MAJOR PROJECT

REPORT

ON

DESIGN AND ANALYSIS OF APERTURE COUPLED ANTENNA WITH DEFECTIVE GROUND

Submitted in partial fulfillment

of the requirements for the award of the degree of

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In

Microwave and Optical Communication Engineering

Submitted by

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CERTIFICATE

Certified that the thesis entitled "Design and Analysis of Aperture Coupled Antenna with defective ground" submitted by **Peeyush Kumar (2K15/MOC/13)** in the partial fulfillment of the requirements for the award of the degree of Master of Engineering (Electronics and Communication Engineering) of Delhi Technological university, is a record of student's own work carried under my supervision and guidance. To the best of our knowledge, this thesis has not been submitted to DTU or to any other University or institute for award of any degree. It is further understood that by this certificate the undersigned do not endorse or approve any statement made, opinion expressed or conclusion drawn herein, but approve the thesis only for the purpose for which it is submitted.

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DECLARATION

I, Peeyush Kumar bearing roll no. 2K15/MOC/13, a student of M.Tech. (Regular) of Electronics & Communication Engineering Department; hereby declare that I own the full responsibility for the information, results etc. provided in this thesis titled "**Design and Analysis of Aperture Coupled Antenna with defective ground**" submitted to Delhi Technological University for the award of M.Tech. (ECE) degree. I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged. I have taken care in all respect to honor the intellectual property right and have acknowledged the contribution of others for using them in academic purpose. I further declare that in case of violation of intellectual property right or copyright, I as the candidate will be fully responsible for the same, my honorable supervisors and Institute will not be responsible for the violation of any intellectual property right.

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Place: Delhi

ACKNOWLEDGEMENT

This thesis work is made possible through the help and support from everyone, including parents, teachers, friends, and in essence, all sentient beings. Whilst it would be simple to name them all, it would not be easy to thank them enough. Especially, please allow me to dedicate my acknowledgment of gratitude toward the enthusiastic supervision and assistance of my supervisor Dr. N.S. Raghava, Professor, Department of Electronics and Communication Engineering, DTU, Delhi throughout this thesis work. Her consistent support and unstinting guidance has always been an immense source of motivation and encouragement. She offered invaluable detailed advices on grammar, organization, and the theme of the papers and thesis work.

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(Peeyush Kumar)

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ABSTRACT

Aperture Coupled Micro-Strip Antenna Design and Analysis

A linearly-polarized aperture coupled patch antenna design is characterized and optimized using Agilent ADS antenna simulation software [1]. This thesis focuses on the aperture coupled patch antenna due to the lack of fabrication and tuning documentation for the design of this antenna and its usefulness in arrays and orthogonally polarized communications. The goal of this thesis is to explore dimension effects on aperture coupled antenna performance, to develop a design and tuning procedure, and to describe performance effects through electromagnetic principles.

Antenna parameters examined in this study include the dimensions and locations of the substrates, feed line, ground plane coupling slot, and patch. The operating frequency, input VSWR, percent bandwidth, polarization ratio, and broadside gain are determined for each antenna configuration.

The substrate material is changed from RT Duroid (material in nominal ADS design [1]) to FR4 due to lower cost and availability. The operating frequency is changed from 2.3GHz (specified in nominal HFSS design) to 2.4GHz for wireless communication applications. Required dimensional adjustments when changing substrate materials and operating frequencies for this antenna are non-trivial and the new design procedure is used to tune the antenna.

The antenna is fabricated using 59mil thick double and single sided FR4 boards joined together with double sided 45mil thick acrylic tape. The antenna is characterized in an anechoic chamber and experimental results are compared to theoretical predictions.

1

INTRODUCTION

1.1 OVERVIEW

Wireless communication has been an emerging field of interest all over the world in the present time. It has grown so rapidly in last couple of decades and has taken a gigantic shape of its own. All over the world possible major communication is taking place through the wireless mode. Satellite communication which is an essentially important technology aspect for any nation has been made possible because of emerging technologies of wireless communication. Recent development of modern technologies like WLAN indicates the major interests towards communication field. Extensive work is being put forward in the direction to overcome the cons of present wireless communication technology. Modern requirement in the wireless communication are the systems which can accommodate high data/information transmission rate at the same time volume of information is to be kept sufficiently enough. Modern wireless communication system requires subsystems which are cost effective and portable to facilitate the installation process over a wide range. Therefore, focus of scientific and researcher's community is to design and develop antennas which are low profile, less bulky/less weight, and offers cost effectiveness in its use in the present international standards. Effectiveness of the performance over a wide range of frequency is a desired concern. Therefore, MPAs came into the picture because of offered characteristics like low profile, less bulky, light weight and easy to mount etc. Though there are few aspects which are not favorable for modern wireless communication systems as these antennas provide lower gain values and operation range covers a short length of frequency. Table 1-1 provides many of the wireless technologies and corresponding frequency range. International Telecommunication Union has divided the frequency spectrum accordingly for different application. These spectrum distribution is done by the ITU for different organizations at all the levels. Commercial purpose spectrum is a back bone for economy of any nation. Defense purpose frequency spectrum is kept restricted for rest of the peoples. There are frequency bands which can be used by the peoples are called license free bands.

Different Frequency Bands and Their Applications

Wireless Applications		Frequency Band (MHz)	Bandwidth (MHz)
GSM	GSM 900	890-960	70
	GSM 1800	1710-1805	95
	GSM 1900	1850-1990	140
IMT		2300-2400	100
		2700-2900	200
		3400-4200	800
		4400-4900	500
WLAN		2400-2484	84
		5150-5350	200
		5725-5825	100
Bluetooth		2400-2500	100
WiMAX		2500-2690	190
		3400-3690	290
		5250-5850	600

Table 1-1

1.2 BRIEF HISTORY OF WIRELESS COMMUNICATION

World has reached in any field of technology to a stage where even it is difficult to observe the footprints of the ancient technology which had been a start of that technology. In the present time, every day breakthrough is happening in many new directions are taking place. If we look back into the history then it is justifying saying that wireless communication was an existing technology from the time when humans were using smoke signals and pigeon carriers to communicate with each other wirelessly. These were the most basic forms of wireless communications used by humans. Very early wireless networks were coming in the picture in an era where there was industry for such networks. These early developed wireless networks then replaced by telegraph which were invented by Samuel Morse in 1938.later invention of telephone took place of these networks. Many years after of telephone networks invention Marconi introduces first radio transmission networks in 1895, this is how wireless communication came into existence largely. First packet radio based networks was developed in the Hawaii university in the year of 1971.all over the world scientists were asked to combine packet data transmission technology and broadcast radio networks inherently into ALOHANET. Through years of 1970's and initial period of 1980's all the major defense organizations as well as the arm forces were keen interested in the above wireless networks to be used in the defense purposes. wireless networks based on data packets had been an influence on commercial domain as well.

Initially packet networks were applied in wide area networks applications in early 1990's. There were many flaws associated with these services like low data transmission rate, high cost and an effective utilization of resources for required applications. As a far more capable technology of wireless networks in the form of cellular networks supplanted to the people, earlier used networks disappeared very quickly. Many commercial organizations coxswained there root away from the technology which was radio based on the arrival of Ethernet technology in 1970's. In the year of 1985 federal communication commission empowered the wireless LAN's by approving the use of commercial, scientific and medicals frequency bands for the use of these networks publicly. Present wireless LAN's technology is based on IEEE 802.11 standard family. Ethernet networks offers a speed of around 100 Mbps and there is an easy observation that performance gap of these networks is going to be increased by the time without any extra frequency spectrum allocation. Even this is happening and seems to increase gap far more in the coming time people preferred wireless networks over the wired networks like LAN's because of an ease of installation and use. Also, they get rid of wires.

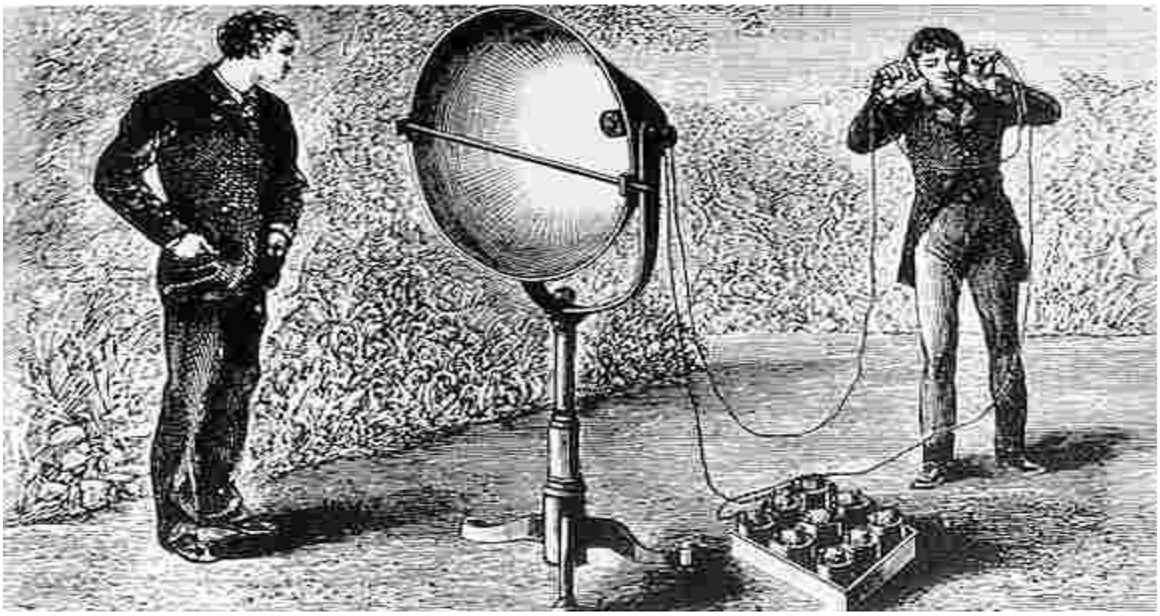


Fig1.1(Bell and Tainter's Photophone of 1980)

It is so obvious that most successful application of wireless networks is cellular communications from every point of view and in every aspect. In the modern time, cellular network providing companies has taken a shape bigger than a nation with a huge economical structure.

1.3 WIRELESS VISION

It has been a frontier in communication technology from last couple of decades. Wireless communication networks have grown very wide all over the world and assisting information transfer between the people and devices. This vision has made it possible to communicate to people around the world through a very handy and portable device and even with the different forms of the information like pictures, videos etc. Wireless entertainment facilitates people anywhere and in any corner of the world with so many possibilities of information transfer between the people. These networks help people or devices to come closer with fast growing new technologies and enormous new possibilities in near future. Wireless video conferencing opens the horizons of new possibilities in every aspect of our life like education, health, entertainment. It is such a tool which can be utilized in the field of education so effectively and a wide number of people can be covered through this technology which accounts for a great contribution towards educating and upliftment of human being all over the world. Under privileged communities can be driven towards a better future by facilitating and connecting them with people all over the world using wireless technology which is not a possible technology architecture with wired communication technologies. Therefore, wireless technology in the field of communication brings and inclusive effort towards the upliftment of human beings which is at utmost priority of any scientific venture or can be said the most effective and impactful application of any technology. In the field of medicine, it is proved to be an amazing technology tool through which people around the world can help each other in best possible way. In the modern time using video conferencing online monitoring of a patient can done from anywhere which provides any ease and operative utilization of human resources and its intellect. wireless communication technology has its another very important, which is communication through sensors. Wireless sensor technology is a rapidly flourishing technology domain for wireless communication networks. This technology has a wide range of application in almost every area from day to day life to defense application as well as in the satellite communication. Commercial implications of this technology include prevention rather an early indication from natural disasters like water level raise in the rivers beyond the safety mark. Weather forecast, situations like earthquake which can create disasters in any nation. Wireless sensors networks prevent people from natural calamities as well as it prevents and provides a sense of security over so many adverse conditions like fire hazardous in a building. Natural resources like water can be used in big organization very effectively in presence of sensor wireless networks. In modern time, our hectic life schedule will sometimes protrude difficulties in the use of natural resources and effective time management without presence of these wireless sensor networks. To bring a clear understanding and ease of operations in different applications wireless technology has been subdivide into different standard depending on the so many aspects involved with the technology. A brief introduction to developments phases of wireless technology is given below.

1ST GENERATION

In the initial phase of development of the mobile technologies or can say in the development of 1st generation mobile technologies people didn’t think of standardizing wireless communication technologies. In the initial phase, these technologies were subjected to a particular area or region and organizations which were using the technologies were concerned about the particular restricted area in which they were operating. However, after couple of years when the wireless communication was growing so rapidly and it was going towards globalization Nordic countries thought of standardizing these technologies. The 1st generation mobile technologies initially providing services in a confined system they were used only by the commercial organizations, Government organizations only. In the years of 1960's and 1970'smobile communication technologies were confined to a partial geographic area. Devices used in this generation of mobile communication technologies were very bulky, heavy and were not so easy to use. Devices were mounted on vehicles and then communication used to set up. The technology use was not an open access to public.

2ND GENERATION

With the time researchers have invented so many ways to communicate information over a wireless network. Therefore 2nd Generation wireless communication was an effort toward improving the ways or the possible forms of information transfer over an available wireless network.2nd Generation wireless services were generally voice messages and data transfer with very slow and low capacity. These are generally GSM and GPRS.

Fig.1.2 Different generations wireless communications scheme

3rd GENERATION

3G technology provided user more efficient communication over long distances without much interruptions. Wide band wireless networks were implemented in the constructing these networks. Packet switching technique is used in the 3G networks to communication of voice calls. It was a sophisticated technology modernization in last few decades. These wireless networks provide high data transfer capacity with decent speed of data transfer.3G operates at 2100 MHz and occupies a bandwidth of 15-20 MHz. High speed internet and video conferencing are major services of 3G networks.

4th GENERATION

A technology ahead of the 2G and 3G, 4G guarantees a downloading speed of around 100Mbps and is yet to trying to boost it further. At that point with the instance of Fourth Generation administrations few of 3G, some extra elements, for example, different forms of media, Newspapers, likewise to watch T.V programs with the clearness as to that of a customary T.V. Dissimilar to 3G, which depends on two parallel foundations comprising of circuit exchanging and bundle exchanging system hubs, 4G will be founded on parcel exchanging as it were. This will require low idleness information transmission.

1.4 OBJECTIVE OF THESIS

Objective of thesis is divide into three parts

- Designing of a conventional aperture coupled antenna, its simulation the Agilent ADS software platform and fabrication of designed antenna and measuring its results on Keysight VNA is done.
- Designing of an aperture coupled antennas with defective ground structure of single circular slot, Double circular slot, four circular slots, its fabrication and measurement on Keysight VNA is done.
- Comparative study and analysis of all the measured results of antennas with DGS and conventional design.

1.5 ORGANIZATION OF THESIS

This thesis is divided into six chapters

Chapter 2 provides the brief introduction to the theory involved with the microstrip patch radiators. It describes to the reader different types of the Microstrip Patch Antennas. In the later section of this chapter different feeding techniques are described with associated advantages.

Chapter 3 is the research paper review which was an essential part to understand the all possible designs of Microstrip Patch Antennas and their advantages. This chapter provides an overview to the reader of modern day MPA antennas being used practically.

Chapter 4 is the chapter where conventional aperture coupled antenna and aperture coupled antennas with DGS is explained.

Chapter 5 provides all the simulated and measured results and their comparison for all the fabricated antennas.

Chapter 6 concludes the thesis with essential remarks and future scope for further research purposes.

MICROSTRIP PATCH ANTENNAS AND THEIR ANALYSIS TECHNIQUES

This chapter describes fundamental theory of Micro Strip Patch Antennas. Initial sections of the chapter evolve the conceptual understanding of different feeding techniques of the antennas and in the later sections methods to perform analysis of the Micro Strip Patch radiators is described with appropriate mathematical background. Further sections of this chapter give the details of applications area of these antennas.

2.1 Microstrip Patch Antenna

Microstrip Patch Antennas are the antennas to be fabricated in printed form of a conducting material on suitable substrate. They are occupying their popularity in the industry of in the practical application because of their low profile, low cost, portability and ease in the fabrication.

A Microstrip radiator in its simplest use of application is a structure with two thin conductors separated with a dielectric of some thickness. Conductor underneath the dielectric assist as ground plane for the structure while the upper patch of conductor act as a radiator. Geometry of the radiating patch is a choice of designer and it depend on the factors like application, ease of fabrication etc. Physical parameters of the antenna depend on the operational frequency range and desired values of gain and return loss. It is taken in the ratio of the wavelength parameter lambda. Conducting material having a good conductivity is used but at the same time cost is also a concern for commercial purposes therefore metals like copper is used. Patch radiates only when it is excited by any type of feed excitation like coaxial feed, which is most widely used feed technique.

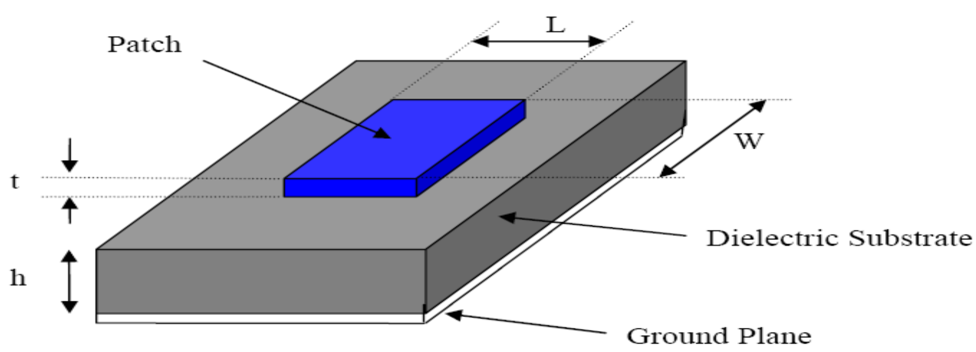


Fig2.1 Basic structure of Micro strip Patch Antenna[13]

Radiating patch is generally etched on the substrate using photolithography techniques. Conducting patch radiates because of the fringing fields between patch edge and ground plane. Microstrip Patch Antennas has a radiating edge and a non-radiating edge. Substrate height of the antenna is a parameter which affects the performance parameter like gain and bandwidth of antenna. Because the patch on the upper side is only participating in the radiating mechanism therefore it is easy to feed/excite the antenna from other side (ground plane). A major concern is the amount of power transferred to the radiating patch there for the feed line should be perfectly matched with impedance exhibited by the antenna. edge. Smith chart matching technique is used for matching the input impedance of the feed line. Many shapes of Micro-strip Patch Antennas used in the industry are being shown in the figure 2.2

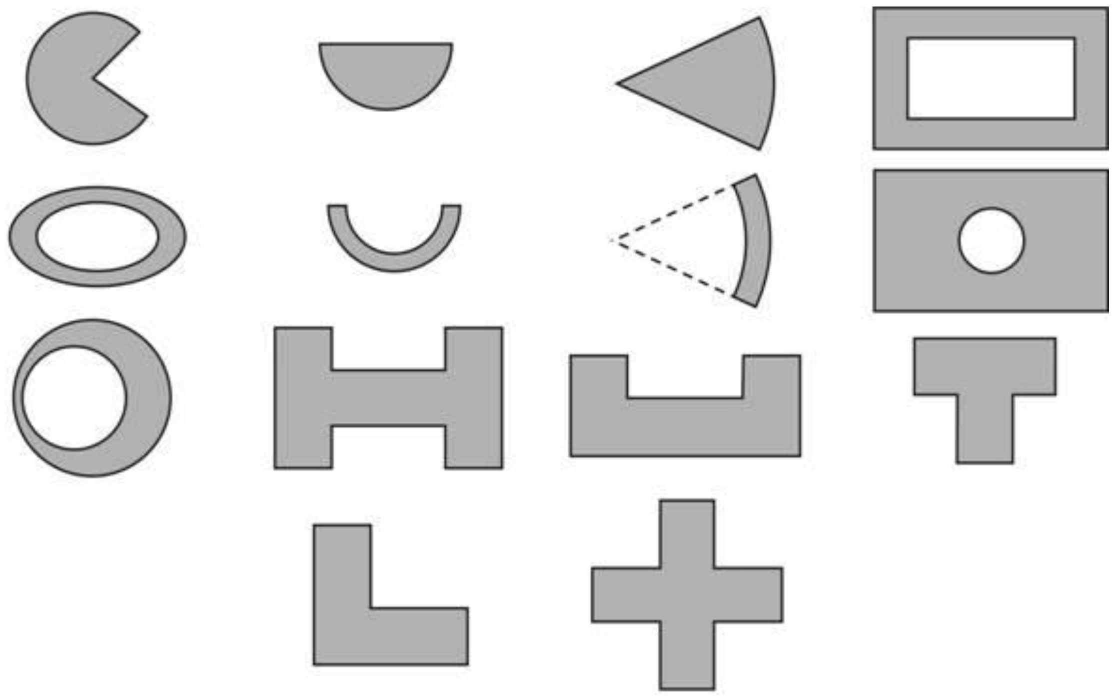


Fig 2.2 Different shapes of Microstrip Patch Antennas

2.2 ADVATAGES AND DISADVANTAGES

Micro-strip Patch Antennas are being widely used in remote application because of their specific features like low profile, ease of mounting and safety position. Therefore, Micro

Strip Patch antennas very favorable for wireless applications for example, pagers and etc. Some of their important features are listed underneath:

- Light weight and less volume
- Low fabrication cost, hence can be manufactured in large quantities.
- Low profile configuration which can be made conformal.
- Supports both type of polarization, linear and nonlinear.
- Can easily be integrated with microwave circuits.
- Capable of multi band frequency operation.
- Can be mounted on the rigid surfaces

Microstrip Patch Antennas suffers from many disadvantages as well which are being listed below

- Narrow bandwidth
- Lower values of gain
- Less efficiency
- Low power handling capacity
- Surface wave losses
- Poor radiations

Micro-strip Patch Antennas are the antennas having a high value of Q and it speaks to the calamities related with the microstrips patch antennas and a vast Q prompts limit the power transmission and low performance effectiveness. Q can be diminished by increasing the thickness of the dielectric substrate. Be that as it may, as the thickness figures, an expanding portion of the aggregate power conveyed by the source goes into a surface wave. This surface wave obligation can be considered an undesirable power misfortune, since it is at last dispersed at the dielectric twists and causes exploitation of the response apparatus qualities. Different issues, for example, bring down pick up and bring down power dealing with limit can be overwhelmed by utilizing a cluster arrangement for the components.

