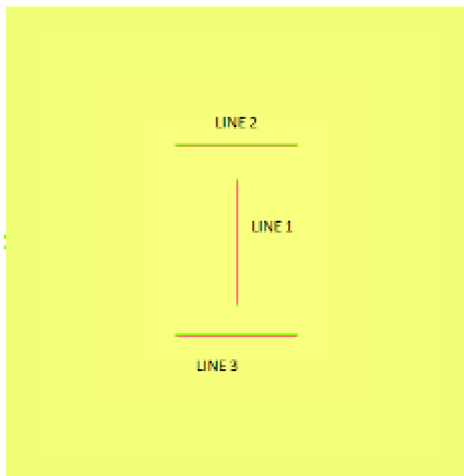

Fig.3 Defected Ground Plane

If 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 array size is suitable to obtain gain between 6-9 dB [7].

After using the defected ground structure technique, the high radiation efficiency of about 94% has been obtained. Also, the high antenna efficiency of about 90% is obtained. 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 patch has a dimension of 1mm. * 40mm. On the other side, LINE 2 and LINE 3 patches 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 [8].

DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line (e.g., microstrip, coplanar and conductor backed coplanar wave guide) which disturbs the shield current distribution in the ground plane cause of the defect in the ground.

The disturbance will change characteristics of a transmission line such as line capacitance and inductance. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance. DGS adds an extra degree of freedom in microwave circuit design and opens the door to a wide range of application.

In the following years, a great lot of novel DGSs were proposed and they had become one of the most interesting areas of research owing to their extensive applicability in the microwave circuits. The parameters of equivalent circuits models of DGSs were also researched and utilized to design planar circuit easily. Until recently, microstrip filter designs were being done with full metallic ground plane present on one side of the substrate.

Many passive and active microwave and millimeter devices have been developed, to suppress the harmonic factors and realize the compact physical dimensions of circuits, for the design flow of circuits with comparatively simple DGS.

V. METHODOLOGY & MATERIALS

In order to realize a compact structure at 2.4 GHZ, the dual polarized microstrip patch antennas are printed on an FR 4 substrate, having a thickness of 1.60 mm and a dielectric permittivity of 4.4.

The microstrip patch antenna array has to be compact with maximum authorized surface area of 150*150 sq. mm. The effective dielectric constant of the FR-4 substrate comes out to be 4.085 on calculation. Between the two microstrip patch antennas printed on a high permittivity substrate, the mutual coupling is high. So, to improve the isolation between the patch antennas, we incorporate the ground plane by the defected ground structure (DGS).

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. The process of fabrication of the antenna array system includes the following steps:

