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## Design and Simulation of Dual Band Microstrip Patch Antenna with Defected Ground Structure

Solomon Azariah R<sup>1</sup>, R.Inbamani<sup>2</sup>, Sasidharan Ravikumar<sup>3</sup>

U.G. Scholar, Dept. of ECE, St. Joseph's Institute of Technology, Chennai, India<sup>1</sup>

U.G. Scholar, Dept. of ECE, St. Mother Theresa Engineering College, Thoothukudi, India<sup>2</sup>

U.G. Scholar, Dept. of ECE, St. Joseph's Institute of Technology, Chennai, India<sup>3</sup>

**ABSTRACT:** this paper focuses in the design of a dual-band microstrip patch antenna (MSA) for dual frequency operation using Defected Ground Structure (DGS). The DGS is the etching done in the ground plane in order to tune the antenna in two different frequencies. The proposed antenna has a rectangular patch of dimensions 12.75mm x 10.75mm with rectangular-shaped strips cut in ground and is fed by a micro strip line, for achieving additional resonances, reduced return losses, obtaining VSWR (Voltage Standing Wave Ratio) value near 1 and reduced antenna size. The designed antenna is also of reduced cost. Therefore proposed dual band antenna can be effectively used for C-band and X-band wireless applications.

**KEYWORDS:** DGS; MSA; VSWR; return loss.

### I. INTRODUCTION

Antennas are our electronic eyes and ears on the world. They are our links with space. They are an integral part of our civilization. Antennas have been around for a long time, millions of years, as the organ of touch. But in the last 100 years they have acquired a new significance as the connecting link between a radio system and the outside world. A MSA is also known as a printed antenna usually means an antenna fabricated using microstrip techniques on a printed circuit board (PCB). They are mostly used at microwave frequencies. An individual MSA consists of a patch of metal of various shapes on the surface of a PCB, with a metal ground plane on the other side of the board. Most MSAs consist of multiple patches in a two-dimensional array. MSAs have become very popular in recent decades due to their thin planar profile. Their ease of fabrication using printed circuit techniques and the ease of integrating the antenna on the same board with the rest of the circuit, and the possibility of adding active devices such as microwave integrated circuits to the antenna itself to make active antennas. The most common type of MSA is the patch antenna. Antennas using patches as constitutive elements in an array are also possible. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common MSA shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead are made of a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but has a wider bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.

Microstrip antenna consists of a very thin metallic strip placed on a ground plane with a di-electric material in-between. The radiating element and feed lines are placed by the process of photo-etching on the di-electric material. Usually, the

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patch or micro-strip is chosen to be square, circular or rectangular in shape for the ease of analysis and fabrication. Thus the three layers of MSA are the ground, substrate and the patch.

## II. RELATED WORK

There are several microstrip patch antenna's designed in the past. Some of the most related work to the objective of this paper is discussed in this segment. Ahmed Dherar et al. [1] have designed a broadband microstrip diamond-shaped patch antenna. The results are presented by simulating MSA at 3.675 GHz and 10.35 GHz frequencies. The antenna was simulated in the frequency range of 1-15 GHz. S11, the input reflection coefficient parameter has a value of -14.63 dB at the frequency of 3.675 GHz and -11.91 dB at the frequency of 10.35 GHz. The simulated values are then used for hardware implementation and the results are compared. J.Zbitou. et al. [2] studied the concept of DGS to improve the characteristics of the antenna. For this purpose the DGS is used in the MSA for some advantages such as antenna size reduction, mutual coupling reduction in antenna arrays etc... In this paper the DGS (DGS) has been employed to miniaturize a MSA and to shift the resonance frequency from an initial value of 10 GHz to a final value at 3.5 GHz, without any change in the dimensions of the original MSA. This antenna is designed on a FR-4 substrate with dielectric constant 4.4 and thickness 1.6 mm and its size is 27 X 30 mm<sup>2</sup>. The antenna is designed, optimized, and miniaturized by using CST tool. Chow-Yen-Desmond Sim. et al. [3] designed a microstrip-fed circular ring slot antenna (CRSA) with a fundamental mode at 2.45 GHz. To suppress the additional harmonic modes excited by the ring slot, a single inverted U-shaped slot (or DGS) is integrated into the CRSA. Through this, harmonic suppression over a wide bandwidth of approximately between 3 and 9 GHz is achieved. This DGS can also be applied to other microstrip-fed ring slot antennas, such as square and triangular ring slot antennas. Sujoy Biswas. et al. [4] demonstrated the controlling of higher order modes up to third harmonic of the fundamental operating frequency in a microstrip line-fed patch antenna successfully. Harmonic rejection in the antenna has been achieved at its feed level using highly compact design of DGS. Rejection characteristics have been improved adding an open stub to the feed line. Relative suppression of radiated fields with and without DGS-control has been quantitatively measured and effective control of harmonics has been experimentally ensured. The area occupied by the proposed DGS has been compared with earlier designs and over 40 – 90% reduction in size has been documented. Edgar Colín-Beltrán. et al. [5] proposed a novel system composed of a circular aperture slot antenna and a Common-Mode (CM) noise rejection filter. This antenna is differentially fed by microstrip coupled transmission lines. In order to eliminate CM noise, a notch filter based on three non-periodical DGS was implemented. The whole system achieves a fractional impedance bandwidth of about 127%. Radiation patterns in E and H planes for different frequencies were obtained for the system. Finally, measurements in the transversal plane show attenuation up to 13 dB when the system with filter was compared against one without it. Chan Hwang See. [6] designed a novel printed diversity monopole antenna for Wi-Fi/WiMAX applications. The antenna comprises two crescent shaped radiators placed symmetrically with respect to a defected ground plane and a neutralization lines is connected between them to achieve good impedance matching and low mutual coupling. Theoretical and experimental characteristics are illustrated for this antenna, which achieves an impedance bandwidth of 54.5% (over 2.4 – 4.2 GHz), with a reflection coefficient less than -10 dB and mutual coupling less than -17 dB. An acceptable agreement is obtained for the computed and measured gain, radiation patterns, envelope correlation coefficient, and channel capacity loss. These characteristics demonstrate that the proposed antenna is an attractive candidate for the multiple-input multiple-output (MIMO). Chandrakanta Kumar. et al. [7] have carried out the experiments with probe-fed circular patches using conventional and defected ground planes and flashed some interesting features relating to cross-polarized (XP) electric fields and associated radiations. Those led to a series of new investigations for understanding the nature of XP fields and to deal with them using DGS for improved XP performance. In the first phase of investigation, the XP radiations of a probe-fed circular patch with conventional ground plane have been critically studied as a function of the radial probe location. Remarkably significant effect is experimentally demonstrated.

