"Defected Ground Structure -Based Microstrip antenna arrays with reduced mutual coupling"

Sanket Gharat[1], Prof. P.P. Narwade[2]

[1]P.G Student, [2] Professor, Dept. of Electronics And Telecommunication Engineering,

M.G.M's CET, Kamothe, Navi Mumbai.

---***---

Abstract – *Mutual coupling is one of well known effect in multi element array antennas. Mutual coupling is an unwanted phenomenon that distorts the behavior of the radiating element in an antenna array. Every element in an antenna array affects every other by radiating over the air or by propagating surface current through the ground plane. Surface current is bigger problem especially when antenna elements are closely placed. In this project Defected Ground Structure (DGS) is used to reduce mutual coupling between elements in a microstrip antenna array. For designing Advanced Digital System (ADS) software is used.*

Key Words: Defected Ground Structure (DGS), Mutual coupling, microstrip antenna.

1. INTRODUCTION

Antenna is one of the important element in RF system in transmitting and receiving signal from and into air as medium. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape. Modern wireless communication system requires low profile, light weight, high gain, and simple structure antennas to assure reliability, mobility, and high efficiency characteristics [1]. These advantages of microstrip antennas make them popular in many wireless communication applications such as telemetry and communications, aviation, naval communications, automatic guidance of intelligent weaponry, radar, GPS systems. The disadvantages of microstrip patch antennas are: narrow frequency band with low efficiency, feeds have high losses and disability to operate at high power levels of waveguide [2].

Mutual coupling is a well-known effect in multi element array antennas. Generally, mutual coupling is an unwanted phenomenon that distorts the behavior of the radiating elements in an antenna array. Every element in an antenna array affects every other element by radiating over the air or by propagating surface currents through the ground plane. Surface currents can be a bigger problem, especially when antenna elements are closely packed. Microstrip patch antennas are well-known antenna types in different kinds of applications, like mobile, airborne and satellite communications. In general, the structure has a thin metallic patch, usually copper, printed on a microwave substrate. There are many methods for reducing the effects of mutual coupling, which include optimizing antenna dimensions, grooving the dielectric, covering the patch by additional dielectric layers, using shorting pins to cancel the capacitive polarization currents of the substrate, adding parasitic conducting tape to the middle of two antennas , using the dielectric as a band gap structure between elements in the array, or using Defected Ground Structures (DGSs) technique which are widely used in microwave circuit and antenna design because they produce the band rejection characteristics similar to EBG structures but with a more compact size[6].

1.1 Problem statement

In many wireless communication systems it is necessary to design antennas with very directive characteristics (high gains) to meet the demands of long distance communication. For these applications, Microstrip antenna arrays are preferred due to their well-known attractive features, such as low profile, light weight and low production cost. However, a common disadvantage of microstrip antennas is the reduced radiation efficiency due to generation of surface waves through the substrate layer. In arrays, surface waves have a significant impact on the mutual coupling between array elements. This effect is a potential source of the performance degradation which includes the impedance mismatching, the increased side-lobe level, the deviation of the radiation pattern from the desired one, and the decrease of gain due to the excitation of surface wave. In the application of continuous wave radar, when the transmitting antenna and the receiving antenna are placed closely side by side, the transmitting energy may even blockade the receiver. Therefore, the mutual coupling between elements of antenna arrays is a critical aspect that must be taken into account in the design process, as it can lead to severe degradations in the overall performance.

To suppress surface waves, several studies are conducted including using shorting pins to cancel the capacitive polarization currents of the substrate, adding parasitic conducting tape to the middle of two antennas, using the dielectric as a band gap structure between elements in the array or in our case using DGS technique which are widely used in microwave circuit and antenna design. Many studies have used DGS for filter design, couplers, dividers, and microstrip antennas. Meanwhile, for antenna applications, DGS is mainly applied to the feeding technique of single element microstrip antennas. However, few researches focus on suppressing mutual coupling based on DGS techniques.