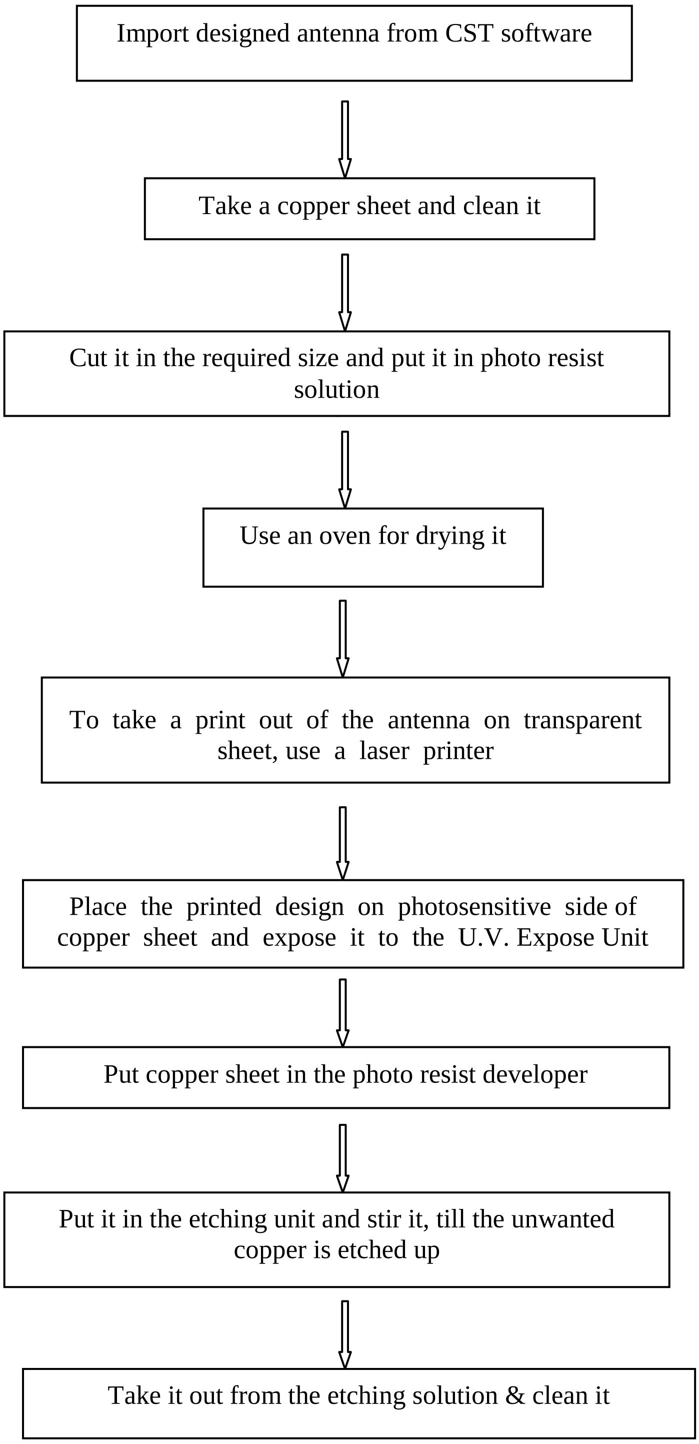

Fig.4 Flow Chart of Fabrication Process [9]

VI. RESULTS OF SIMULATION

6.1. Return Loss

The Return Loss of the simulated microstrip patch antenna and the antenna array has been 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 between the two patch antenna elements was around -21 dB. But, when the Defected Groud Structure (DGS), formed after the etching of copper from the ground plane substrate, is placed at the ground plane on the dielectric substrate, it reduces the mutual coupling to upto -31 dB across these patch antennas.