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### III. ANTENNA DESIGN AND SIMULATION RESULTS

Ground plane: In telecommunication, a ground plane is a flat or nearly flat horizontal conducting surface that serves as part of an antenna, to reflect the radio waves from the other antenna elements. The plane does not necessarily have to be connected to ground. Ground plane shape and size play major roles in determining its radiation characteristics including gain. A ground plane is often made as large as possible, covering most of the area of the PCB which is not occupied by circuit traces. In multilayer PCBs, it is often a separate layer covering the entire board. This serves to make circuit layout easier, allowing the designer to ground any component without having to run additional traces; component leads needing grounding are routed directly through a hole in the board to the ground plane on another layer. The large area of copper also conducts the large return currents from many components without significant voltage drops, ensuring that the ground connection of all the components are at the same reference potential. The ground plane used in this paper is of copper material with thickness 0.035 mm. Substrate of MSA: A dielectric material is an electrical insulator that can be polarized by an applied electric field. When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in an electrical conductor but only slightly shift from their average equilibrium positions causing dielectric polarization. In the proposed system a FR4 substrate with relative permittivity 4.4 is used and the height of the substrate is 1.6 mm. FR-4 is a composite material composed of woven fibre-glass cloth with an epoxy resin binder. "FR" stands for flame retardant. FR-4 glass epoxy is a popular and versatile high-pressure thermoset plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid

| RELATIVE PERMITTIVITY OF COMMON SUBSTANCES |                       |
|--|-----------------------|
| SUBSTANCE                                  | RELATIVE PERMITTIVITY |
| Calcium titanate                           | 150                   |
| Ebonite                                    | 2.7 - 2.9             |
| FR4 PCB material                           | 4.8 typically         |
| Glass                                      | 5 - 10                |
| Marble                                     | 8.3                   |
| Mica                                       | 5.6 - 8.0             |
| Paper                                      | 3.85                  |
| Paraffin wax                               | 2 - 2.4               |
| Polyethylene                               | 2.25                  |
| Polyimide                                  | 2.25                  |
| Polypropylene                              | 2.2 - 2.36            |
| Porcelain (ceramic)                        | 4.5 - 6.7             |
| PTFE (Teflon)                              | 2.1                   |
| Rubber                                     | 2.0 - 2.3             |
| Silicon                                    | 11.68                 |
| Silicon dioxide                            | 3.9                   |
| Strontium titanate                         | 200                   |
| Air 0°C                                    | 1.000594              |
| Air 20°C                                   | 1.000528              |
| Carbon monoxide 25°C                       | 1.000634              |
| Carbon dioxide 25°C                        | 1.000904              |
| Hydrogen 0°C                               | 1.000265              |
| Helium 25°C                                | 1.000067              |
| Nitrogen 25°C                              | 1.000538              |
| Sulphur dioxide 22°C                       | 1.00818               |

conditions. These attributes, along with good fabrication characteristics, lend utility to this grade for a wide variety of electrical and mechanical applications.