1.2 Objectives.

The objectives of this project are:

1) To design, simulate coupler strips operating at a resonant frequency of 2 GHz.
2) To design antenna array with defected ground structure to reduce the mutual coupling between them.
3) To compare the performance of the DGS based antenna and conventional antenna.
4) To design microstrip antenna array and reduce mutual coupling between them using DGS.

2. LITERATURE SURVEY

Md. Muzammil Adnan et. al. (2014), in this paper design of conventional Rectangular patch Microstrip antenna has been proposed and its performance is analyzed. The design parameters of antenna are selected to achieve compact dimensions as well as best possible characteristics such as high gain, increased bandwidth with minimum return loss. Hence improved design has been demonstrated over elementary one. These antennas have been designed at 2.4GHz which enables its usage in wireless communication domain such as Wireless Local Area Network (WLAN) [1]. George Casu[1] et. al.(2014), This paper explains detail analysis on the design and implementation of 4x1 and 8x1 microstrip patch antenna (array) of given specifications using IE3D software and a dielectric material FR4 with dielectric substrate permittivity of 4.28.
Atul Kumar et al. (2014), This review paper describes how we can increase the performance of the patch antenna by using metamaterials or how we can improve the gain & bandwidth. Authors first provide the introduction of metamaterials and microstrip patch antenna after that describe the parameter of microstrip patch antenna which can improve by using metamaterials and discuss future scope and application of metamaterials [3]. Mohamed I. et. al. (2012),In this paper, a low mutual coupling design for a two element micro strip antenna array was proposed. A dumb-bell shaped defect on the ground plane of the antenna is inserted between the patches creating a band gap in the operation frequency band of the antenna. By suppressing the surface waves, it provides a very low mutual coupling between array elements. L. H. Weng et.al. (2008), This paper focuses on a tutorial overview of DGS. The basic conceptions and transmission characteristics of DGS are introduced and the equivalent circuit models of varieties of DGS units are also presented.

3. MICROSTRIP PATCH ANTENNA

The basic form of a microstrip patch antenna consists of an arbitrary shaped copper or any other metal trace on one side of a PCB substrate with other side grounded. The metal trace can have the shape of a rectangle, square, circle, triangle, dipole, or any other geometry as shown in Fig. 1. Among these shapes, square, rectangle, dipole, and circle are most famous for ease in design, analysis and fabrication, and having appealing radiation characteristics especially low cross polarization. The dipole shape is appealing for possessing larger bandwidth and occupying less space. This property makes microstrip dipoles desirable for the antenna arrays. The patch antenna can be fed using coaxial, strip line, aperture coupling or proximity-coupling methods [4].

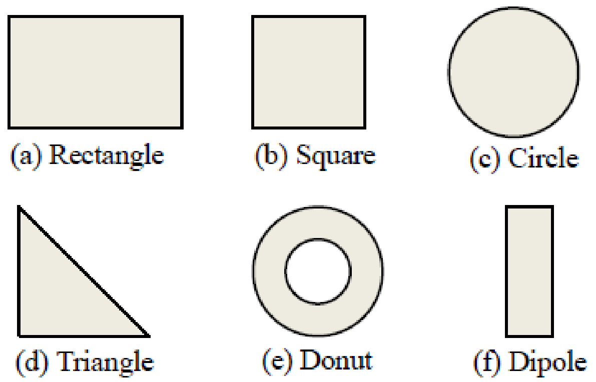

Fig. 1: Common shapes of microstrip patch elements [4]

3.1 Feed techniques:

Microstrip patch antennas are most widely use today, particularly this has many advantage in frequency range of 1 to 6 GHz. Deschamps first proposed the concept of the Microstrip antenna (MSA) in 1953. Microstrip antennas are also known as microstrip patch antennas, or simply patch antennas. A microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The microstrip antenna radiates relatively broad beam broadside to the plane of substrate. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular or any other configuration. There are many configurations that can be used to feed microstrip antennas. Microstrip line, coaxial probe, aperture coupling and proximity coupling are some of feed techniques [3].