2.3 FEEDING TECHNIQUES

Micro-strip Patch Antennas can be fed by different techniques. There are some direct methods and some indirect methods present in the feeding techniques available for the micro-strip patch antennas. Generally, these techniques are divided into two major categories which are contacting and non-contacting method. In contacting method, the RF power is being fed directly to the parasitic patch/radiating patch using a conducting material having a good conducting index such as Micro-strip line in the inset feed antenna or simple Micro-strip patch antenna the radiating patch using a connecting element such as a microstrip line. In the scheme of non-contacting feed technique, the RF power to the radiating patch is coupled through the electromagnetic field coupling between the radiating patch and the feed line, example of this feed scheme comprises of antennas like aperture coupled antenna, proximity feed antenna. electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. Most commonly antenna feed technique of this method is coaxial feed.

2.4 DIRECT MICROSTRIP LINE FEED

In this sort of feeding technique, a leading micro-strip line is directly connected to the edge of the radiating patch of the antenna. Micro-strip connected as appeared in Figure 2.3. The directing strip is narrow in width and physical parameters like length and width are calculated from the frequency range of the application from the fundamentals of Micro-Strip Patch Antennas. Location of the point of contact of strip line with the edge of radiating patch is decided by the impedance matching requirements. Generally, the value of impedance to be matched by the deed line is 50Ω and the coordinates of the location are kept fix and this sort of feed is an encouraging technique for the designers, this feed method is most suitable for the planar antennas working at the lower frequency ranges. This is accomplished by appropriately controlling the inset position. Subsequently this is a simple bolstering plan, since it gives simplicity of manufacture and straightforwardness in displaying and additionally impedance coordinating.

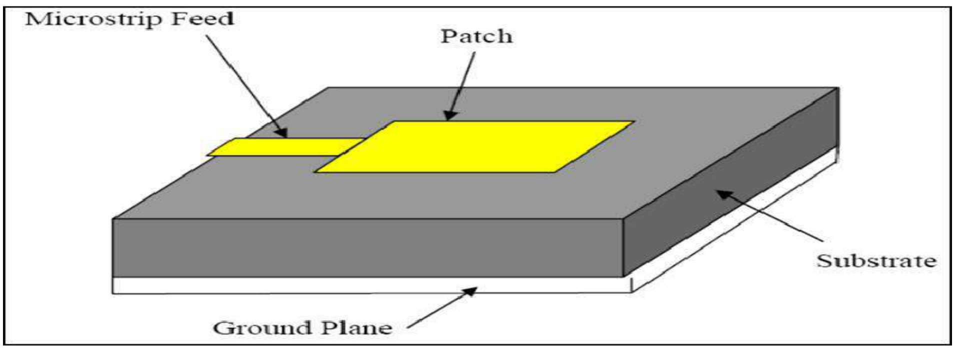


Fig 2.3 Micro strip Line Feed[13]

2.4 COAXIAL FEED

Most efficient feed technique for the practical purposes is the coaxial feed. A cylindrical metal with small radius is coated with a non-conducting material and finally it is covered with the thin layer of a good conducting material like copper. It is the technique where impedance matching is achieved most effectively as compared to others. The primary favorable position of this sort of bolstering plan is that encourage can be set at any coveted area inside the fix to coordinate with its information impedance. This feeding strategy is widely used because inn this feeding technique impedance matching is obtained so easily, sometimes it is difficult to manufacture because of the low values of the radius of the coaxial feed, it has low spurious radiation. Notwithstanding, its significant disfavor is that it gives limited capacity and is hard to demonstrate since an opening must be pierced in the substrate and the connector projects outside the ground plane, consequently not making it totally planar for thick substrates ($h > 0.02\lambda o$). Similarly, for thicker substrates, the expanded test length makes the impedance more inductive, encouragement to the coordinating issues. It is seen over that for a thick dielectric substrate, which gives expansive transfer of RF power, the microstrip line encourage and the coaxial feed technique experience the hostile effects.

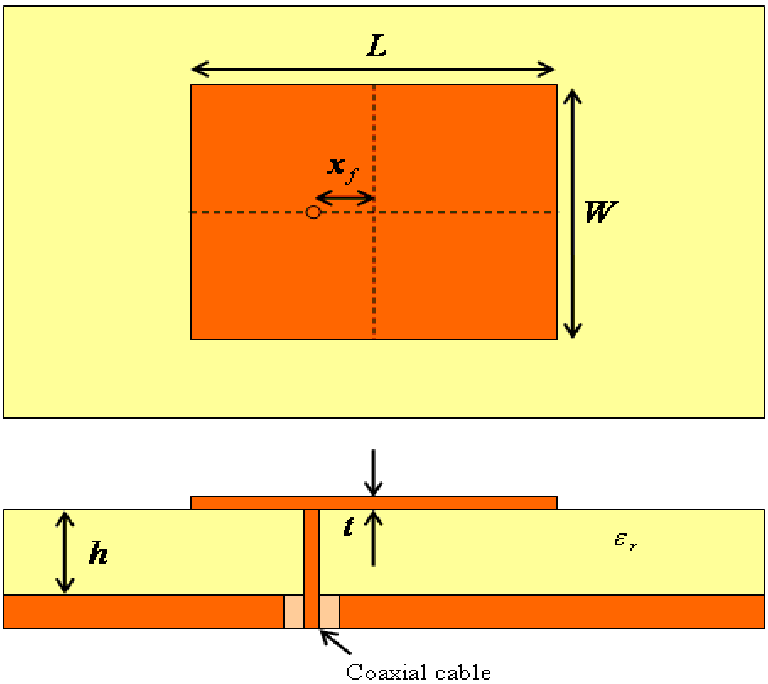


Fig 2.4 Coaxial feed[13]

2.5 APERTURE COUPLED FEED

In this kind of feeding strategy, the radaiting patch and the microstrip feeding line is separated by two substrates of different heights and the ground plane is located in between the two substrates as appeared in Fig 2.5. Figure shows the coupling between the microstrip line and the aperture created in the ground plane. Through this aperture electromagnetic energy is coupled to the radiating patch that is how radiating patch gets its excitation and radiates into the air.

The distance between the aperture and the radiating patch decides the quotient of energy radiated from the energy fed into the feed line beneath the substrate on the bottom layer. Size of the aperture decides the operating frequency and the amount of energy to be coupled to the radiating patch. Normally the aperture is kept just under the radiating patch at the center position so that the maximum coupling is achieved and prompting lower cross polarization because of symmetry of the design. The measure of coupling from the sustain line to the fix is dictated by the shape, size and area of the opening.

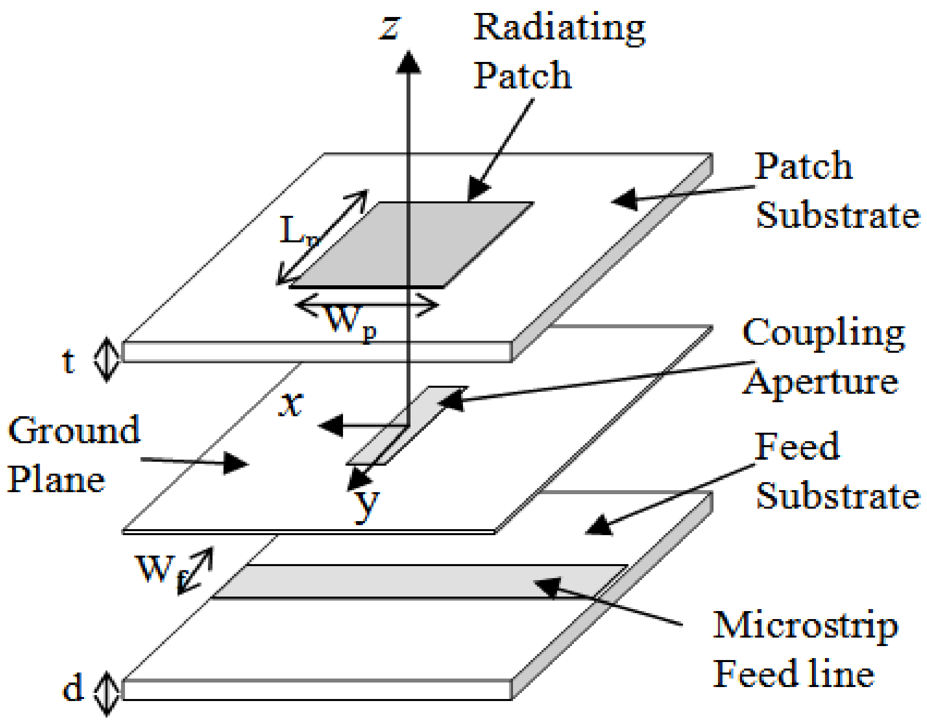


Fig 2.5 Aperture Coupled Feed[13]

Since the ground plane is the plane which lies in between the two important conductor planes of a Microstrip Patch Antennas it is the plane which limits the spurious radiation by the antenna. By and large, a high dielectric material is utilized for the base substrate and a thick, low dielectric consistent material is utilized for the best substrate to enhance radiation from the fix. This feeding plans have some advantages as well as some very useful advantages for the applications where frequency range is high aperture couple technique of the feeding technique is used.

2.6 PROXIMITY COUPLED FEED

Electromagnetic coupling is the phenomenon used for proximity coupled feed. Figure 2.6 describe the proximity feed technique designed for a Micro-strip Patch Antenna in which two This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the MPA.

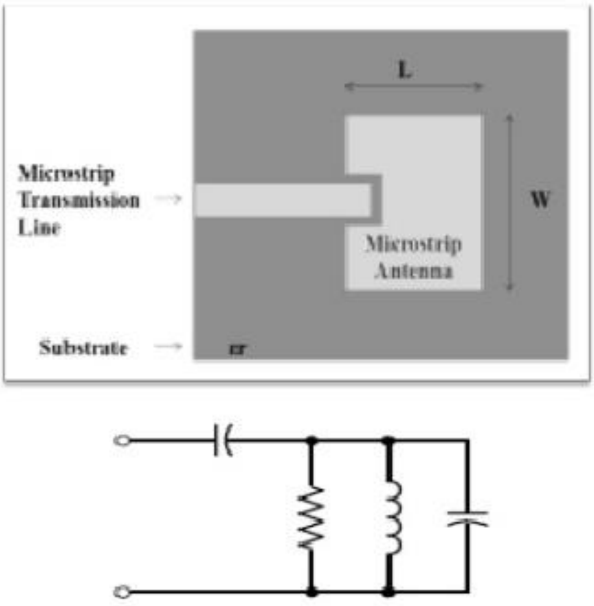


Fig 2.6 Proximity Feed[13]

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor due to Soldering	Good	Good
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with	2-5%	2-5%	2-5%	2-5%
Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed Radiation	More	More	Less	Minimum

Table 2-1: Comparison of different Feed Techniques

2.7 ANALYSIS METHODS

Microstrip Patch antennas are analyzed using three models which are transmission line mode, cavity model, full wave model. The most efficient model to analyze the antenna is considered as the cavity model but generally transmission line model is used because of its ease. Otherwise rest two models give more insight into the analysis. This model speaks to the microstrip patch antennas as the two wires separated an dielectric spaces of width W and height h, can be treated as a transmission line of length L having inductors and capacitors its elements in the parallel branches here resistance involved is neglected because for micro strip patch antennas the thickness of metal conductor is very low. The microstrip is basically non-homogeneous line of two dielectrics, normally the substrate and air.

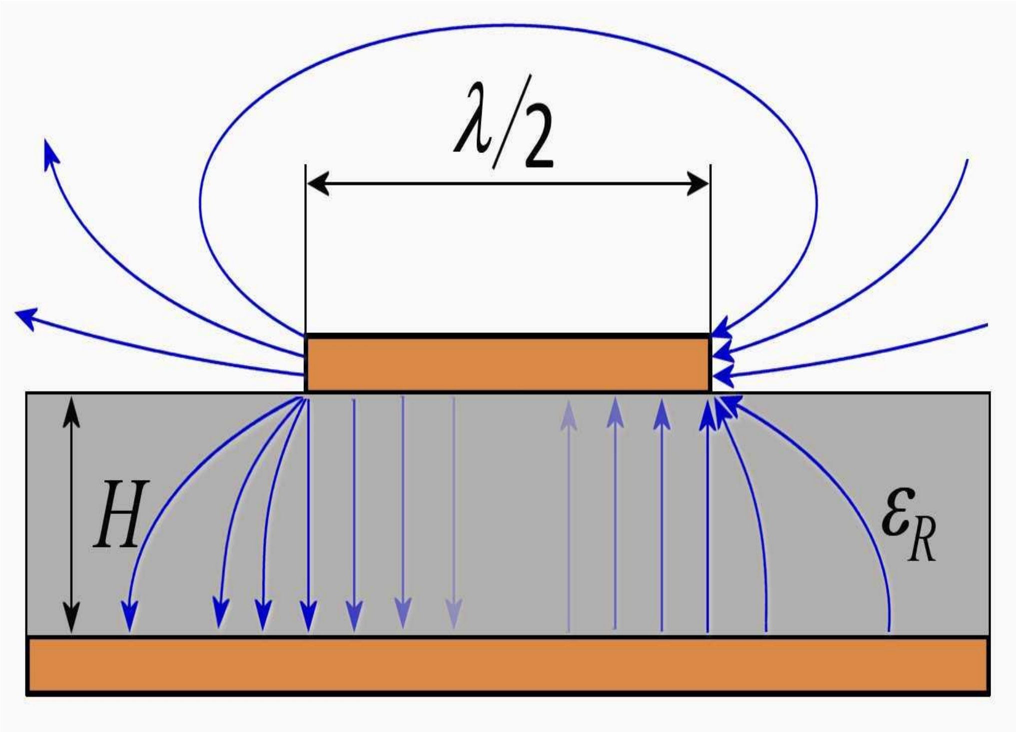


Fig 2.7 Radiation Mechanism of MPA's[9]

Subsequently, as observed from Figure2.7, the majority of the electric field lines oscillates in the substrate and parts of a few lines in air. Accordingly, this transmission line model of the microstrip patch antennas spick-and-span transverse electric-attractive (TEM) method of transmission, since the stage speeds would be idiosyncratic noticeable all around and the substrate. Rather, the dominant method of stimulating would be the semi TEM mode. With a specific end goal to work in the key TM10 mode, the length of the fix must be a tad not exactly λ/2 where λ is the wavelength in the dielectric medium and is equivalent to ß0⁄sreff where λ0 is the free space wavelength. The TM10 mode recommends that the field swings one λ/2 cycles laterally the length, and there is no variability along the width of the fix. In the Figure 2.8 demonstrated as follows, the microstrip patch antennas reception apparatus is taken to by two openings, isolated by a transmission line of length L and open circuited at both the closures. Along the width of the fix, the voltage is greatest and current is least because of the open finishes. The fields at the boundaries can be settled into usual and digressive segments concerning the ground plane. It is seen from Figure, that the typical parts of the electric field at the two edges along the width are in inverse ways and in this manner out of stage since the fix is λ/2 long and hence forth they cross out each other in the broadside course. The unnecessary parts (Figure 3.11), which are in stage, implies that the subsequent fields join to give greatest transmitted field ordinary to the surface of the structure.

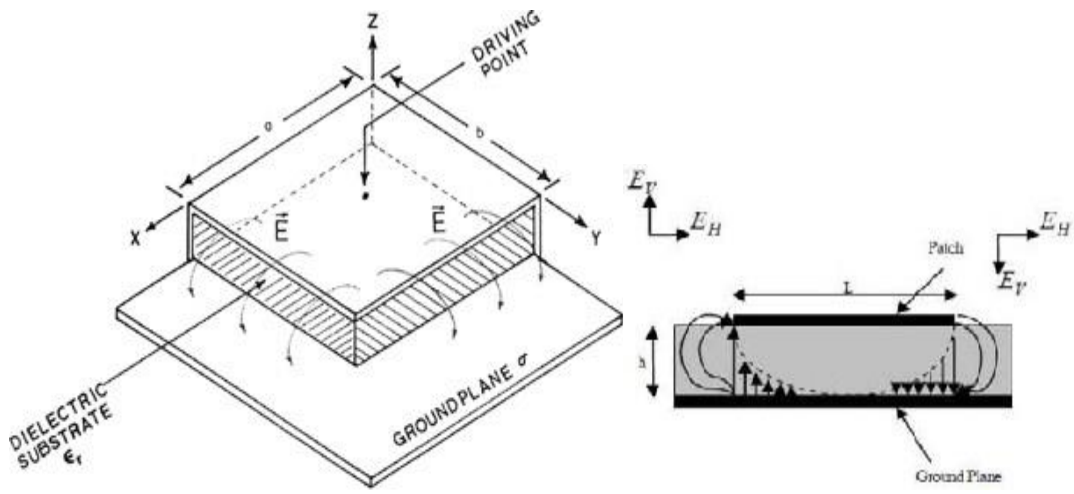


Fig2.8 Radiation Mechanism of MPA's[9]

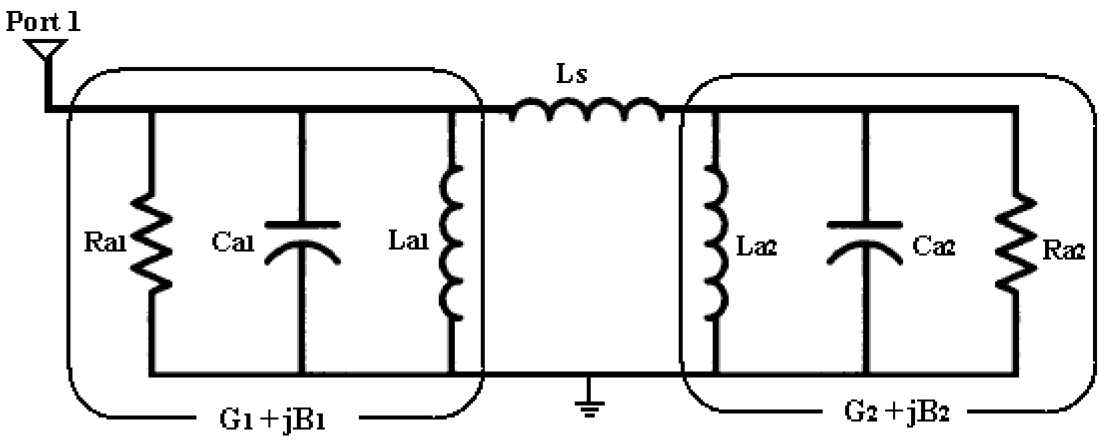


Fig2.9 Equivalent Circuit of MPA's[9]

2.8 PARAMETERS OF ANTENNA

2.8.1 Return Loss

This is the best and convenient method to calculate the input and output of the signal sources. It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the 'Return loss'.