Patch: The most commonly employed MSA is a rectangular patch placed on the substrate which looks like a truncated microstrip transmission line. It is approximately of one-half wavelength long. When air is used as the dielectric substrate, the length of the rectangular MSA is approximately one-half of a free-space wavelength. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric

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constant of the substrate increases. The patch used is of copper material with thickness 0.035 mm. Feed line: A feed line is used to excite to radiate by direct or indirect contact. There are many different methods of feeding and four most popular methods are microstrip line feed, coaxial probe, aperture coupling and proximity coupling. In this proposed antenna a microstrip line feed of copper material is used.

### DESIGN EQUATIONS OF MSA

1.  $\lambda = \frac{c}{f}$
2.  $W = \frac{c}{2f} * \sqrt{\frac{2}{\epsilon_r + 1}}$
3.  $L = L_{eff} - 2\Delta L$
4.  $L_{eff} = \frac{c}{2f\sqrt{\epsilon_r}}$
5.  $\Delta L = (0.412) * (h) * \left\{ \frac{(\epsilon_{r_{eff}} + 0.3) * (\frac{W}{h} + 0.264)}{(\epsilon_{r_{eff}} - 0.258) * (\frac{W}{h} + 0.8)} \right\}$
6.  $\epsilon_{r_{eff}} = \frac{(\epsilon_r + 1)}{2} + \frac{(\epsilon_r - 1)}{2} * \left\{ 1 + 12 * \left( \frac{h}{W} \right) \right\}^{-\frac{1}{2}}$
7.  $W_g = W + 6h$
8.  $L_g = L + 6h$

Where

- L -length of the patch
- W -width of the patch
- h -height of the substrate
- $\lambda$  -wavelength
- f -resonant frequency
- $\epsilon_r$  -relative permittivity
- $W_g$  -width of the ground
- $L_g$  -length of the ground

$\epsilon_{r_{eff}}$  - Effective relative permittivity

Thus by substituting the corresponding values in the above equations we can calculate the necessary antenna parameters. The obtained values are then modified slightly by trial and error method to get better results. Thus the values obtained from the trial or error method with correspondence from the values of obtained from the design equations are given as follows

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| PARAMETERS | VALUES   |
|------------|----------|
| Lg         | 14 mm    |
| Wg         | 14 mm    |
| L          | 10.75 mm |
| W          | 12.75 mm |
| Hs         | 1.6 mm   |
| Ht         | 0.035 mm |
| Gpf        | 1 mm     |
| Fi         | 4.8 mm   |

## DESIGN STRUCTURES OF ANTENNA

### DESIGN-1 (without DGS)

#### FRONT VIEW

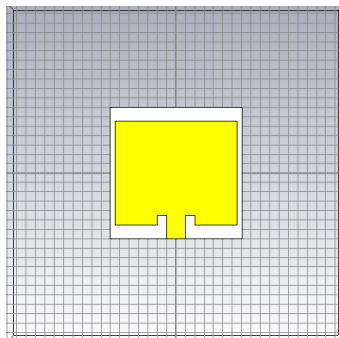


Figure 3.1- Front view of design-1

The antenna is designed using the above values and their front and back views are recorded. There are two designs proposed, design-1 consists of a basic MSA without any DGS and design-2 consists of a MSA with DGS etched in the ground surface.

#### BACK VIEW

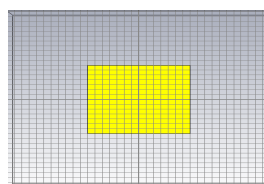


Figure 3.2- Back view of design-1

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## DESIGN-2 (with DGS)

### FRONT VIEW

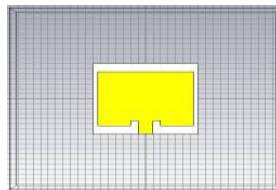


Figure 3.3- Front view of design-2

The aim of this chapter is to evaluate the return loss and VSWR of the antenna without DGS and the MSA with DGS and compare their characteristics, record the values and then compare the simulation results with the hardware results.

### BACK VIEW

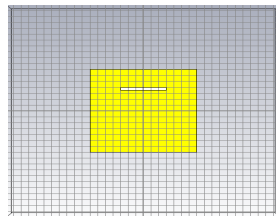


Figure 3.4-Back view of design-2

Return loss is the loss in the reflected signal from the transmission line which occurs due to the impedance mismatch. VSWR is the ratio of the power of the reflected signal to the power of the input signal.