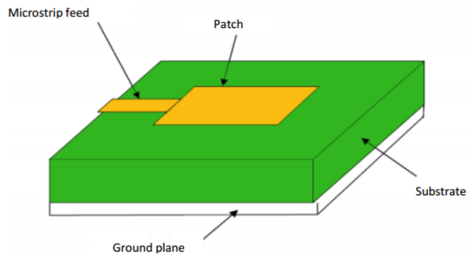

Fig.2: Microstrip line feed

The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

Patch antennas has following advantage or disadvantage [3]

Advantage:

- Lightweight and have a small volume.
- Low fabrication cost Easier to integrate with other MICs on the same substrate -They allow both linear polarization and circular polarization.
- They can be made compact for use in personal mobile communication
- They allow for dual- and triple-frequency operations.

Disadvantage:

- Low bandwidth.
- Low gain.
- Low power handling capability.

3.2 Proposed Solution

1) Defected Ground Structure is incorporated in order to reduce the mutual coupling. This may also reduce the size of an antenna and increase the bandwidth [8].
2) Spacing between arrays increased with dumb bell shaped Defected Ground Structure (DGS).

3.2 Defected Ground Structure (DGS)

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. This 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 [10].

3.2.1 Basic Structure of DGS

The dumbbell DGS are composed of two $a \times b$ rectangular defected areas, $g \times w$ gaps and a narrow connecting slot wide etched areas in backside metallic ground plane as shown in Fig. 3. This is the first DGS.

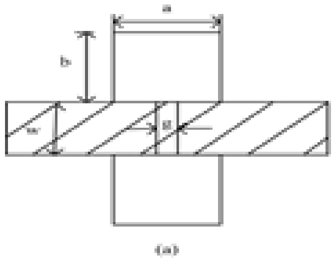

Fig. 3: dumbbell shaped DGS.

3.3 design of microstrip antenna

The antenna used in this paper is a rectangular patch printed on a substrate as shown in Fig.4. The patch antenna is having attractive features such as low profile, lightweight, easy to fabricate and conformity to mounting post. However the disadvantage of the patch antenna includes the narrow bandwidth, low gain and directivity [2].

In order to obtain the patch antenna with desired working frequency, the following formula is used to obtain the suitable parameter.

The width (w) of the patch can be calculated as

$$w = \frac{c}{2f\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \qquad (1)$$

W= 38 mm

With 'c' is the free space velocity of light, 'f' is the frequency of operation, 'ε_r'is the dielectric constant and h is the height of the dielectric substrate. The effective dielectric constant (ε_{reff}) can be determined by

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \qquad (2)$$

= 3.979

The actual length of patch (L) is calculated by

$$L = L_{eff} - 2\Delta L. \qquad (3)$$

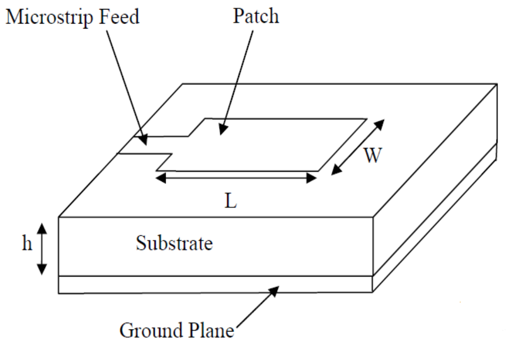

Fig.4: Conventional microstrip patch antenna [2]

Whereas, the effective length of the patch (*Leff*) and the length extension (*ΔL*) can be determine respectively using

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (4)$$

=31mm

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (5)$$

Finally, the ground plane parameters of the patch antenna can be calculated as

$$L_g = 6h + L \quad (6)$$

$$W_g = 6h + W \quad (7)$$

Using equation no. 1 and putting values of c, f and ε_r.

$$w = \frac{c}{2f\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Where,

C is the speed of light (3x108 m/s),

f is the operating frequency of 2 GHz.