2.8.1 Gain and Directivity

A performance parameter which describe an antenna for an application is the radiation pattern generated by the antenna. It is a capability of antenna which describe how antenna radiated energy through all directions. Radiation pattern measurement is done in dB scale and it refers to a direction in which antenna radiation maximally. The directivity for antenna can be defined as the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged in all the directions. Gain can be defined as the amount of energy taken in the reference of the energy radiated by an Omni-directional antenna.

The directivity of the antenna depends on the shape of the radiation pattern. The measurement is done taking a reference of isotropic point source from the response. The quantitative measure of this response is known as the directive gain for the antenna in given direction.

2.8.2 Radiation Pattern

Micro-strip Patch Antennas radiates because of discontinuities on the edges of the radiating patch. Gap between the edge of radiating of Micro-strip Patch Antenna and the ground plane also contributes to the radiations. Radiations intensities at different angles can me measure. MPAs has radiation patterns that can be calculated easily using anechoic chamber setup for accurate calculation of the pattern for the patch antenna. A two dimensional view of radiation pattern is shown in the figure 2.9 below.

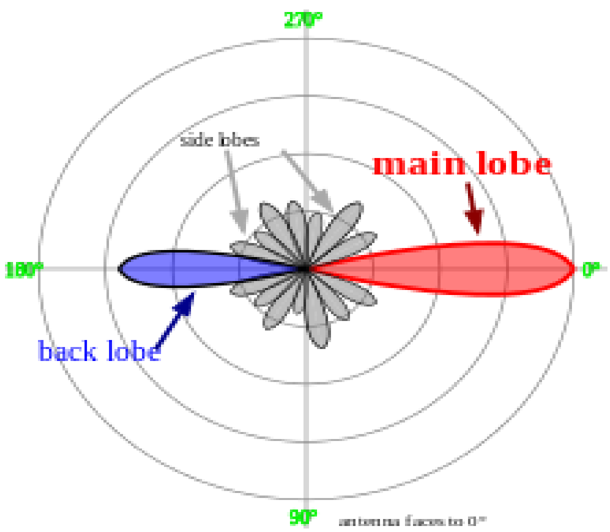


Fig 2.9 Radiation Pattern of an antenna

2.8.3 VSWR

Power transfer of an optimum amount between any transmitter end and the receiver end is really important for information transfer. In a communication module this is possible only when there is an impedance match is acquired by the both the ends impedances. Usually an impedance of 50 Ω is kept on the terminals and Smith chart technique is used to perform impedance matching.

To achieve the antenna configuration in such a way where power transfer is made to obtain an optimum value there is some portion of power which gets reflected and leads to create voltage standing waves, in the antenna theory it is described by voltage standing wave ratio(VSWR).

LITERATURE SURVEY

2.1 INTRODUCTION

It was essentially important to have a thorough understanding of Microstrip patch antennas and technology involved in the design of microstrip antenna's before starting this thesis. Major source of important information for thesis has been the online available books, journals, research papers etc. The main area in the reading literature review is the design methodologies of Microstrip patch antenna design and its parameters. Parametric variations in the microstrip patch antennas to improve their performance are also a concern of reviewed literature. Research paper literature review is being presented here in this chapter.

2.2RESEARCH PAPER LITERATURE REVIEW

Whenever we start a new work or a project it is better to have a clear understanding of the involved technologies and different aspects of the project such that it prevents a researcher undergo unnecessary complexities and failures. Reading research papers related to microstrip antenna design was very helpful in performing this task of designing antenna.

Initially microstrip radiator was introduced in year 1953 by Deschamps. Gutton and Bassinor had a patent over this mechanism in1955.however it took more than 20 years to fabricate antennas of this radiation mechanism. Till year 1970 where everybody was looking for the miniaturization of electronic circuits and large-scale integration microstrip antennas were being manufactured at a very small scale. Development of such antennas accelerated when there were inventions of substrates with good thermal and conducting properties. These substrates process a good radiating characteristic. Improved monolithic fabrication technique helped this area grow. Extensive research and development took place in this domain to exploit the advantages of such antennas in different industry levels like defense. First microstrip antenna was practically developed by Howell [1] and Munson [2] After few years Micro-strip Patch Antennas proved their importance in the applications where low-profile antennas are required and after that these antennae were used for many commercial and defense applications.

This paper[3] offers a clear understanding of input impedance and associated performance parameters like return loss and radiation pattern form the inset fed microstrip patch antenna. A shifted squared cosine variation describes the resonant input resistance at the edge of microstrip radiator with the variation of feed location for a given substrate and a particular geometry. Parameter variation takes place with the notch width and patch shape.

This paper [4] discusses about Micro-strip Antennas being operated at GPS and Bluetooth communication frequency range. Microstrip antenna structure consists of an appropriate substrate with a suitable height with top and beneath a patch of good conducting material. Microstrip patch is being excited by a coaxial connector. Geometrical parameters are decided upon the range of operation frequency. Bandwidth provide at both the bands is not wide therefore to improve bandwidth substrate parameters are altered. To achieve the impedance matching and a decent gain at both the radiating frequencies relative position between the parasitic patch and the patch at the bottom is varied.

In general[5], MPA’s has a drawback of lower gain values, lower efficiency and narrow bandwidth. Therefore, to get enhancement in the bandwidth of MPA’s different heights of substrate is being used and corresponding bandwidth increment is observed.

This paper[6], evolves and understanding of the reader towards the bandwidth improvement of the conventional microstrip patch antennas on comparatively thin substrates. Modern techniques are adopted like L-probe feed, Inverted patch structure with air filled dielectric and slotted patch. The impedance bandwidth of proposed antenna is 22%. Antenna is suitable for an application of the frequency range 1.84-2.29 GHz. Therefore, it can be said that proposed antenna provides a broadband in comparison with the conventional Microstrip Patch Antenna. Air gaps are very common to use in Microstrip Patch Antennas in present days. Though in earlier days it was not easy to fabricate antennas with air gap but now it is possible.

This paper [7] explains different design aspects of a high gain L-shaped Microstrip Patch Antenna printed on FR-4 substrate. The geometry possesses a dimension of 60 X 70 and a height of 1.6 mm. The dual band operation nature of antenna is obtained by creating L-shape slots. Designed antenna is then simulated using CST microwave studio 2010.It can be observed from simulated results that antenna is working in the frequency range of 5.0 GHz to 6 GHz. A maximum gain of 8.4 dBi and 7.1dBi is achieved respectively in the lower and higher frequency regions.

A Microstrip Patch Antenna[8] with single band frequency operation is discussed in this paper. Direct strip line feed is compared with coaxial line feed technique. Comparison in the paper provides a clear understanding that coaxial feed is better as using this provides better gain, lower values of return loss. Bandwidth comparison is also done for both the feeding techniques and results shows that coaxial fed antenna gives better bandwidth over direct strip line feed antenna.

First two basic geometries [9] used in microstrip patch antenna design is rectangular and circular shapes. The reason behind keeping geometry simple is ease of fabrication there for mostly for the application these antennas are used. Different characteristics offered by these antennas like dual band operation, frequency agility, feed line flexibility, beam scanning in the desired angles is the advantages of these Microstrip Antennas. Generally the directivity of the circular patch antennas are rather better than the rectangular Patch Antennas, therefore circular shape Patch radiators are used widely.

An inset[10] feed Microstrip Patch Antenna is designed for dual frequency operation .Impedance matching is obtained using the standard smith chart method. Impedance matching is done to improve the power transfer to the antenna at the input. Parameters of antenna like length, width and inset depth are tweak to obtain the desired range of frequency for many applications. Antenna width decides the operational frequency whereas the length of the antenna is a controlling parameter for the resistance value. A gain of 7.2 dBi is measured with a decent bandwidth of 1.4 GHz.

In this paper[11] design of an aperture coupled antenna is presented for a frequency lying in X-band range therefore can be used for wireless communication applications. Paper describes the design consideration for the aperture coupled antenna. An aperture coupled antenna consists of two substrate layers with different heights. Here for ease of design same substrate is used in both the layers with two different heights of 0.762 mm and 0.508 mm. Dielectric constant for the substrate used is 3.2.Simulation the antenna design on the software platform giving a Gain of 7.3 dBi. Parametric variation is performed to enhance the bandwidth of the antenna.

This paper [12] represents comparison of a simple aperture coupled antenna and another antenna with fractals on it. These antennas are design for a frequency range of almost 5.7 GHz to 5.875 GHz. Two different substrates of heights h1=1.6 mm and h2=0.8 mm is used. Dielectric constants for the two substrates are 4.3 and 2.2. Designed structure is then simulated on CST Microwave Studio software and a gain of 5.7 dBi is obtained with a size reduction of 22.9 %. Therefore, size miniaturization is claimed in the paper. Frequency of operation is around 5.8 GHz therefore antenna can be used in the RFID applications.

A simple aperture coupled antenna is presented [13] in this paper. Later parametric simulation is performed to enhance the performance parameters of the antenna. Antenna is designed for a frequency of 2GHz.Rectangular geometry for the radiating patch is preferred with a dimension of 48 mm width and 66 mm height. Two substrates are used with the dielectric constants of 1.07 and 4.4 with two different thicknesses as 1.58 mm and 1.7 mm. Simulation the design on the CST Microwave studio provides a main lobe gain of 8.185 dBi. Different parameters are to be tweaked to get the desired performance parameters.

This paper presents [14] design of an aperture coupled antenna with substrate having dielectric constant 3.5, ROGERS RT6035.Radiating and parasitic patches are kept at heights of 1 mm and 3 mm respectively with the reference of the plane which consist the feed line. Input impedance of the antenna is optimized to a value of 50 Ω. The structure is supported using foam in the bottom. Operational frequency is at 14 GHz. Therefore, the designed antenna can be used in the satellite communication application. A gain of 8.2 dBi is observed with a fractional bandwidth of 33.2 %.

Proposed antenna [15] is an array of 2 X 1. It consists of two aperture coupled antennas with an Wilkinson power divider network. Designing of the antenna is having two substrate model of the aperture coupled antenna. Bottom layer substrate is Rogers 4003C with a height of 0.508 mm and bottom side layer of the antenna uses the standard substrate of Rogers 5880 with a height of .508 mm. Dielectric constant of both the dielectric is not same and which is having a value of 4.4 and 2.2 respectively. Designed antenna is a very low-profile antenna because of the height values taken for the antenna. Because of this feature of antenna, it can be used in the defense applications. Antennas elements are connected using basic Wilkinson power divider.

This paper [16] describes the design and discuss the simulation results of an aperture coupled antenna with defected ground structure for wireless applications. A microstrip line of quarter wavelength is being used for the feeding purpose. Antenna operates at a frequency of 2.5 GHz. This type of technique for feeding is used to get higher impedance match at the input of antenna Defected ground structure is used for betterment of bandwidth achieved from conventional antenna. A improvement in bandwidth and a gain value of 7 dBi is obtained.

In this paper [17], an ideal triple frequency monopole antenna is designed and simulated. At the ground plane of the antenna a structure of dual L-shaped strips is etched. Antenna is fed by a crossed microstrip line. DGS on the ground plane provides additional resonance points in the return loss graph, or in the bandwidth of the antenna an improvement is observed and the gain of the antenna increases with the use of DGS. Antenna acquires an area of 20mm X 30 mm. It can be used in the ISM band frequency range of applications. When compared to conventional antenna the results measured in case of DGS are far better.

An antenna [18] with DGS is presented in this paper with enhanced bandwidth and gain. Antenna with a fractional bandwidth of 31% is designed. Designed antenna offers a double frequency operation. Antenna is simulated using CST Microwave Studio and tested with anechoic chamber and VNA.

This paper presents [19] an efficient design of an aperture coupled antenna with high front to back ratio and better polarization purity. From the conventional design, this antenna is different because it uses a quarter wavelength chock which is being added to the antenna to improve the front to back ration. Proposed antenna is occupying very small area therefore miniaturization is achieved in the antenna. Front to back ratio of 22 dB and cross polarization below -44 dB is obtained as the measured result of the antenna. When antenna without chock or conventional antenna is compared with the antenna with the chock added 27 % increase in bandwidth is obtained.

Objective of this paper [20] to make a clear understanding over the use of DGS in Microstrip Patch Antennas. DGS structures provides and effective and improved fractional bandwidth. For the application where double frequency operation is required defective ground structures are applied over the patch of microstrip patch antennas. Use of DGS enables polarization purity increment therefore; antennas with DGS structures can be used in transceivers applications.

4

DESIGN OF MICROSTRIP FED APERTURE COUPLED ANTENNA WITH DEFECTIVE GROUND

This Chapter describes the design methodology of micro-strip fed aperture coupled antennas with different defective grounds consisting of circular slot.

4.1 MICRO STRIP FED APERTURE COUPLED ANTENNA

Micro-strip fed aperture coupled antenna presented here, with defective ground possess a decent impedance matching. This antenna provides a worthy wide bandwidth over the frequency range from 6.1 GHz to 9.2 GHz which lies in the range of C and X band of standard classification. Above antenna can used for the application in radar, microwave relays etc. Software platform used for the antenna design used is Agilent ADS (Advanced design system tool). Micro-strip fed line of 50 Ω is designed using parameter variations in length and width of micro-strip line. Design of the antenna and effects of slots in the ground plane is discussed with the other parameters on the antenna performance.

4.1.1 ANTENNA DESIGN AND ITS WORKING PRINCIPLE

Fig.4.1 describe the design of proposed antenna. Substrate used for the antenna is FR-4 with a standard height of 1.6 mm. It is a multilayer design in which bottom layer of substrate having a thickness value of 1.6 mm consist of a copper patch on the top with dimensions of 20 mm length and width, both equal. Underneath a micro-strip line of 50 Ω is etched. This is the first layer of the design. In second layer same substrate with a height of 1.5 mm having a patch of length 15 mm and width 15 mm designed.

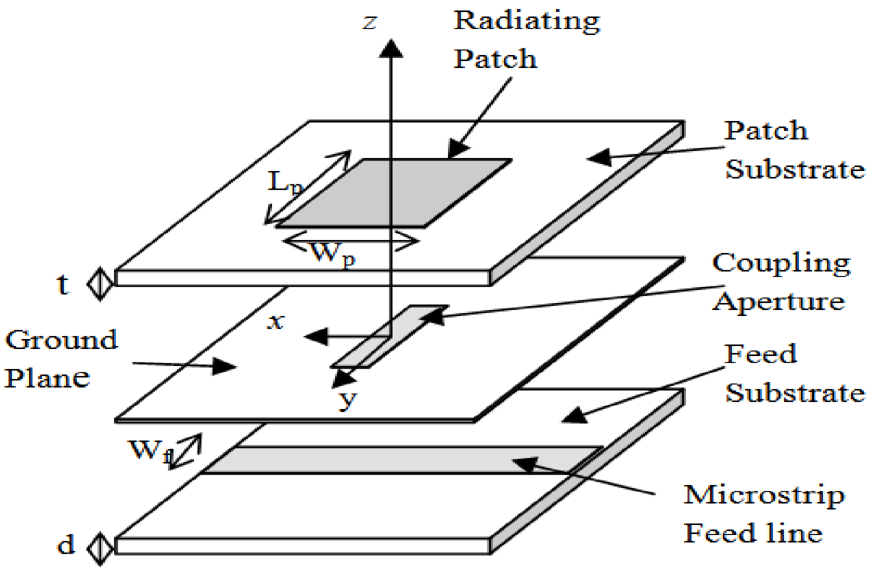


Fig.4.1 Basic structure of aperture coupled antenna

Physical parameters (Length and Width) of micro-strip line which is being used underneath the first substrate layer to feed antenna with an impedance of 50 Ω is obtained from a software utility provided in Agilent ADS. Feed line is used to provide an impedance matching of 50 Ω such that an optimum amount of power can be fed into the antenna for higher power requirement applications. A standard height of substrate of 1.6 mm from ADS directory is used. Above this substrate a patch of length of 20 mm and width of 20 mm is etched with a thickness of 35 micron. This patch layer of a suitable conducting material like copper is referred as ground for the antenna structure and excitation to antenna is setup taking this plane a reference. For second layer, same substrate is used with a height of 1.5 mm. Top of this substrate consist of a patch of good conducting material of square dimensions of 15 mm. Dimensions parameters of patch decides operating frequency, radiation resistance, therefore for a frequency of operation, appropriate dimensions are calculated from formulas. An aperture in the ground plane is cut of rectangular geometry. Shape of aperture is kept rectangular for ease of calculations of frequency and bandwidth.

4.2.2 DESIGN OF COVENTIONAL APERTURE COUPLED ANTENNA

Feed line parameters as length L_f width W_f obtain an optimum value of 24.4 mm and 2.262mm. Stub length is kept as 3.8 mm. Stub length is usually kept as $\lambda/4$.Therefore for antenna operating at a frequency of comes out as above value. Ground plane is kept in square shape and dimension is kept as 20 mm for length and width. An aperture with rectangular geometry is cut into the ground plane with a length of 7.2 mm and width of 1mm.

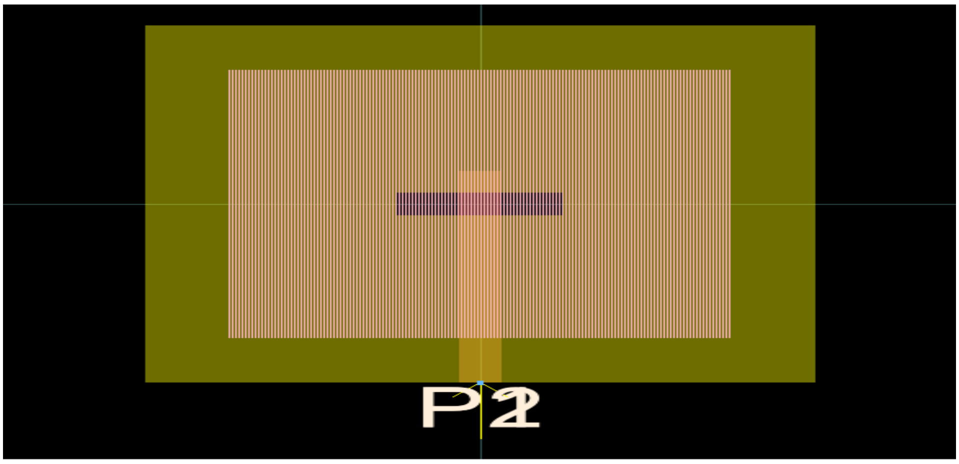


Fig 4.2 Design of conventional aperture coupled antenna

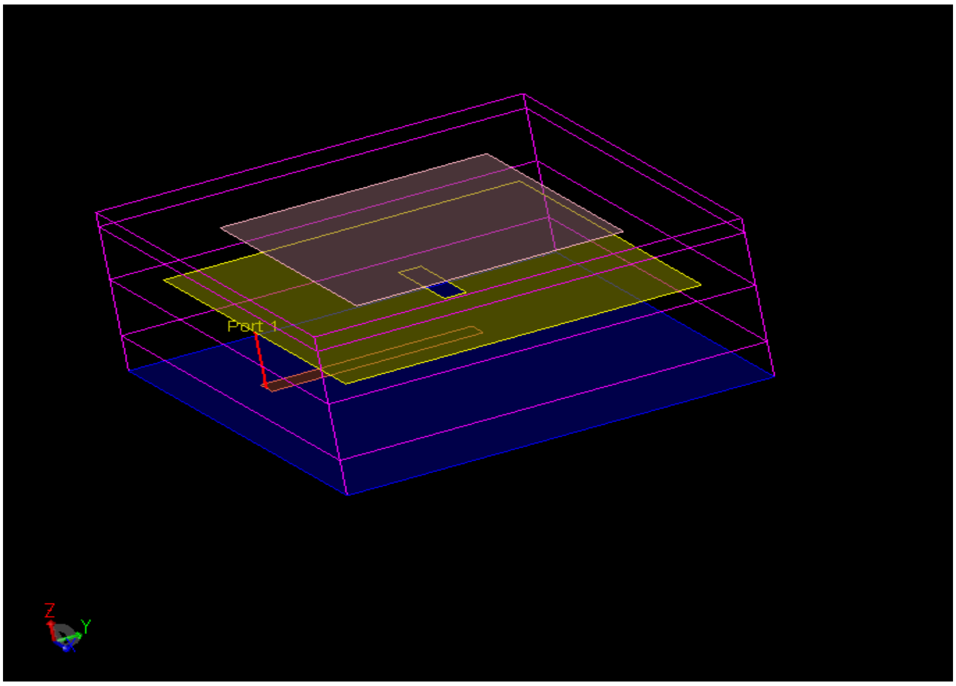


Fig4.3 3D view of conventional aperture coupled antenna

In conventional aperture coupled antenna input is excited through a microstrip feed which is at the bottom of the lower substrate layer. On the top of this layer a conductor plane with an aperture is etched, which is called ground plane for the structure. A view of substrate layers and conductor layers is being shown in the figure below.