## RETURN LOSSES:

### DESIGN 1:

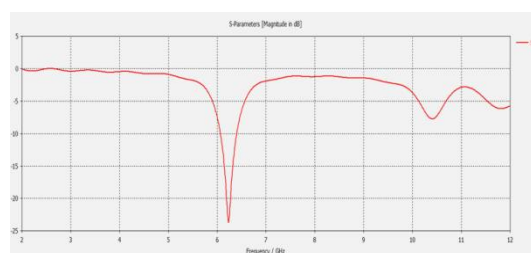


Figure 3.5- Return loss of design-1

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DESIGN 2:

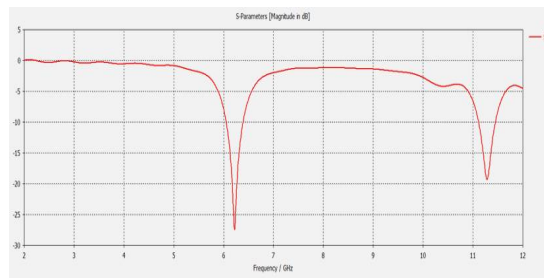


Figure 3.6- Return loss of design-2

VSWR:

DESIGN 1:

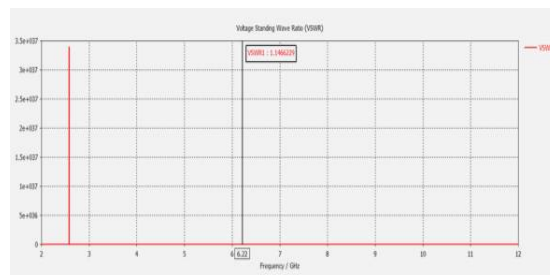


Figure 3.7- VSWR of design-1

DESIGN 2:

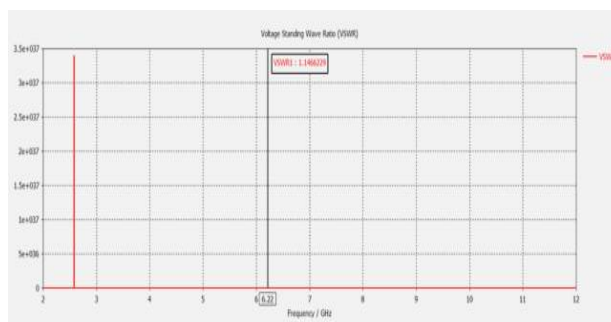


Figure 3.8- VSWR of design-2



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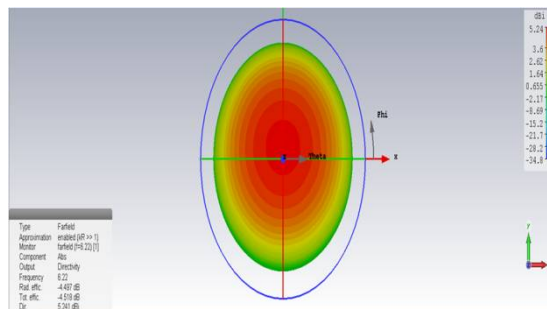
## TABULATION

Thus from the above tabulation we can see that the design 2 with DGS is having low return loss and the VSWR value is nearby 1. Thus by using the concept of the DGS a better design is implemented.

| PARAMETERS  | DESIGN 1 |          | DESIGN 2 |          |
|-------------|----------|----------|----------|----------|
|             | C - band | X - band | C - band | X - band |
| RETURN LOSS | -23.3    | -7.75    | -27.46   | -19.32   |
| VSWR        | 1.14     | 2.38     | 1.08     | 1.24     |

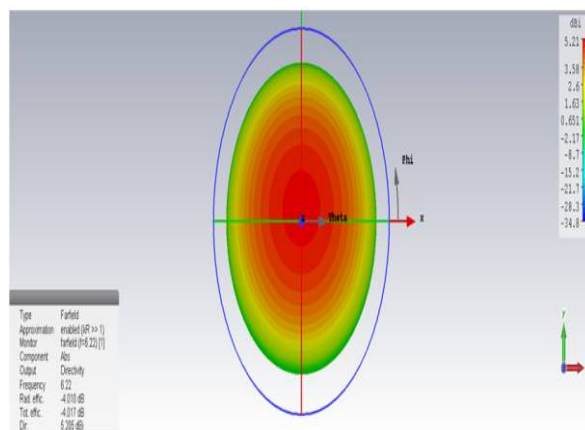
### DIRECTIVITY: DESIGN 1:

Figure 3.9- Directivity of design-1



### DESIGN 2:

Figure 3.10- Directivity of design-2



## IV. CONCLUSION & FUTURE ENHANCEMENT

The designed antenna has a reduced design cost, the VSWR value is nearly brought to 1 and the return loss is reduced. The dimensions of the antenna are also reduced. This work has a very vast scope in future. Project can be updated in



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near future as and when requirement for the same arises, as it is very flexible in terms of expansion. And in future the proposed system may be further developed and the return loss may be reduced further than that of the Teflon design.

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