ε_r is the dielectric permittivity 4.4 [5].

Using equation no. 2 and putting values of εr, h and w.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}}$$

Where,

h is the thickness of the dielectric substrate, h = 1.55.

ε_r is the dielectric permittivity 4.4.

We get ε_{reff} = 3.979.

Using equation no. 4 and 5 and put in equation no. 3.

$$L = L_{eff} - 2\Delta L. = 30 \text{ mm}.$$

With these specifications patch is design using ADS software. The patch design layout is shown in fig. 5. without putting DGS.

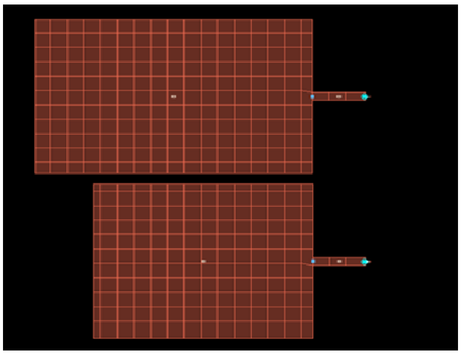

Fig.5 antenna patch design with out DGS.

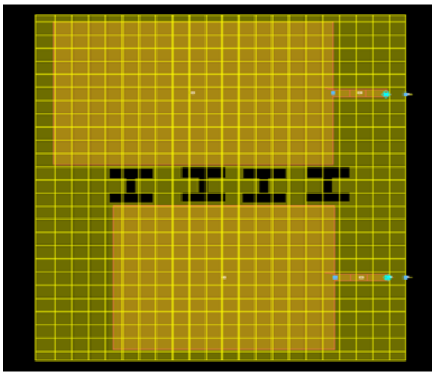

Fig.6 antenna patch design with DGS.

After designing two patches ground plane is put below patches. Dumb bell shape DGS are put with proper dimensions and simulated using ADS software.

Parameter	Specifications
Operating frequency	2.612
Length of patch	30mm, 30 mm
Width of patch	38mm, 48 mm
Substrate	Fr4
Dielectric constant of substrate	4.6

Table 1: design specifications of patch antenna

4. SIMULATION RESULTS

The proposed antenna is simulated through the simulation tool ADS to evaluate its performance. According to frequency need width and lengths of patches are changed.

By varying probe feed length, feed position, ground plane, width and length of slot, mutual coupling is studied. The gain and bandwidth is enhanced for the rectangular shaped patch with minimum mutual coupling.

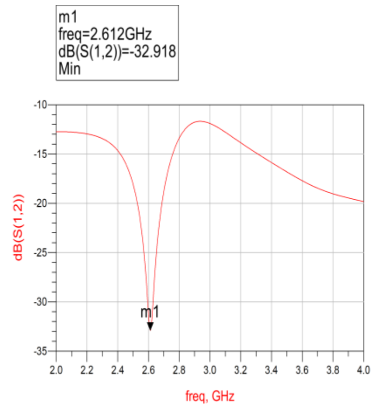

Fig. 6: Mutual coupling without DGS using ADS.

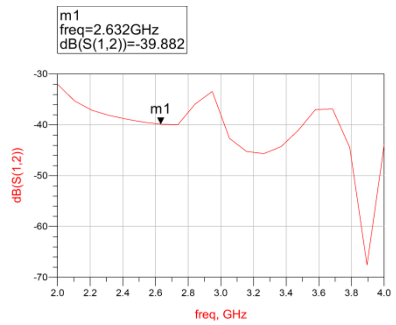

Fig. 7: Mutual coupling with DGS using ADS.

Fig. 6 and fig. 7 shows the S12 parameter (mutual coupling) for the proposed microstrip antenna. Fig. 6 shows mutual coupling without DGS that is -32.918 dB. And fig.7 shows mutual coupling with dumb bell shape DGS. Mutual coupling with dumbbell shape DGS inserted is -39.882 dB.