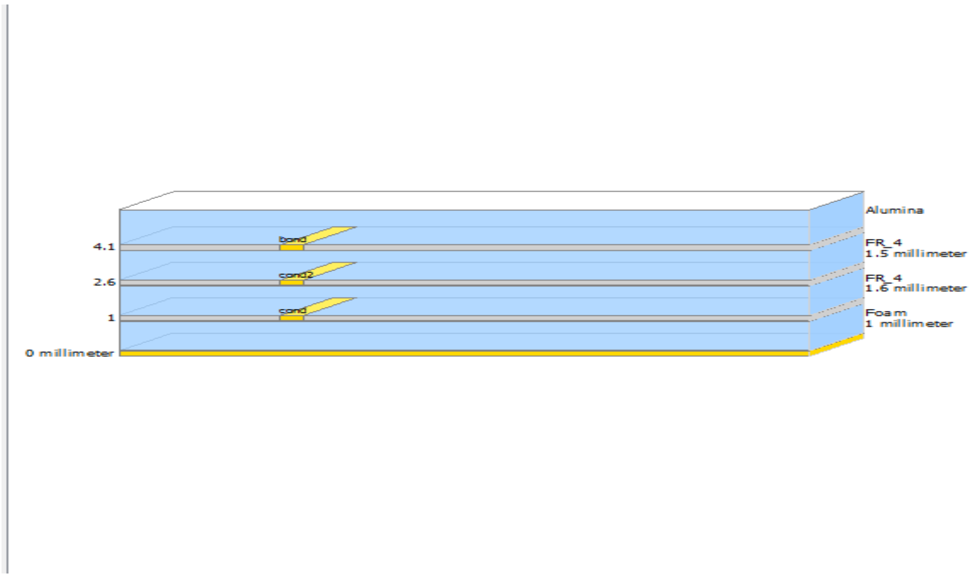


Fig4.4 Substrate view for proposed antenna

4.2.3 DESIGN OF APERTURE COUPLED ANTENNA WITH DGS

Fig.4.1 describe the design of proposed antenna. Substrate used for the antenna is FR-4 with a standard height of 1.6 mm. It is a multilayer design in which bottom layer of substrate having a thickness value of 1.6 mm consist of a copper patch on the top with dimensions of 20 mm length and width, both equal. Underneath a micro-strip line of 50 Ω is etched. This is the first layer of the design. In second layer same substrate with a height of 1.5 mm having a patch of length 15 mm and width 15 mm designed. parameters (Length and Width) of micro-strip line which is being used underneath the first substrate layer to feed antenna with an impedance of 50 Ω is obtained from a software utility provided in Agilent ADS. Feed line is used to provide an impedance matching of 50 Ω such that an optimum amount of power can be fed into the antenna for higher power requirement applications.

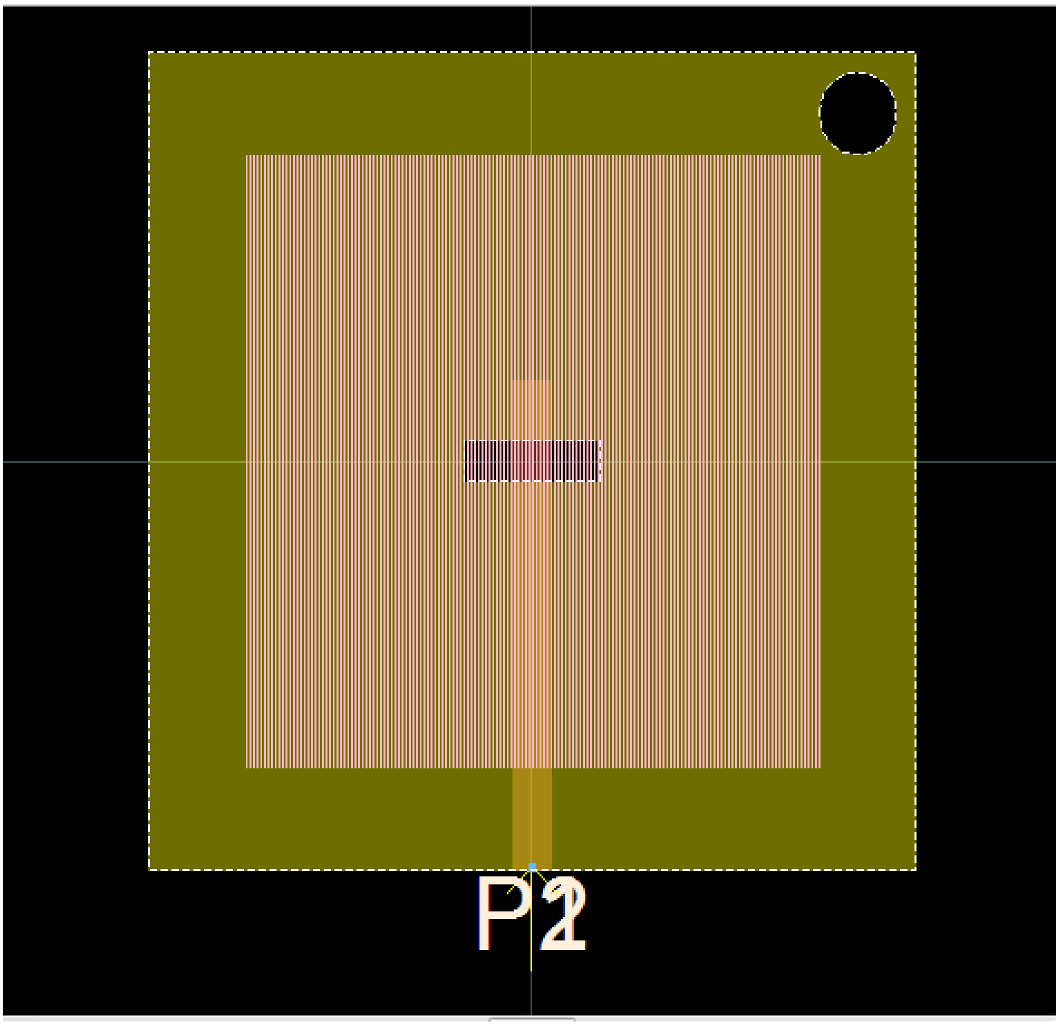


Fig4.5 Aperture coupled Antenna with DGS (single circular slot)

A scaled view of the Aperture Coupled Antenna with single circular slot is being shown below. Both the layers of substrate is having a dielectric constant of 3.2 but are of different heights.

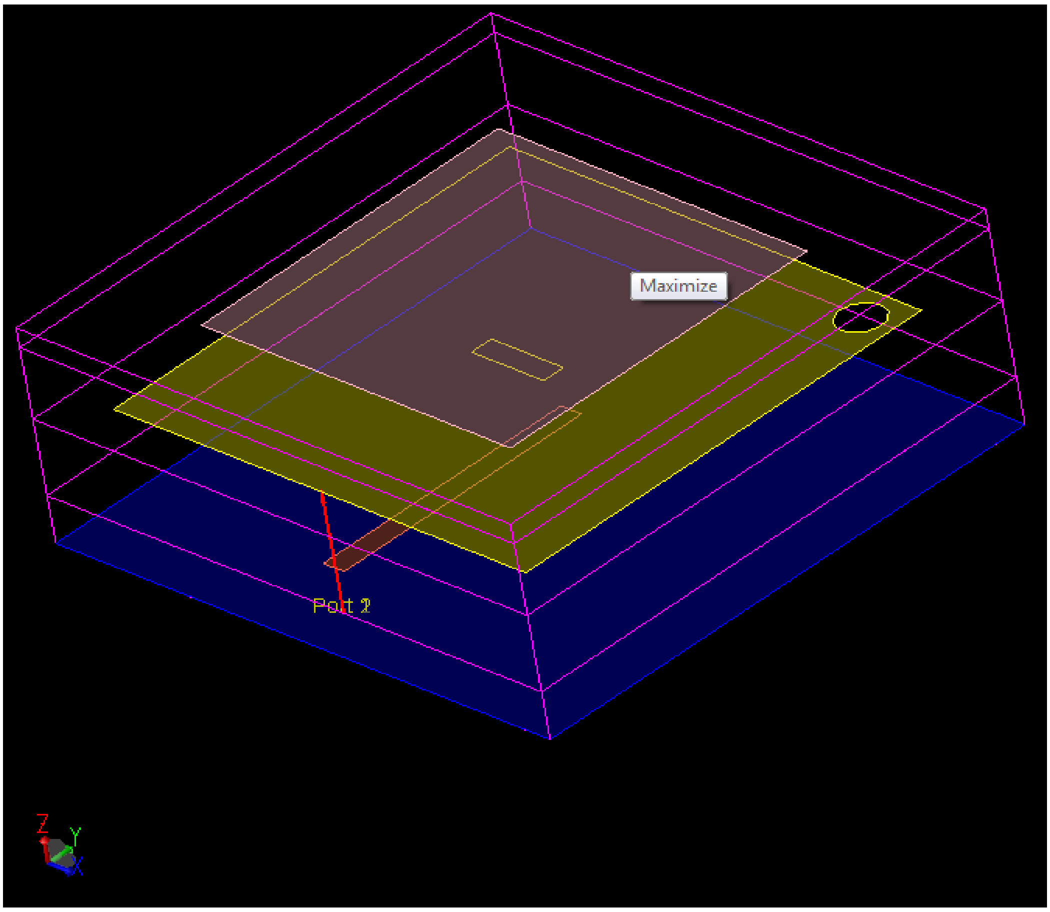


Fig4.6 Aperture Coupled Antenna with DGS (single slot)

Defective ground structure is used in the Microstrip Patch Antennas to improve the performance parameters of antenna like bandwidth, gain. Therefore, above Aperture Coupled Antenna is having a circular slot in its ground plane at a location 1 mm away from its both the edges.

4.2.4 APERTURE COUPLED ANTENNA WITH DOUBLE CIRCULAR SLOT

An Aperture Coupled Antenna is designed using the same dimensions and other physical parameters but with double circular slots. Circular slots are created in the ground plane with a radius of 2 mm and they are on the diagonally opposite of the rectangular radiating patch. Creating the slots on the ground plane at diagonally opposite locations improve the bandwidth of the antenna which will be discussed in the next chapter.

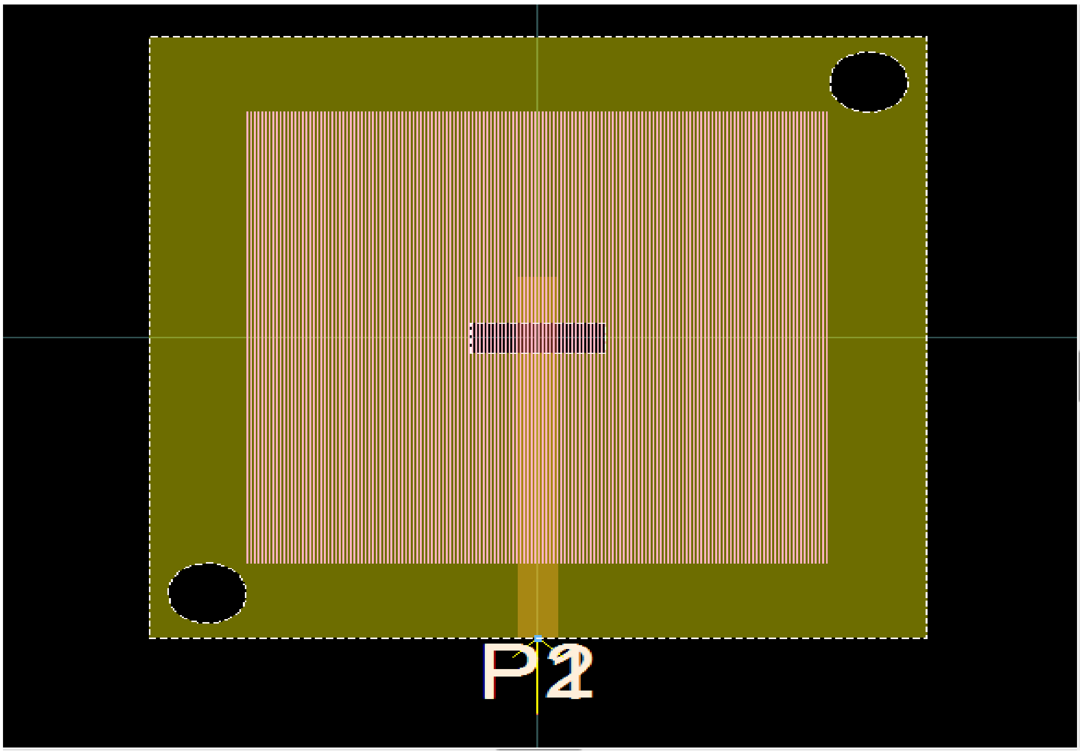


Fig 4.7 Aperture Coupled Antenna with double slot

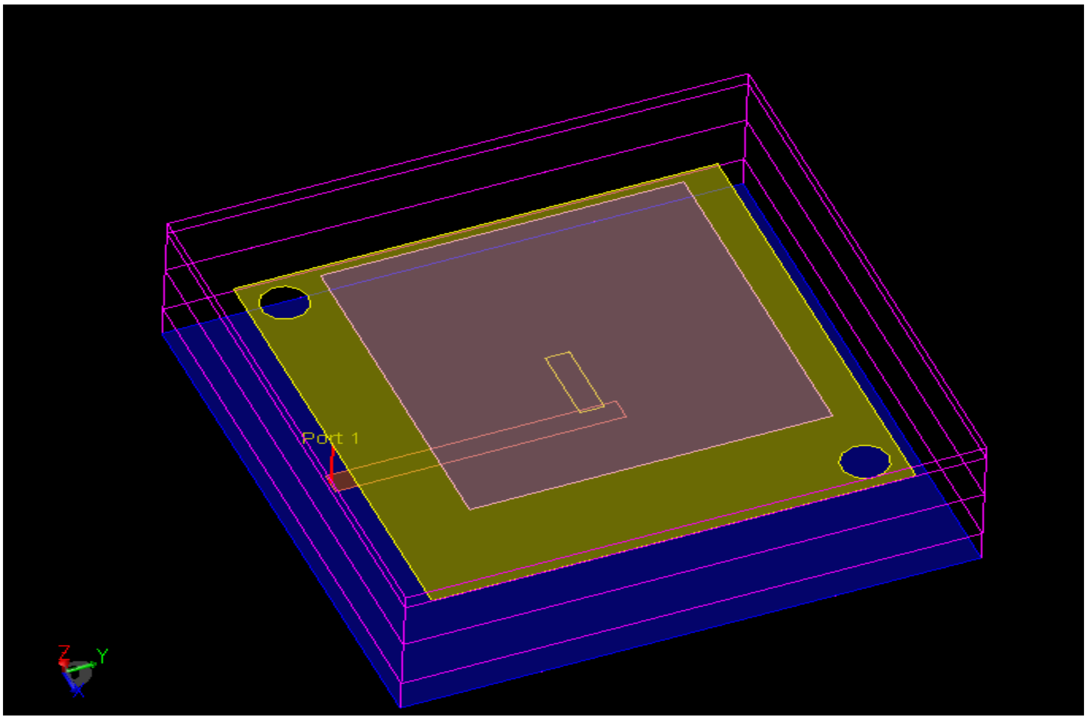


Fig 4.7 Aperture Coupled Antenna with double slots

4.2.5 APERTURE COUPLED ANTENNA WITH FOUR SLOTS

An Aperture Coupled Antenna is designed using the same dimensions and other physical parameters but with double circular slots. Circular slots are created in the ground plane with a radius of 2 mm and they are on the diagonally opposite of the rectangular radiating patch. Creating the slots on the ground plane at diagonally opposite locations improve the bandwidth of the antenna which will be discussed in the next chapter.

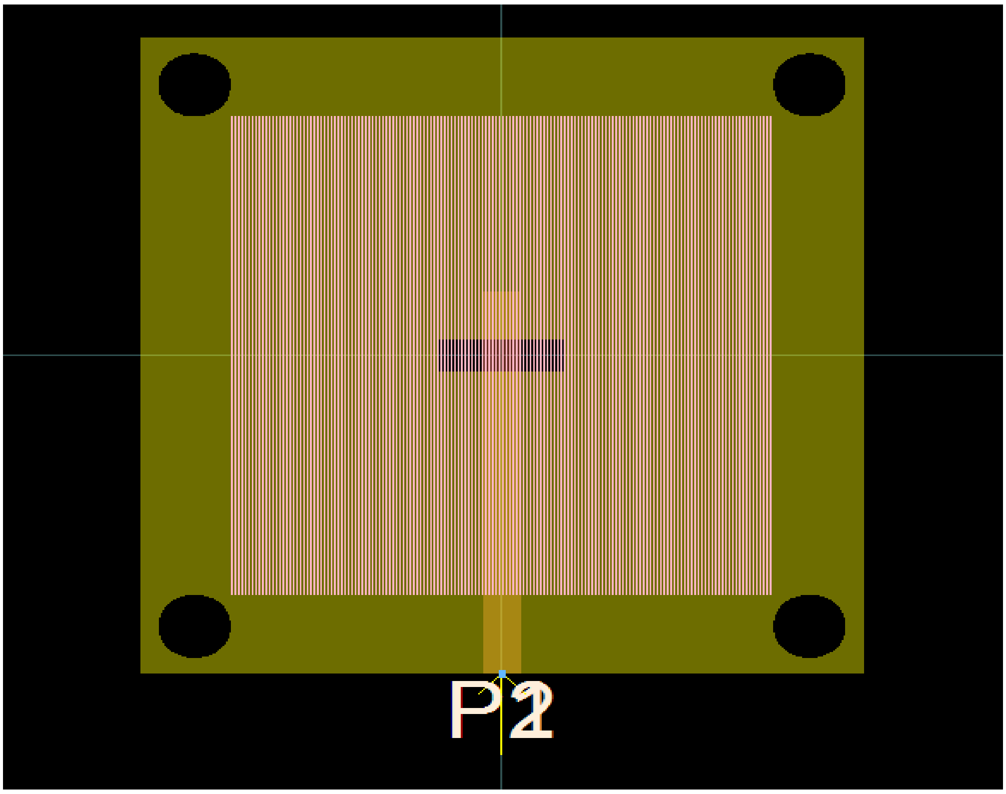


Fig 4.8 Aperture Coupled Antenna with four slots

A standard height of substrate of 1.6 mm from ADS directory is used. Above this substrate a patch of length of 20 mm and width of 20 mm is etched with a thickness of 35 micron. This patch layer of a suitable conducting material like copper is referred as ground for the antenna structure and excitation to antenna is setup taking this plane a reference. For second layers, same substrate is used with a height of 1.5 mm. Top of this substrate consist of a patch of good conducting material of square dimensions of 15 mm. Dimensions parameters of patch decides operating frequency, radiation resistance, therefore for a frequency of operation, appropriate dimensions are calculated from formulas. An aperture in the ground plane is cut of rectangular geometry. Shape of aperture is kept rectangular for ease of calculations of frequency and bandwidth. Feed line parameters as length Lf width Wf obtain an optimum value of 24.4 mm and 2.262mm. Stub length is kept as 3.8 mm. Stub length is usually kept as λ/4.Therefore for antenna operating at a frequency of comes out as above value. Ground plane is kept in square shape and dimension is kept as 20 mm for length and width.