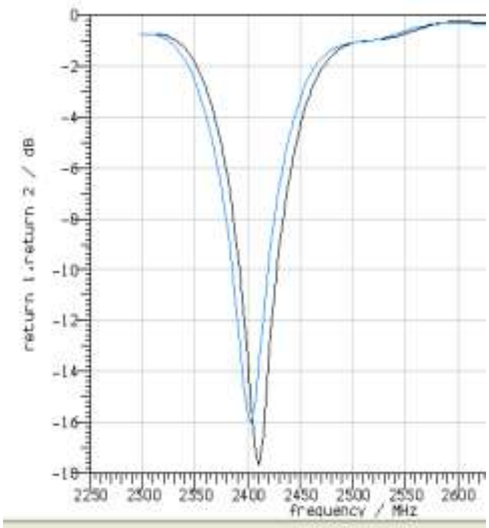

Fig.5Return Loss- s_{11} *v/s Freq. for Patch Antennas [10]*

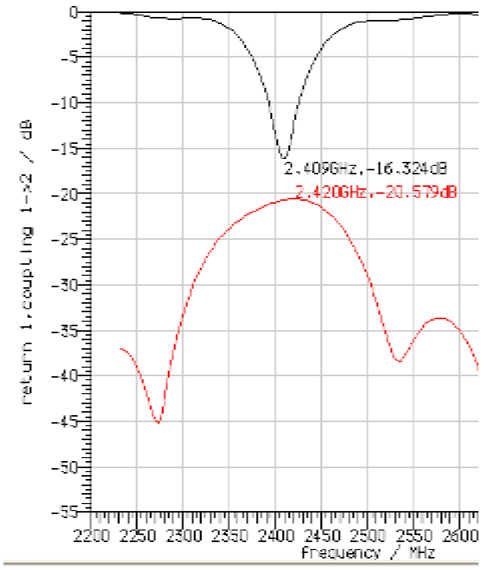

Fig.6 Return Loss- s_{11}, s_{21} *v/s Freq. in absence of DGS [11]*

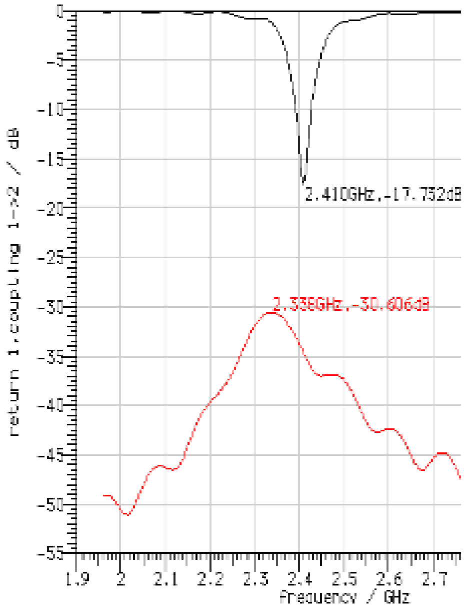

Fig.7 Return Loss- s_{11}, s_{21} *v/s Freq. in presence of DGS*

6.2. Radiation Pattern

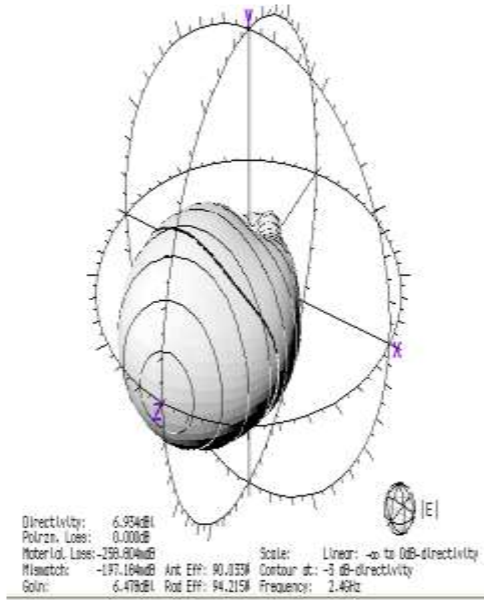

Fig.8 Radiation Pattern of Patch Antenna Array System

6.3. Percentage Efficiency of Patch Antenna Array

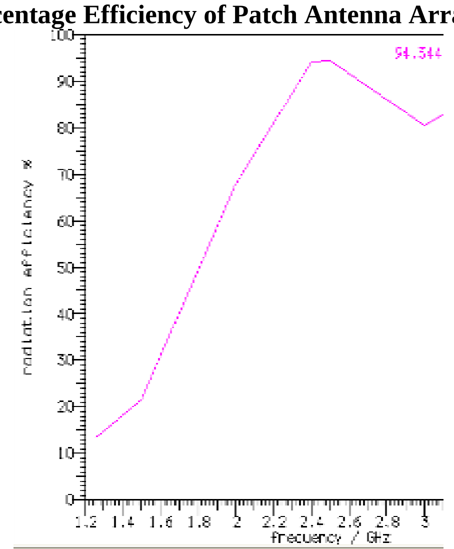

Fig.9 Radiation Efficiency (in %) v/s Freq. of Array System

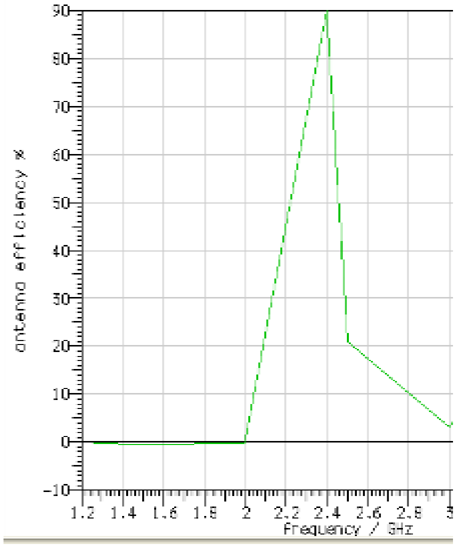

Fig.10 Antenna Efficiency (in %) v/s Freq. of Array [11]

6.4. Mutual Coupling Comparison among two Antennas

When there was no DGS present, the mutual coupling between the patch antenna elements was high and various observations were obtained through the antenna simulation software. These observations are given in the following table:

Distance between two antennas (in mm.)	**Observed Freq. (in GHZ.)**	**Mutual Coupling (in dB)**
6	2.40	-14.57
16	2.41	-16.85
20	2.41	-17.45
24	2.42	-18.16
28	2.42	-18.98
32	2.42	-19.79
34	2.42	-20.57

Table2. Mutual Coupling, when DGS is absent

Now, when DGS is introduced in the Array system, the mutual coupling between patch elements is greatly reduced. The following observations are obtained in the presence of Defected Ground Structure (DGS) in the antenna array system:

Distance between two antennas (in mm.)	**Observed Freq. (in GHZ.)**	**Mutual Coupling (in dB)**
6	2.40	-22.13
16	2.35	-27.50
20	2.35	-27.87
24	2.34	-28.83
28	2.34	-28.87
32	2.34	-29.60
34	2.34	-30.60

Table3. Mutual Coupling, when DGS is present

On comparison of results from both the tables above, it is clear that there is a reduction of about 10dB in the mutual coupling of two patch antennas, having a distance of 34 mm., when the Defected Ground Structure is present in the antenna array system [12].

VII. CONCLUSION

Mutual coupling between the two microstrip patch antenna elements has been studied very carefully in this research work. 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 two 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 by using the CST Antenna Full Wave Electromagnetic Simulator.

VIII. FUTURE WORK

The presented work has been performed 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. These ways are discussed in the following points:

- 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, instead of quarter wave transformer, for fulfilling the concept of impedance matching between the input feed line and the microstrip patch array elements.

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