5. CONCLUSIONS

Antenna patch operating at a resonant frequency of 2.612 GHz (S band) is simulated using Advanced Design System (ADS) software. Low mutual coupling design for a two element microstrip patch is designed. A dumb-bell shaped defect on the ground plane of the antenna is inserted between the patches. After inserting dumb bell shape DGS mutual coupling get reduced. After designing coupler strip with defected ground structure, observed that mutual coupling is reduced in between coupler strip. Mutual coupling loss for infinite ground antenna patch is -32.918 dB and that for antenna patch with finite ground and DGS mutual coupling loss is -39.882dB. So by inserting DGS below closely placed antenna we can reduce mutual coupling between two patches.

REFERENCES

[1] Md. Muzammil Adnan1 Siddarama R. Patil, **"Design and Analysis of Micro Strip patch Antenna with optimization for Wireless Communication".** *International Journal for Scientific Research & Development,* IJSRD, Vol. 2, Issue 07, page no. 138-141, 2014.

[2] George Casu, Cătălin Moraru, Andrei Kovacs, **"Design and Implementation of Microstrip Patch Antenna Array".** *Communications (COMM), 10th International Conference*, page no. 1-4, 2014.

[3] Atul Kumar, Nitin Kumar, Dr. S.C. Gupta, **"Review on Microstrip Patch Antennas using Metamaterials".** *International Journal of Engineering Research and General Science*, Volume 2, Issue 4, page no. 678-682, 2014.

[4] Muhammad Imran Nawaz, Zhao Huiling, Muhammad Sabir Sultan Nawaz **"A Review on Wideband Microstrip Patch Antenna Design Techniques".** *International Conference on Aerospace Science & Engineering* (ICASE), pages 1-8, 2013.

[5] Vijayan T **"Performance of Microstrip Directional Coupler Using Synthesis Technique".** *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* Vol. 2, Issue 3, page no. 761-767, 2013.

[6] Mohamed I. Ahmed, and A. Sebak, Esmat A. Abdallah. **"Mutual Coupling Reduction Using Defected Ground Structure (DGS) for Array Applications".** *Antenna Technology and Applied Electromagnetics* (ANTEM), page no. 1-5, 2012.

[7] S. Xiao M.-C. Tang Y.-Y. Bai S. Gao B.-Z. Wang. **"Mutual coupling suppression in microstrip array using defected ground structure".** *IET Microw. Antennas Propag*, Vol. 5, Issue 12, page no. 1488–1494, 2011.

[8] A. K. Arya, A. Patnaik, M. V. Kartikeyan. **"A Compact Array with Low Mutual Coupling using Defected Ground Structures".** *Applied Electromagnetics Conference,* Page no. 1-4, 2011.

[9] Ashwini Kumar Arya, Kartikeyan Machavaram, A. Patnaik. **" Defected Ground Structure in the perspective of Microstrip Antennas"**, *Research*

gate, page no. 79-84. 2010.

[10] L. H. Weng, Y. C. Guo, X. W. Shi, and X. Q. Chen. " **An Overview On Defected Ground Structure**". *Progress In Electromagnetics Research B*, Vol. 7, page no.173–189, 2008.

[11] Ashwini Arya, M. v. Kartikeyan, A.Patnaik. " **Efficiency Enhancement of Microstrip Patch Antenna with Defected Ground Structure".** *Proceedings of international conference on Microwave,* page no. 729-731, 2008.

[12] Mohsen Salehi, Alireza Motevasselian, Ahad Tavakoli, and Teimur Heidari. **"Mutual Coupling Reduction Of Microstrip Antennas Using Defected ground Structure".** page no. 1-5, 2006.

[13] D.M. Pozar. **"Microstrip antennas"**. *Proceedings of the IEEE*. Volume 80, Issue 1, Page(s):79 – 91, 1992.