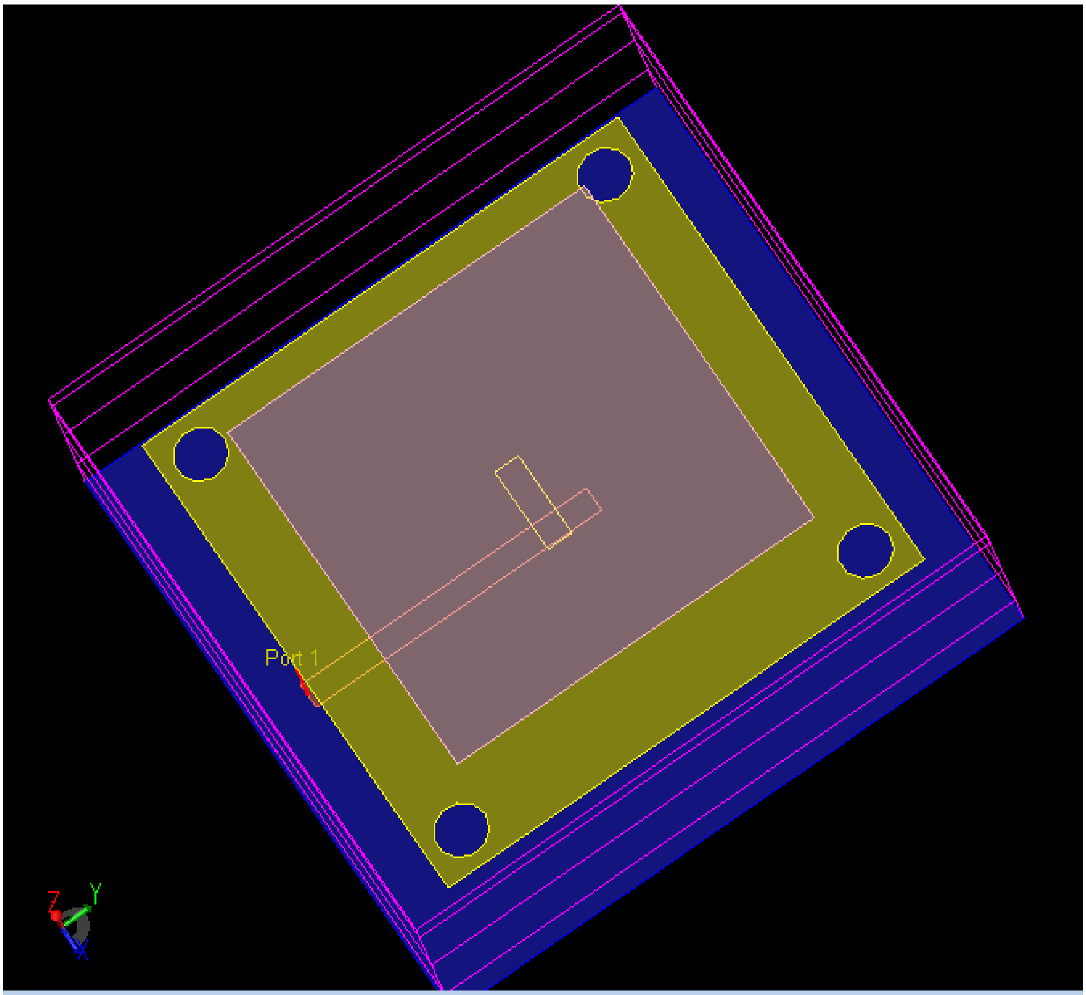


Fig 4.9 Aperture Coupled Antenna with four slots

An aperture with rectangular geometry is cut into the ground plane with a length of 7.2 mm and width of 1mm.Defective ground structure is used in the Microstrip Patch Antennas to improve the performance parameters of antenna like bandwidth, gain. Therefore, above Aperture Coupled Antenna is having a circular slot in its ground plane at a location 1 mm away from its both the edges.

RESULTS AND DISCUSSION

5.1 RESULT DISCUSSION OFAPERTURE COUPLED ANTENNA WITH DGS AND ITS COMPARATIVE ANALYSIS WITH CONVENTIONAL APERTURE COUPLED ANTENNA

5.1.1 Simulation Results

5.1.2 S-parameters

Antenna is simulated using software platform Agilent ADS. Simulated return loss(S-parameter) are shown for the conventional designed antenna.

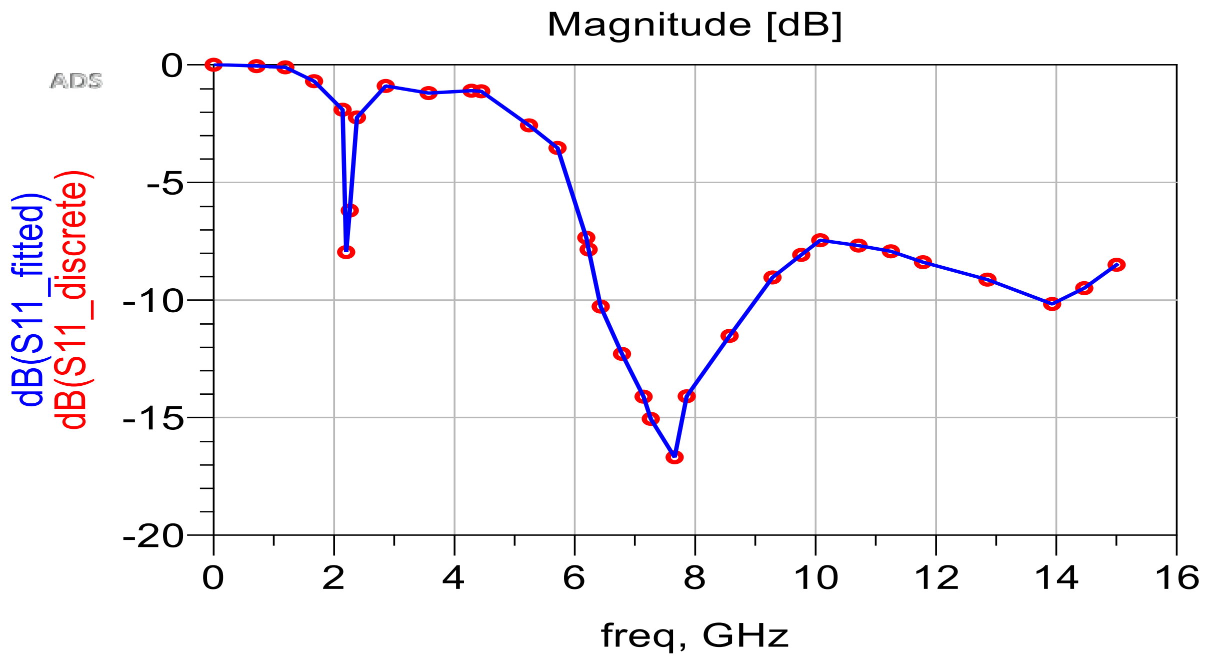


Fig5.1 S-parameter of conventional Aperture Coupled Antenna

Here conventional Aperture Coupled Antenna is simulated and a return loss value of -17.22 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 0.84 GHz. Antenna is simulated using Agilent ADS software.

S-parameters measured

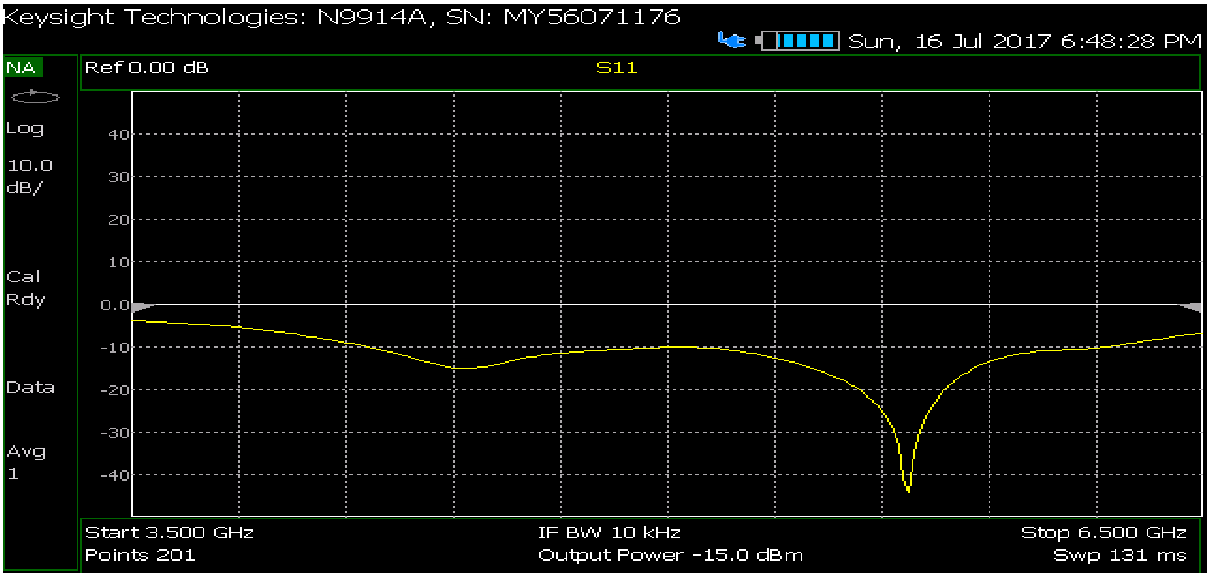


Fig 5.2 S-parameter of conventional Aperture Coupled Antenna (Measured)

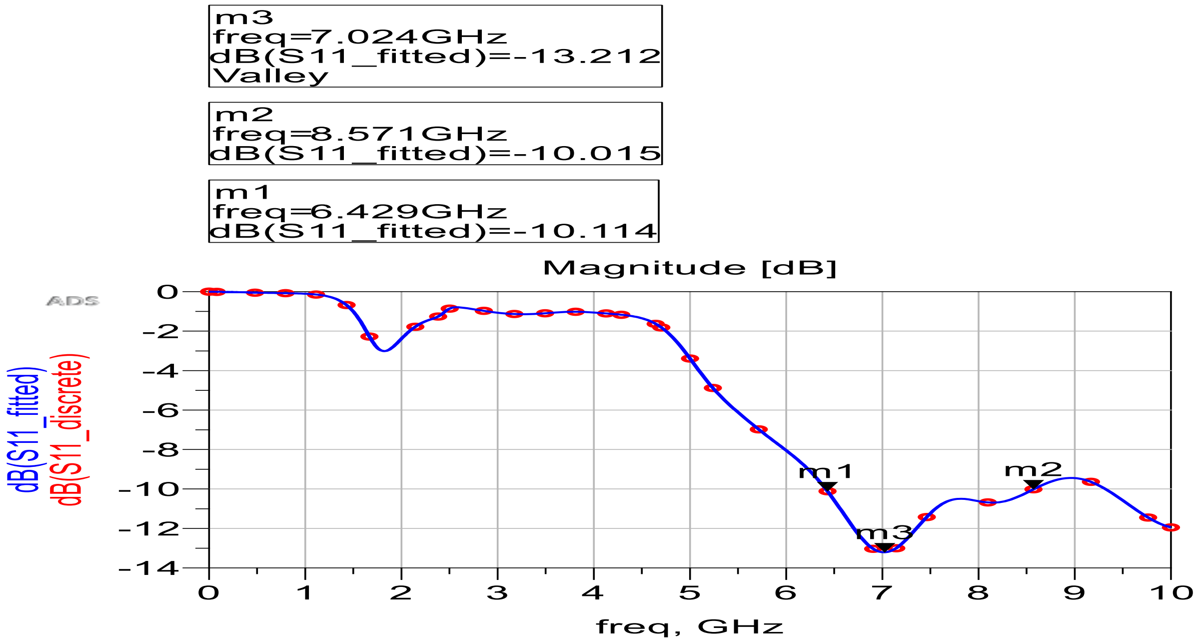


Fig 5.3 S-parameter of Aperture Coupled Antenna with single slot

Here Aperture Coupled Antenna with single circular slot is simulated and a return loss value of -13.44 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 1.01 GHz. Antenna is simulated using Agilent ADS software.

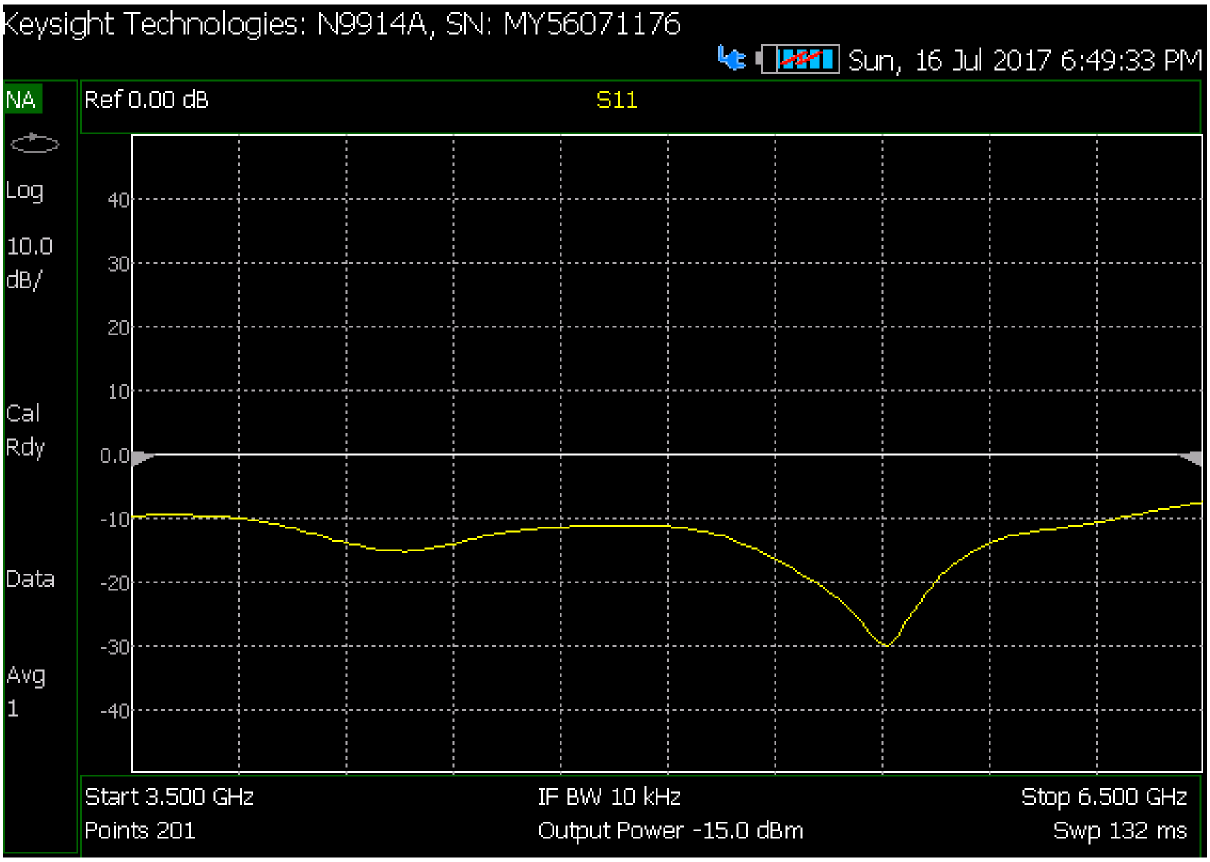


Fig5.4 S-parameter of Aperture Coupled Antenna with single slot(Measured)

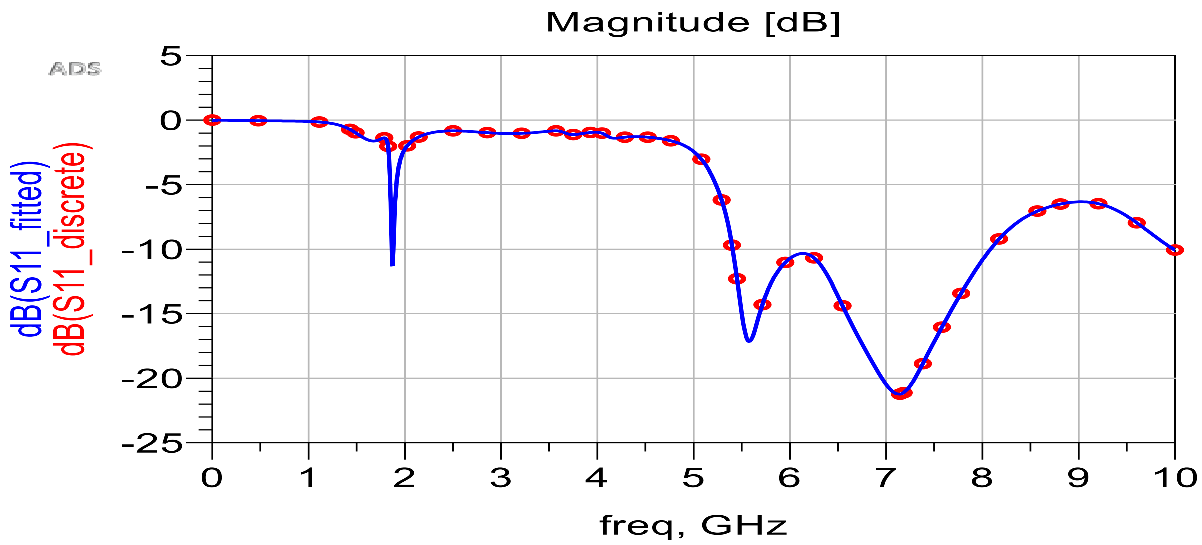


Fig5.5 S-parameter of Aperture Coupled Antenna with double slot

Here Aperture Coupled Antenna with single circular slot is simulated and a return loss value of -22.5 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 1.57 GHz. Antenna is simulated using Agilent ADS software.

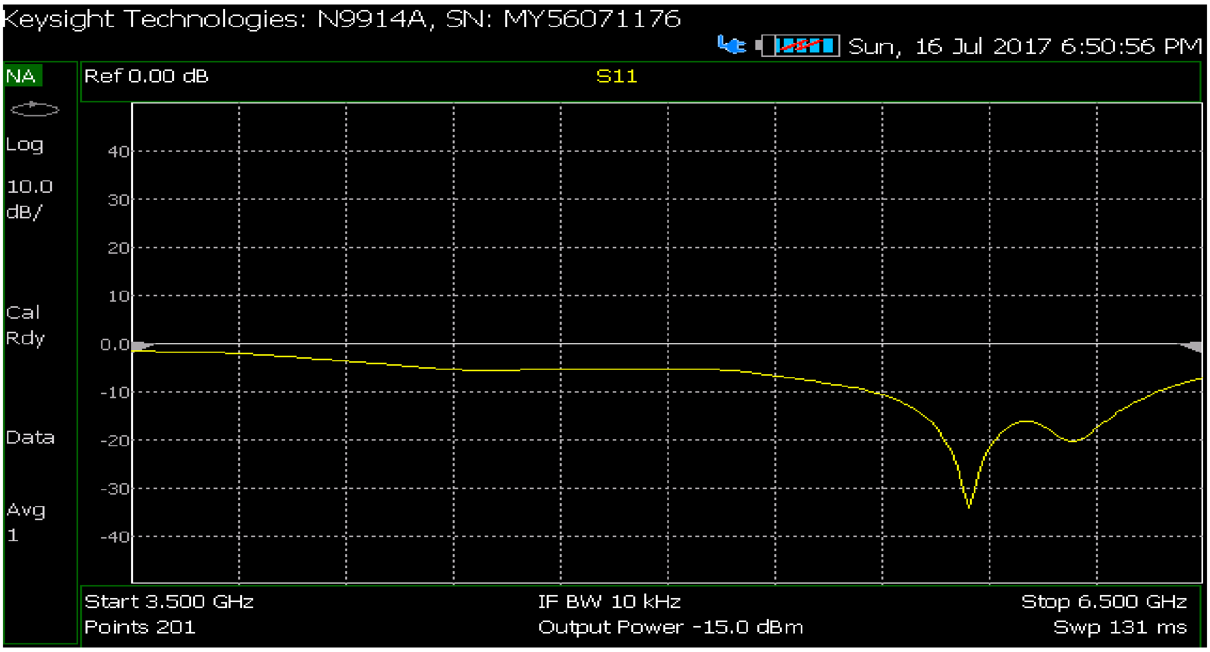


Fig 5.6 S-parameter of Aperture Coupled Antenna with double slot(Measured)

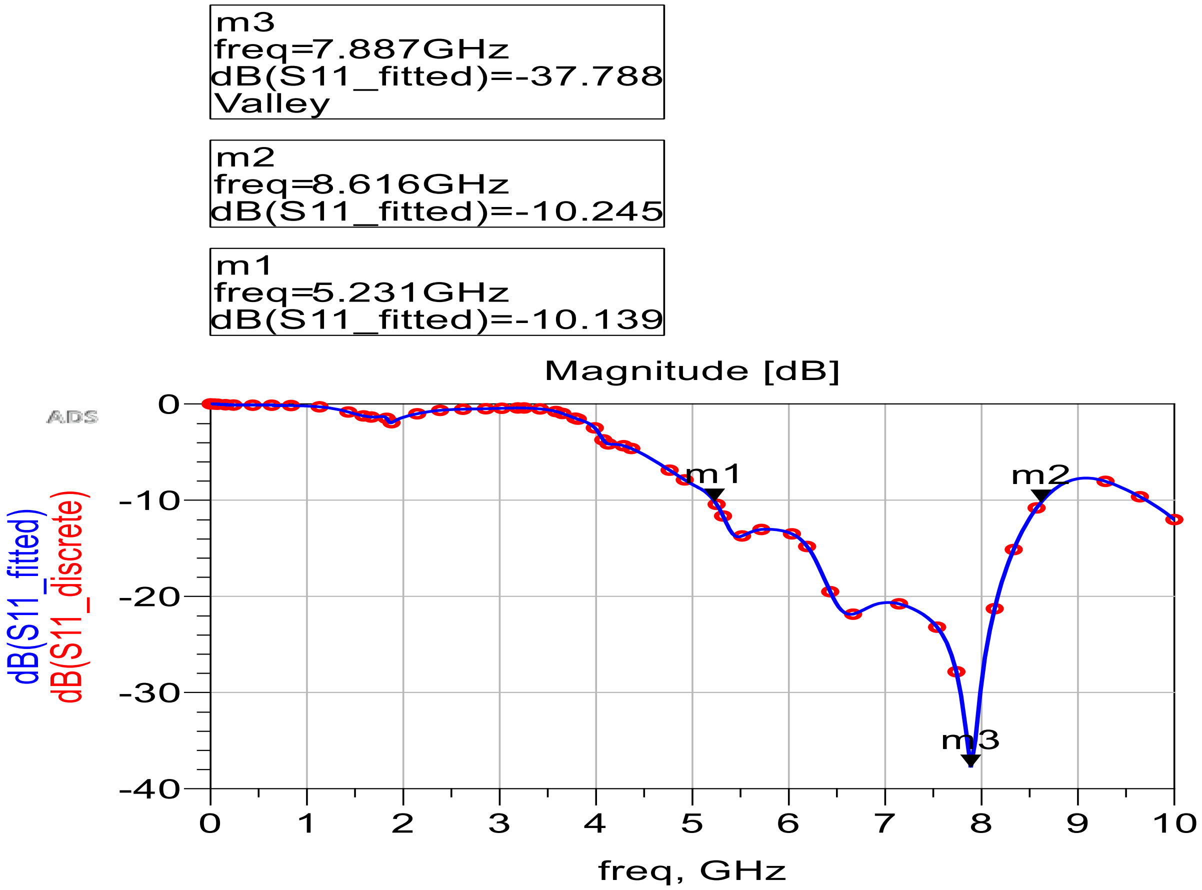


Fig 5.7 S-parameter of Aperture Coupled Antenna with four slots

Here Aperture Coupled Antenna with single circular slot is simulated and a return loss value of -35.44 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 3.2 GHz. Antenna is simulated using Agilent ADS software.

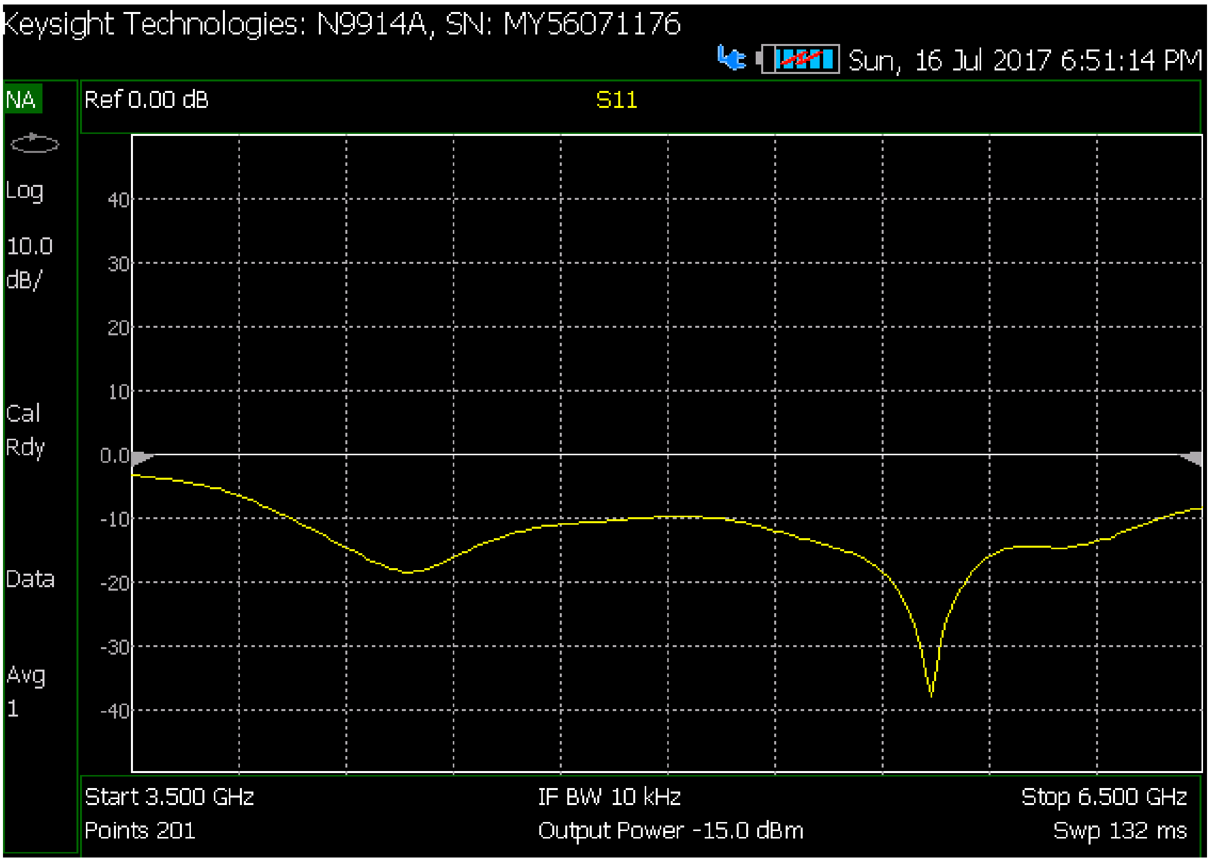


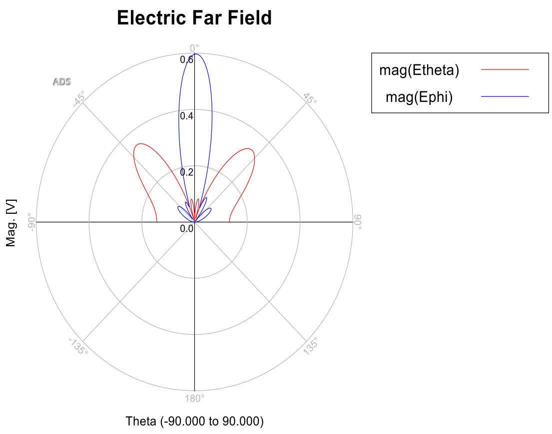
Fig 5.8 S-parameter of Aperture Coupled Antenna with four slot(Measured)

Fig 5.9 VNA measurement of fabricated antenna

COMPARATIVE ANALYSIS

Antennas with defective ground plane structure offer more bandwidth than the conventional Aperture Coupled Antenna. As can be from above graphs bandwidth is increasing with the presence of DGS.

ELECTRIC FAR FIELD



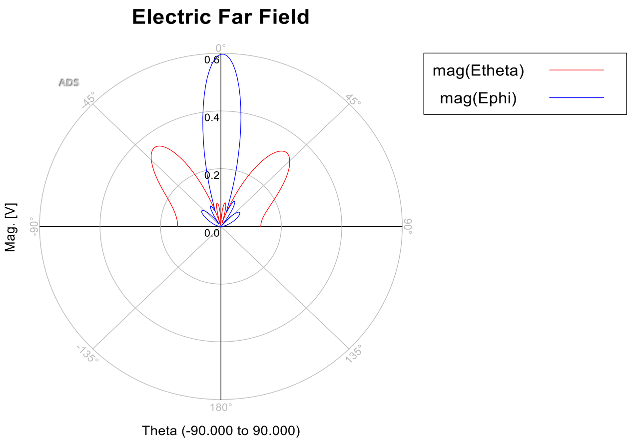
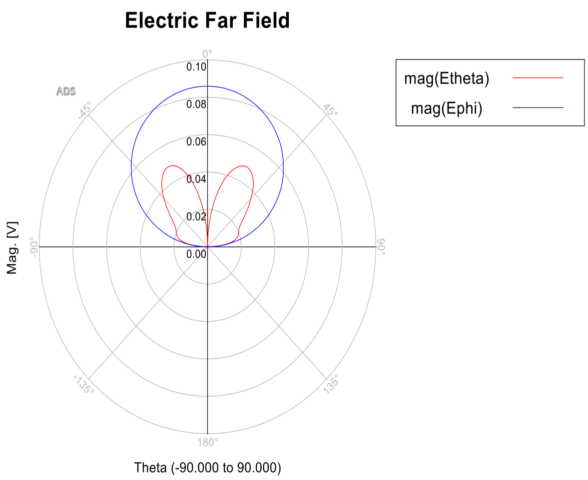


Fig 5.9 Far field for conventional design

Fig 5.10 Far field for conventional design



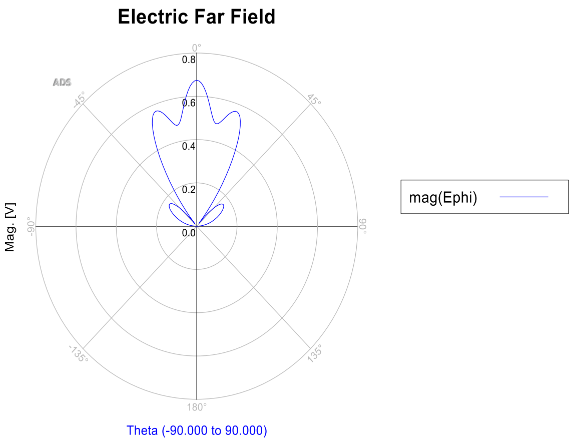


Fig 5.11 Far field for conventional design

Fig 5.12 Far field for conventional design

When comparative study is done then it is observed that electric far field is better in case of Aperture Coupled Antenna with Defective Ground Structure.

6

CONCLUSION AND FUTURE SCOPE

This chapter sums up complete work done in the thesis, and then reaches to a conclusion which would help researchers in future to further improvements in the designed antennas.

Initially a conventional Aperture Coupled Micro-Strip Antenna is designed in the frequency range of 6 to 8GHz.Required dimension for designing were obtained using fundamentals of the patch antenna design. This antenna is consisting of two layers of substrates with heights of 1.6 mm and 1.5 mm with the same dielectric constants. The substrate is chosen to form the standard library of the Agilent ADS directory. Simulating this antenna gives s-parameter value of -17.44 dB.

Further in the later chapter Aperture Coupled Antennas are designed using the defective ground structure. Substrate chosen for designing of this antenna is same as the substrate chosen for the conventional Aperture Coupled Antenna. Dimension for the antenna are chosen from the required frequency range from the fundamentals of micro-strip patch antennas. Dimensions values are very small for these antennas therefore, miniaturization is obtained. A return loss values of -33.45 dB is obtained and fractional bandwidth improvement of 57% is obtained. A comparative analysis of the different Aperture Coupled Antennas is done as they are having single circular slot, double circular slot, and four circular slots.

Comparative analysis shows that presence of the DGS structure on the ground plane improves the antenna performance parameters. Fabricated antennas can be used in the applications like WLAN and in future mobile applications.

FUTURE SCOPE

Parametric variations of the physical parameters of the antenna are manually done but, this can be done using the software.

Shapes of the DGS structure is kept circular slots but in the future to enhance the performance parameters of the antenna more geometries on the ground plane can be etched.

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CERTIFICATE

Certified that the thesis entitled *"*Design and Analysis of Aperture Coupled Antenna with defective ground*"* submitted by **Peeyush Kumar (2K15/MOC/13)** in the partial fulfillment of the requirements for the award of the degree of Master of Engineering (Electronics and Communication Engineering) of Delhi Technological university, is a record of student's own work carried under my supervision and guidance. To the best of our knowledge, this thesis has not been submitted to DTU or to any other University or institute for award of any degree. It is further understood that by this certificate the undersigned do not endorse or approve any statement made, opinion expressed or conclusion drawn herein, but approve the thesis only for the purpose for which it is submitted.

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DECLARATION

I, Peeyush Kumar bearing roll no. 2K15/MOC/13, a student of M.Tech. (Regular) of Electronics & Communication Engineering Department; hereby declare that I own the full responsibility for the information, results etc. provided in this thesis titled *"***Design and Analysis of Aperture Coupled Antenna with defective ground***"* submitted to Delhi Technological University for the award of M.Tech. (ECE) degree. I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged. I have taken care in all respect to honor the intellectual property right and have acknowledged the contribution of others for using them in academic purpose. I further declare that in case of violation of intellectual property right or copyright, I as the candidate will be fully responsible for the same, my honorable supervisors and Institute will not be responsible for the violation of any intellectual property right.

(Peeyush Kumar)

Date:
Place: Delhi

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(Peeyush Kumar)

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ABSTRACT

Aperture Coupled Micro-Strip Antenna Design and Analysis

A linearly-polarized aperture coupled patch antenna design is characterized and optimized using Agilent ADS antenna simulation software [1]. This thesis focuses on the aperture coupled patch antenna due to the lack of fabrication and tuning documentation for the design of this antenna and its usefulness in arrays and orthogonally polarized communications. The goal of this thesis is to explore dimension effects on aperture coupled antenna performance, to develop a design and tuning procedure, and to describe performance effects through electromagnetic principles.

Antenna parameters examined in this study include the dimensions and locations of the substrates, feed line, ground plane coupling slot, and patch. The operating frequency, input VSWR, percent bandwidth, polarization ratio, and broadside gain are determined for each antenna configuration.

The substrate material is changed from RT Duroid (material in nominal ADS design [1]) to FR4 due to lower cost and availability. The operating frequency is changed from 6.5GHz (specified in nominal ADS design) to 6.8GHz for wireless communication applications. Required dimensional adjustments when changing substrate materials and operating frequencies for this antenna are non-trivial and the new design procedure is used to tune the antenna.

The antenna is fabricated using 59mil thick double and single sided FR4 boards joined together with double sided 45mil thick acrylic tape. The antenna is characterized in an anechoic chamber and experimental results are compared to theoretical predictions.

LIST OF ABRIVATIONS

CPW	Coplanar Waveguide
DGS	Defected Ground Structures
MMIC	Monolithic Microwave Integrated Circuits
MPA	Microstrip Patch Antennas
PCB	Printed Circuit Board
Q	Quality Factor
RFIC	Radio Frequency Integrated Circuits
RFID	Radio Frequency Identification
S	Scattering (return loss)
TEM	Transverse Electric-Magnetic
TM	Transverse Magnetic
VSWR	Voltage Standing Wave Ratio
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

1

INTRODUCTION

1.1 OVERVIEW

Wireless communication has been an emerging field of interest all over the world in the present time. It has grown so rapidly in last couple of decades and has taken a gigantic shape of its own. All over the world possible major communication is taking place through the wireless mode. Satellite communication which is an essentially important technology aspect for any nation has been made possible because of emerging technologies of wireless communication. Recent development of modern technologies like WLAN indicates the major interests towards communication field. Extensive work is being put forward in the direction to overcome the cons of present wireless communication technology. Modern requirement in the wireless communication are the systems which can accommodate high data/information transmission rate at the same time volume of information is to be kept sufficiently enough. Modern wireless communication system requires subsystems which are cost effective and portable to facilitate the installation process over a wide range. Therefore, focus of scientific and researcher’s community is to design and develop antennas which are low profile, less bulky/less weight, and offers cost effectiveness in its use in the present international standards. Effectiveness of the performance over a wide range of frequency is a desired concern. Therefore, MPAs came into the picture because of offered characteristics like low profile, less bulky, light weight and easy to mount etc. Though there are few aspects which are not favorable for modern wireless communication systems as these antennas provide lower gain values and operation range covers a short length of frequency. Table 1-1 provides many of the wireless technologies and corresponding frequency range. International Telecommunication Union has divided the frequency spectrum accordingly for different application. These spectrum distribution is done by the ITU for different organizations at all the levels. Commercial purpose spectrum is a back bone for economy of any nation. Defense purpose frequency spectrum is kept restricted for rest of the peoples. There are frequency bands which can be used by the peoples are called license free bands.

Different Frequency Bands and Their Applications

Wireless Applications		Frequency Band (MHz)	Bandwidth (MHz)
GSM	GSM 900	890-960	70
	GSM 1800	1710-1805	95
	GSM 1900	1850-1990	140
IMT		2300-2400	100
		2700-2900	200
		3400-4200	800
		4400-4900	500
WLAN		2400-2484	84
		5150-5350	200
		5725-5825	100
Bluetooth		2400-2500	100
WiMAX		2500-2690	190
		3400-3690	290
		5250-5850	600

Table 1-1

1.2 BRIEF HISTORY OF WIRELESS COMMUNICATION

World has reached in any field of technology to a stage where even it is difficult to observe the footprints of the ancient technology which had been a start of that technology. In the present time, every day breakthrough is happening in many new directions are taking place. If we look back into the history then it is justifying saying that wireless communication was an existing technology from the time when humans were using smoke signals and pigeon carriers to communicate with each other wirelessly. These were the most basic forms of wireless communications used by humans. Very early wireless networks were coming in the picture in an era where there was industry for such networks. These early developed wireless networks then replaced by telegraph which were invented by Samuel Morse in 1938.later invention of telephone took place of these networks. Many years after of telephone networks invention Marconi introduces first radio transmission networks in 1895, this is how wireless communication came into existence largely. First packet radio based networks was developed in the Hawaii university in the year of 1971.all over the world scientists were asked to combine packet data transmission technology and broadcast radio networks inherently into ALOHANET. Through years of 1970’s and initial period of 1980's all the major defense organizations as well as the arm forces were keen interested in the above wireless networks to be used in the defense purposes. wireless networks based on data packets had been an influence on commercial domain as well.

Initially packet networks were applied in wide area networks applications in early 1990’s. There were many flaws associated with these services like low data transmission rate, high cost and an effective utilization of resources for required applications. As a far more capable technology of wireless networks in the form of cellular networks supplanted to the people, earlier used networks disappeared very quickly. Many commercial organizations coxswained there root away from the technology which was radio based on the arrival of Ethernet technology in 1970’s. In the year of 1985 federal communication commission empowered the wireless LAN’s by approving the use of commercial, scientific and medicals frequency bands for the use of these networks publicly. Present wireless LAN’s technology is based on IEEE 802.11 standard family. Ethernet networks offers a speed of around 100 Mbps and there is an easy observation that performance gap of these networks is going to be increased by the time without any extra frequency spectrum allocation. Even this is happening and seems to increase gap far more in the coming time people preferred wireless networks over the wired networks like LAN’s because of an ease of installation and use. Also, they get rid of wires.

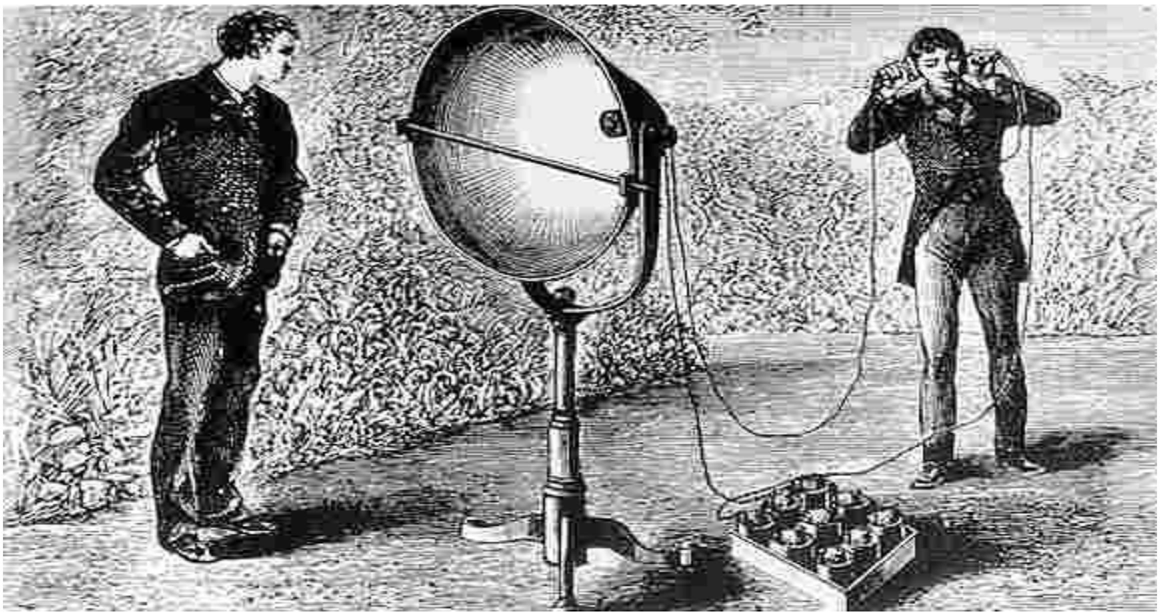
Fig1.1(Bell and Tainter's Photophone of 1980)

It is so obvious that most successful application of wireless networks is cellular communications from every point of view and in every aspect. In the modern time, cellular network providing companies has taken a shape bigger than a nation with a huge economical structure.

1.3 WIRELESS VISION

It has been a frontier in communication technology from last couple of decades. Wireless communication networks have grown very wide all over the world and assisting information transfer between the people and devices. This vision has made it possible to communicate to people around the world through a very handy and portable device and even with the different forms of the information like pictures, videos etc. Wireless entertainment facilitates people anywhere and in any corner of the world with so many possibilities of information transfer between the people. These networks help people or devices to come closer with fast growing new technologies and enormous new possibilities in near future. Wireless video conferencing opens the horizons of new possibilities in every aspect of our life like education, health, entertainment. It is such a tool which can be utilized in the field of education so effectively and a wide number of people can be covered through this technology which accounts for a great contribution towards educating and upliftment of human being all over the world. Under privileged communities can be driven towards a better future by facilitating and connecting them with people all over the world using wireless technology which is not a possible technology architecture with wired communication technologies. Therefore, wireless technology in the field of communication brings and inclusive effort towards the upliftment of human beings which is at utmost priority of any scientific venture or can be said the most effective and impactful application of any technology. In the field of medicine, it is proved to be an amazing technology tool through which people around the world can help each other in best possible way. In the modern time using video conferencing online monitoring of a patient can done from anywhere which provides any ease and operative utilization of human resources and its intellect. wireless communication technology has its another very important, which is communication through sensors. Wireless sensor technology is a rapidly flourishing technology domain for wireless communication networks. This technology has a wide range of application in almost every area from day to day life to defense application as well as in the satellite communication. Commercial implications of this technology include prevention rather an early indication from natural disasters like water level raise in the rivers beyond the safety mark. Weather forecast, situations like earthquake which can create disasters in any nation. Wireless sensors networks prevent people from natural calamities as well as it prevents and provides a sense of security over so many adverse conditions like fire hazardous in a building. Natural resources like water can be used in big organization very effectively in presence of sensor wireless networks. In modern time, our hectic life schedule will sometimes protrude difficulties in the use of natural resources and effective time management without presence of these wireless sensor networks. To bring a clear understanding and ease of operations in different applications wireless technology has been subdivide into different standard depending on the so many aspects involved with the technology. A brief introduction to developments phases of wireless technology is given below.

1ST GENERATION

In the initial phase of development of the mobile technologies or can say in the development of 1st generation mobile technologies people didn't think of standardizing wireless communication technologies. In the initial phase, these technologies were subjected to a particular area or region and organizations which were using the technologies were concerned about the particular restricted area in which they were operating. However, after couple of years when the wireless communication was growing so rapidly and it was going towards globalization Nordic countries thought of standardizing these technologies. The 1st generation mobile technologies initially providing services in a confined system they were used only by the commercial organizations, Government organizations only. In the years of 1960's and 1970'smobile communication technologies were confined to a partial geographic area. Devices used in this generation of mobile communication technologies were very bulky, heavy and were not so easy to use. Devices were mounted on vehicles and then communication used to set up. The technology use was not an open access to public.

2ND GENERATION

With the time researchers have invented so many ways to communicate information over a wireless network. Therefore 2nd Generation wireless communication was an effort toward improving the ways or the possible forms of information transfer over an available wireless network.2nd Generation wireless services were generally voice messages and data transfer with very slow and low capacity. These are generally GSM and GPRS.

1G	2G	3G	4G	5G
1981	1992	2001	2010	2020(?)
2 Kbps	64 Kbps	2 Mbps	100 Mbps	10 Gbps
Basic voice service using analog protocols	Designed primarily for voice using the digital standards (GSM/CDMA)	First mobile broadband utilizing IP protocols (WCDMA / CDMA2000)	True mobile broadband on a unified standard (LTE)	'Tactile Internet' with service-aware devices and fiber-like speeds

Fig.1.2

3rd GENERATION

3G technology provided user more efficient communication over long distances without much interruptions. Wide band wireless networks were implemented in the constructing these networks. Packet switching technique is used in the 3G networks to communication of voice calls. It was a sophisticated technology modernization in last few decades. These wireless networks provide high data transfer capacity with decent speed of data transfer.3G operates at 2100 MHz and occupies a bandwidth of 15-20 MHz. High speed internet and video conferencing are major services of 3G networks.

4th GENERATION

A technology ahead of the 2G and 3G, 4G guarantees a downloading speed of around 100Mbps and is yet to trying to boost it further. At that point with the instance of Fourth Generation administrations few of 3G, some extra elements, for example, different forms of media, Newspapers, likewise to watch T.V programs with the clearness as to that of a customary T.V. Dissimilar to 3G, which depends on two parallel foundations comprising of circuit exchanging and bundle exchanging system hubs, 4G will be founded on parcel exchanging as it were. This will require low idleness information transmission.

1.4 OBJECTIVE OF THESIS

Objective of thesis is divide into three parts

- Designing of a conventional aperture coupled antenna, its simulation the Agilent ADS software platform and fabrication of designed antenna and measuring its results on Keysight VNA is done.
- Designing of an aperture coupled antennas with defective ground structure of single circular slot, Double circular slot, four circular slots, its fabrication and measurement on Keysight VNA is done.
- Comparative study and analysis of all the measured results of antennas with DGS and conventional design.

1.5 ORGANIZATION OF THESIS

This thesis is divided into six chapters

Chapter 2 provides the brief introduction to the theory involved with the microstrip patch radiators. It describes to the reader different types of the Microstrip Patch Antennas. In the later section of this chapter different feeding techniques are described with associated advantages.

Chapter 3 is the research paper review which was an essential part to understand the all possible designs of Microstrip Patch Antennas and their advantages. This chapter provides an overview to the reader of modern day MPA antennas being used practically.

Chapter 4 is the chapter where conventional aperture coupled antenna and aperture coupled antennas with DGS is explained.

Chapter 5 provides all the simulated and measured results and their comparison for all the fabricated antennas.

Chapter 6 concludes the thesis with essential remarks and future scope for further research purposes.

2

MICROSTRIP PATCH ANTENNAS AND THEIR ANALYSIS TECHNIQUES

This chapter describes fundamental theory of Micro Strip Patch Antennas. Initial sections of the chapter evolve the conceptual understanding of different feeding techniques of the antennas and in the later sections methods to perform analysis of the Micro Strip Patch radiators is described with appropriate mathematical background. Further sections of this chapter give the details of applications area of these antennas.

2.1 MICROSTRIP PATCH ANTENNAS

Microstrip Patch Antennas are the antennas to be fabricated in printed form of a conducting material on suitable substrate. They are occupying their popularity in the industry of in the practical application because of their low profile, low cost, portability and ease in the fabrication.

A Microstrip radiator in its simplest use of application is a structure with two thin conductors separated with a dielectric of some thickness. Conductor underneath the dielectric assist as ground plane for the structure while the upper patch of conductor act as a radiator. Geometry of the radiating patch is a choice of designer and it depend on the factors like application, ease of fabrication etc. Physical parameters of the antenna depend on the operational frequency range and desired values of gain and return loss. It is taken in the ratio of the wavelength parameter lambda. Conducting material having a good conductivity is used but at the same time cost is also a concern for commercial purposes therefore metals like copper is used.

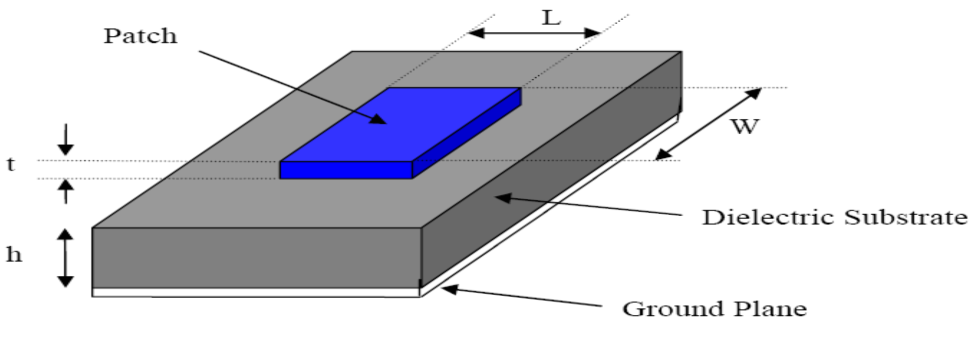

Fig2.1 Basic structure of Microstrip Patch Antenna[13]

Radiating patch is generally etched on the substrate using photolithography techniques. Conducting patch radiates because of the fringing fields between patch edge and ground plane. Microstrip Patch Antennas has a radiating edge and a non-radiating edge. Substrate height of the antenna is a parameter which affects the performance parameter like gain and bandwidth of antenna. Because the patch on the upper side is only participating in the radiating mechanism therefore it is easy to feed/excite the antenna from other side (ground plane). A major concern is the amount of power transferred to the radiating patch there for the feed line should be perfectly matched with impedance exhibited by the antenna. edge. Smith chart matching technique is used for matching the input impedance of the feed line. Many shapes of Micro-strip Patch Antennas used in the industry are being shown in the figure 2.2

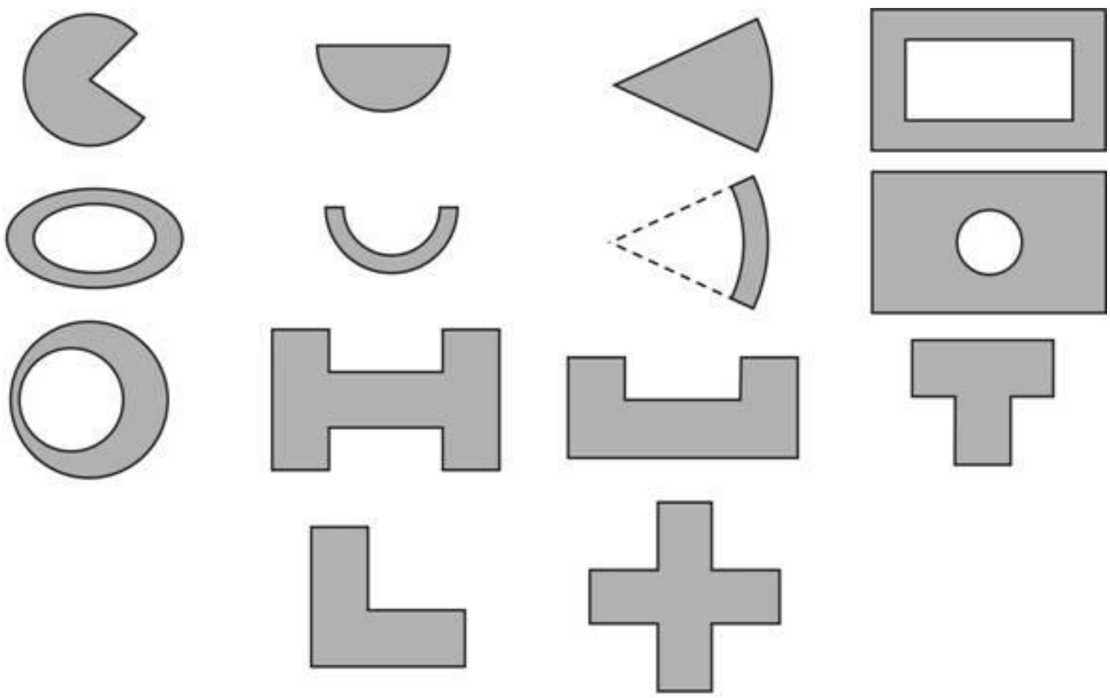

Fig 2.2 Different shapes of Microstrip Patch Antennas

2.2 ADVATAGES AND DISADVANTAGES

Micro-strip Patch Antennas are being widely used in remote application because of their specific features like low profile, ease of mounting and safety position. Therefore, Micro Strip Patch antennas very favorable for wireless applications for example, pagers and etc. Some of their important features are listed underneath:

- Light weight and less volume
- Low fabrication cost, hence can be manufactured in large quantities.
- Low profile configuration which can be made conformal.
- Supports both type of polarization, linear and nonlinear.
- Can easily be integrated with microwave circuits.
- Capable of multi band frequency operation.
- Can be mounted on the rigid surfaces

Microstrip Patch Antennas suffers from many disadvantages as well which are being listed below

- Narrow bandwidth
- Lower values of gain
- Less efficiency
- Low power handling capacity
- Surface wave losses
- Poor radiations

Micro-strip Patch Antennas are the antennas having a high value of Q and it speaks to the calamities related with the microstrips patch antennas and a vast Q prompts limit the power transmission and low performance effectiveness. Q can be diminished by increasing the thickness of the dielectric substrate. Be that as it may, as the thickness figures, an expanding portion of the aggregate power conveyed by the source goes into a surface wave. This surface wave obligation can be considered an undesirable power misfortune, since it is at last dispersed at the dielectric twists and causes exploitation of the response apparatus qualities. Different issues, for example, bring down pick up and bring down power dealing with limit can be overwhelmed by utilizing a cluster arrangement for the components.

2.3 FEEDING TECHNIQUES

Micro-strip Patch Antennas can be fed by different techniques. There are some direct methods and some indirect methods present in the feeding techniques available for the micro-strip patch antennas. Generally, these techniques are divided into two major categories which are contacting and non-contacting method. In contacting method, the RF power is being fed directly to the parasitic patch/radiating patch using a conducting material having a good conducting index such as Micro-strip line in the inset feed antenna or simple Micro-strip patch antenna the radiating patch using a connecting element such as a microstrip line. In the scheme of non-contacting feed technique, the RF power to the radiating patch is coupled through the electromagnetic field coupling between the radiating patch and the feed line, example of this feed scheme comprises of antennas like aperture coupled antenna, proximity feed antenna. electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. Most commonly antenna feed technique of this method is coaxial feed.

2.4.1 DIRECT MICROSTRIP LINE FEED

In this sort of feeding technique, a leading micro-strip line is directly connected to the edge of the radiating patch of the antenna. Micro-strip connected as appeared in Figure 2.3. The directing strip is narrow in width and physical parameters like length and width are calculated from the frequency range of the application from the fundamentals of Micro-Strip Patch Antennas. Location of the point of contact of strip line with the edge of radiating patch is decided by the impedance matching requirements. Generally, the value of impedance to be matched by the deed line is 50Ω and the coordinates of the location are kept fix and this sort of feed is an encouraging technique for the designers, this feed method is most suitable for the planar antennas working at the lower frequency ranges. This is accomplished by appropriately controlling the inset position. Subsequently this is a simple bolstering plan, since it gives simplicity of manufacture and straightforwardness in displaying and additionally impedance coordinating.

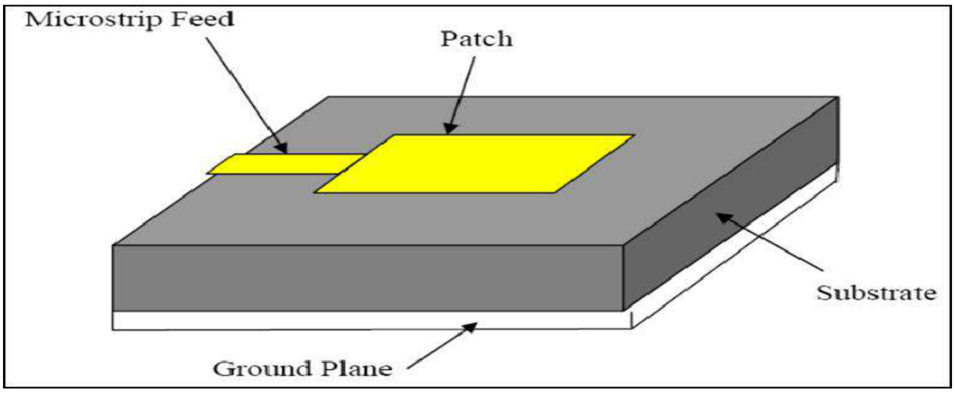

Fig 2.3 Microstrip Line Feed[13]

2.4.2 COAXIAL FEED

Most efficient feed technique for the practical purposes is the coaxial feed. A cylindrical metal with small radius is coated with a non-conducting material and finally it is covered with the thin layer of a good conducting material like copper. It is the technique where impedance matching is achieved most effectively as compared to others. The primary favorable position of this sort of bolstering plan is that encourage can be set at any coveted area inside the fix to coordinate with its information impedance. This feeding strategy is widely used because inn this feeding technique impedance matching is obtained so easily, sometimes it is difficult to manufacture because of the low values of the radius of the coaxial feed, it has low spurious radiation. Notwithstanding, its significant disfavor is that it gives limited capacity and is hard to demonstrate since an opening must be pierced in the substrate and the connector projects outside the ground plane, consequently not making it totally planar for thick substrates ($h > 0.02\lambda o$). Similarly, for thicker substrates, the expanded test length makes the impedance more inductive, encouragement to the coordinating issues. It is seen over that for a thick dielectric substrate, which gives expansive transfer of RF power, the microstrip line encourage and the coaxial feed technique experience the hostile effects.

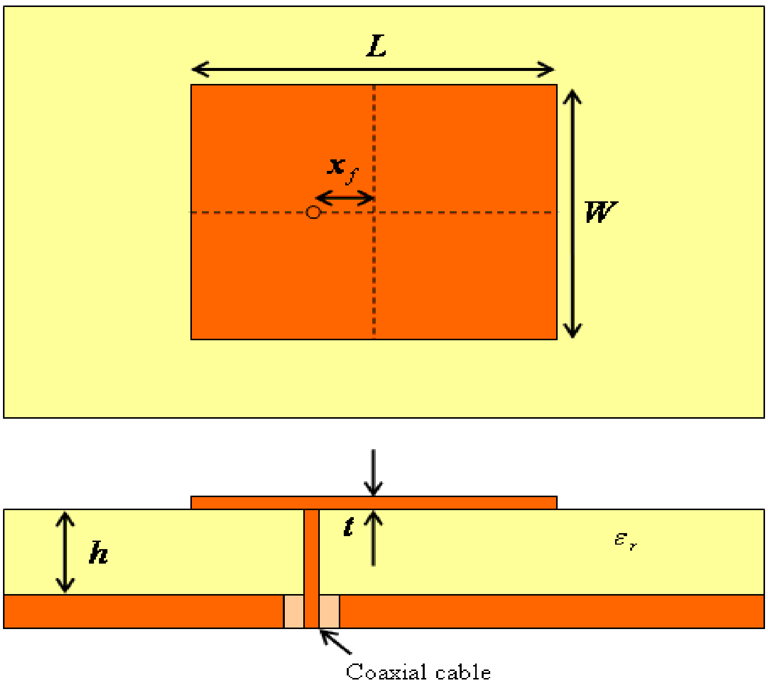

Fig 2.4 Coaxial feed[13]

2.4.3 APERTURE COUPLED FEED

In this kind of feeding strategy, the radiating patch and the microstrip feeding line is separated by two substrates of different heights and the ground plane is located in between the two substrates as appeared in Fig 2.5. Figure shows the coupling between the microstrip line and the aperture created in the ground plane. Through this aperture electromagnetic energy is coupled to the radiating patch that is how radiating patch gets its excitation and radiates into the air.

The distance between the aperture and the radiating patch decides the quotient of energy radiated from the energy fed into the feed line beneath the substrate on the bottom layer. Size of the aperture decides the operating frequency and the amount of energy to be coupled to the radiating patch. Normally the aperture is kept just under the radiating patch at the center position so that the maximum coupling is achieved and prompting lower cross polarization because of symmetry of the design. The measure of coupling from the sustain line to the fix is dictated by the shape, size and area of the opening.

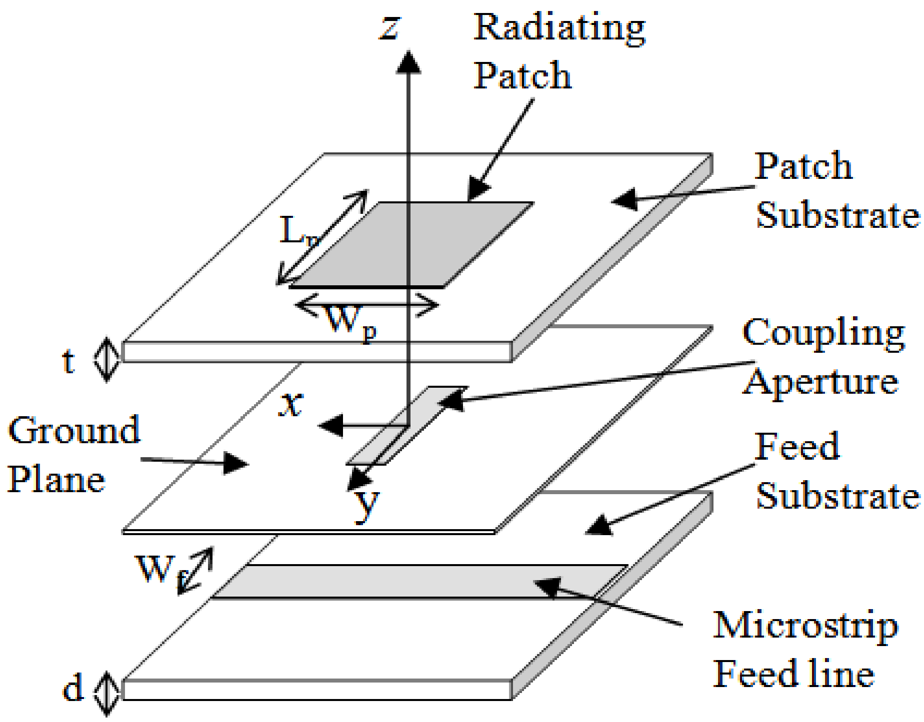

Fig 2.5 Aperture Coupled Feed[13]

Since the ground plane is the plane which lies in between the two important conductor planes of a Microstrip Patch Antennas it is the plane which limits the spurious radiation by the antenna. By and large, a high dielectric material is utilized for the base substrate and a thick, low dielectric consistent material is utilized for the best substrate to enhance radiation from the fix. This feeding plans have some advantages as well as some very useful advantages for the applications where frequency range is high aperture couple technique of the feeding technique is used.

2.4.4 PROXIMITY COUPLED FEED

Electromagnetic coupling is the phenomenon used for proximity coupled feed. Figure 2.6 describe the proximity feed technique designed for a Micro-strip Patch Antenna in which two This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the MPA.

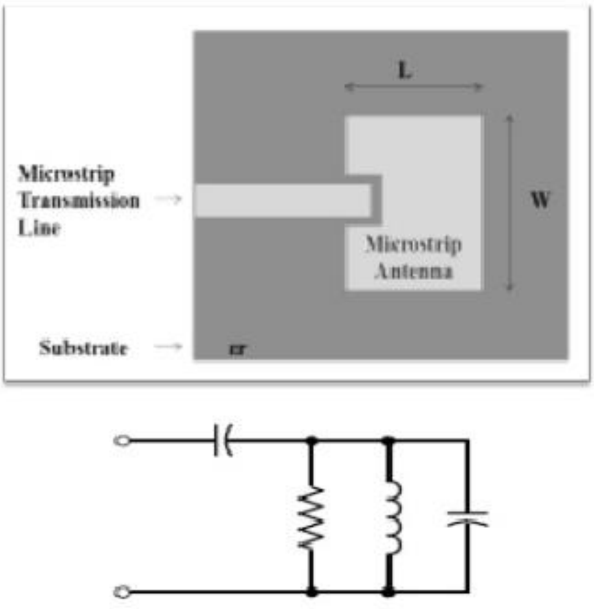

Fig 2.6 Proximity Feed[13]

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor due to Soldering	Good	Good
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with	2-5%	2-5%	2-5%	2-5%
Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed Radiation	More	More	Less	Minimum

Table 2-1: Comparison of different Feed Techniques

2.5 ANALYSIS METHODS

Microstrip Patch antennas are analyzed using three models which are transmission line mode, cavity model, full wave model. The most efficient model to analyze the antenna is considered as the cavity model but generally transmission line model is used because of its ease. Otherwise rest two models give more insight into the analysis. This model speaks to the microstrip patch antennas as the two wires separated an dielectric spaces of width W and height h, can be treated as a transmission line of length L having inductors and capacitors its elements in the parallel branches here resistance involved is neglected because for micro strip patch antennas the thickness of metal conductor is very low. The microstrip is basically non-homogeneous line of two dielectrics, normally the substrate and air.

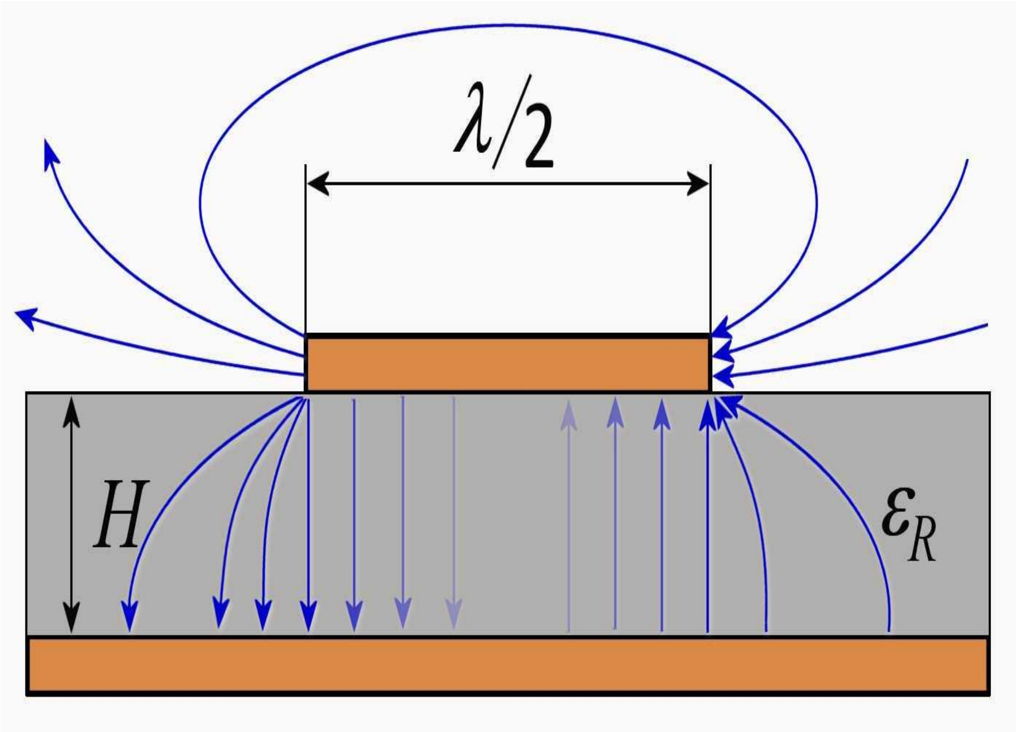

Fig 2.7 Radiation Mechanism of MPA's[9]

Subsequently, as observed from Figure2.7, the majority of the electric field lines oscillates in the substrate and parts of a few lines in air. Accordingly, this transmission line model of the microstrip patch antennas spick-and-span transverse electric-attractive (TEM) method of transmission, since the stage speeds would be idiosyncratic noticeable all around and the substrate. Rather, the dominant method of stimulating would be the semi TEM mode. With a specific end goal to work in the key TM10 mode, the length of the fix must be a tad not exactly λ/2 where λ is the wavelength in the dielectric medium and is equivalent to ß0⁄sreff where λ0 is the free space wavelength. The TM10 mode recommends that the field swings one λ/2 cycles laterally the length, and there is no variability along the width of the fix. In the Figure 2.8 demonstrated as follows, the microstrip patch antennas reception apparatus is taken to by two openings, isolated by a transmission line of length L and open circuited at both the closures. Along the width of the fix, the voltage is greatest and current is least because of the open finishes. The fields at the boundaries can be settled into usual and digressive segments concerning the ground plane. It is seen from Figure, that the typical parts of the electric field at the two edges along the width are in inverse ways and in this manner out of stage since the fix is λ/2 long and hence forth they cross out each other in the broadside course. The unnecessary parts (Figure 3.11), which are in stage, implies that the subsequent fields join to give greatest transmitted field ordinary to the surface of the structure.

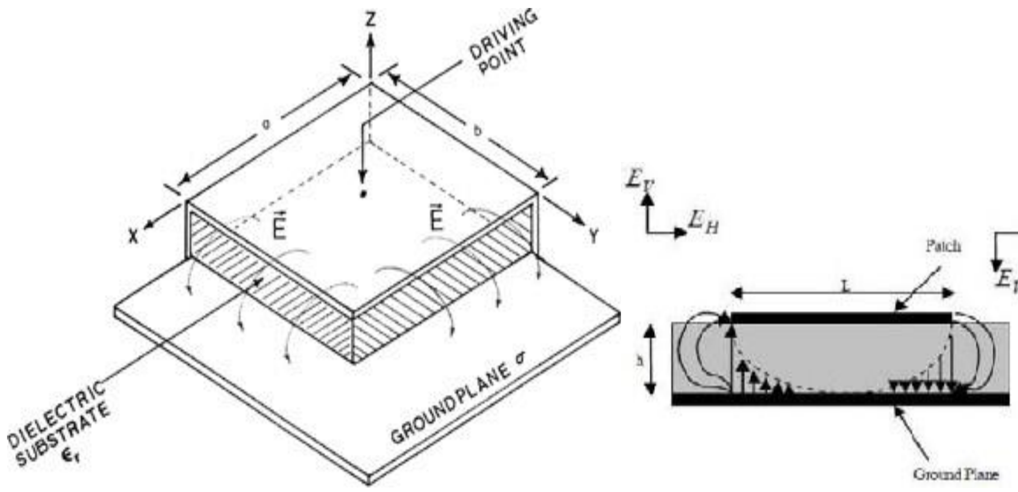

Fig2.8 Radiation Mechanism of MPA's[9]

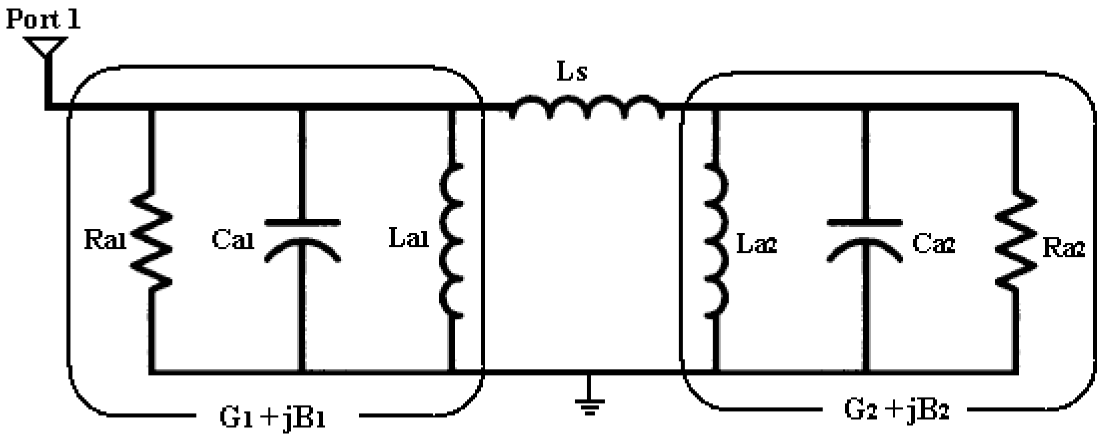

Fig2.9 Equivalent Circuit of MPA's[9]

2.6 PARAMETERS OF ANTENNA

2.6.1 Return Loss

This is the best and convenient method to calculate the input and output of the signal sources. It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the 'Return loss'.

2.6.2 Gain and Directivity

A performance parameter which describe an antenna for an application is the radiation pattern generated by the antenna. It is a capability of antenna which describe how antenna radiated energy through all directions. Radiation pattern measurement is done in dB scale and it refers to a direction in which antenna radiation maximally. The directivity for antenna can be defined as the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged in all the directions. Gain can be defined as the amount of energy taken in the reference of the energy radiated by an Omni-directional antenna.

The directivity of the antenna depends on the shape of the radiation pattern. The measurement is done taking a reference of isotropic point source from the response. The quantitative measure of this response is known as the directive gain for the antenna in given direction.

2.6.3 Radiation Pattern

Micro-strip Patch Antennas radiates because of discontinuities on the edges of the radiating patch. Gap between the edge of radiating of Micro-strip Patch Antenna and the ground plane also contributes to the radiations. Radiations intensities at different angles can me measure. MPAs has radiation patterns that can be calculated easily using anechoic chamber setup for accurate calculation of the pattern for the patch antenna. A two dimensional view of radiation pattern is shown in the figure 2.9 below.

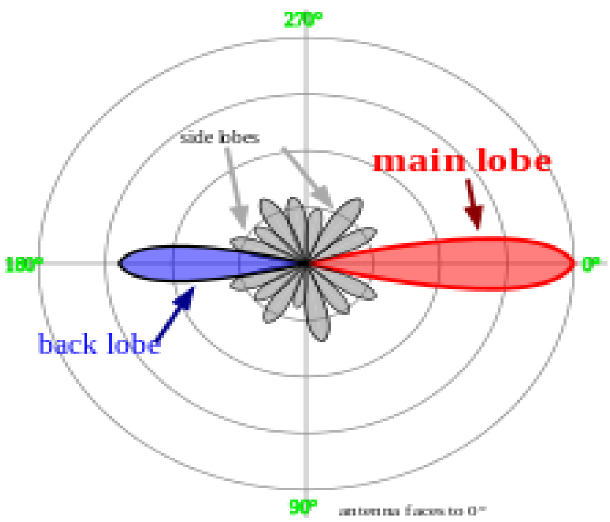

Fig 2.9 Radiation Pattern of an antenna

2.6.4 VSWR

Power transfer of an optimum amount between any transmitter end and the receiver end is really important for information transfer. In a communication module this is possible only when there is an impedance match is acquired by the both the ends impedances. Usually an impedance of 50 Ω is kept on the terminals and Smith chart technique is used to perform impedance matching.

To achieve the antenna configuration in such a way where power transfer is made to obtain an optimum value there is some portion of power which gets reflected and leads to create voltage standing waves, in the antenna theory it is described by voltage standing wave ratio(VSWR).

3

LITERATURE SURVEY

3.1 INTRODUCTION

It was essentially important to have a thorough understanding of Microstrip patch antennas and technology involved in the design of microstrip antenna's before starting this thesis. Major source of important information for thesis has been the online available books, journals, research papers etc. The main area in the reading literature review is the design methodologies of Microstrip patch antenna design and its parameters. Parametric variations in the microstrip patch antennas to improve their performance are also a concern of reviewed literature. Research paper literature review is being presented here in this chapter.

3.2RESEARCH PAPER LITERATURE REVIEW

Whenever we start a new work or a project it is better to have a clear understanding of the involved technologies and different aspects of the project such that it prevents a researcher undergo unnecessary complexities and failures. Reading research papers related to microstrip antenna design was very helpful in performing this task of designing antenna.

Initially microstrip radiator was introduced in year 1953 by Deschamps. Gutton and Bassinor had a patent over this mechanism in1955.however it took more than 20 years to fabricate antennas of this radiation mechanism. Till year 1970 where everybody was looking for the miniaturization of electronic circuits and large-scale integration microstrip antennas were being manufactured at a very small scale. Development of such antennas accelerated when there were inventions of substrates with good thermal and conducting properties. These substrates process a good radiating characteristic. Improved monolithic fabrication technique helped this area grow. Extensive research and development took place in this domain to exploit the advantages of such antennas in different industry levels like defense. First microstrip antenna was practically developed by Howell [1] and Munson [2] After few years Micro-strip Patch Antennas proved their importance in the applications where low-profile antennas are required and after that these antennae were used for many commercial and defense applications.

This paper[3] offers a clear understanding of input impedance and associated performance parameters like return loss and radiation pattern form the inset fed microstrip patch antenna. A shifted squared cosine variation describes the resonant input resistance at the edge of microstrip radiator with the variation of feed location for a given substrate and a particular geometry. Parameter variation takes place with the notch width and patch shape.

This paper [4] discusses about Micro-strip Antennas being operated at GPS and Bluetooth communication frequency range. Microstrip antenna structure consists of an appropriate substrate with a suitable height with top and beneath a patch of good conducting material. Microstrip patch is being excited by a coaxial connector. Geometrical parameters are decided upon the range of operation frequency. Bandwidth provide at both the bands is not wide therefore to improve bandwidth substrate parameters are altered. To achieve the impedance matching and a decent gain at both the radiating frequencies relative position between the parasitic patch and the patch at the bottom is varied.

In general[5], MPA's has a drawback of lower gain values, lower efficiency and narrow bandwidth. Therefore, to get enhancement in the bandwidth of MPA's different heights of substrate is being used and corresponding bandwidth increment is observed.

This paper[6], evolves and understanding of the reader towards the bandwidth improvement of the conventional microstrip patch antennas on comparatively thin substrates. Modern techniques are adopted like L-probe feed, Inverted patch structure with air filled dielectric and slotted patch. The impedance bandwidth of proposed antenna is 22%. Antenna is suitable for an application of the frequency range 1.84-2.29 GHz. Therefore, it can be said that proposed antenna provides a broadband in comparison with the conventional Microstrip Patch Antenna. Air gaps are very common to use in Microstrip Patch Antennas in present days. Though in earlier days it was not easy to fabricate antennas with air gap but now it is possible.

This paper [7] explains different design aspects of a high gain L-shaped Microstrip Patch Antenna printed on FR-4 substrate. The geometry possesses a dimension of 60 X 70 and a height of 1.6 mm. The dual band operation nature of antenna is obtained by creating L-shape slots. Designed antenna is then simulated using CST microwave studio 2010.It can be observed from simulated results that antenna is working in the frequency range of 5.0 GHz to 6 GHz. A maximum gain of 8.4 dBi and 7.1dBi is achieved respectively in the lower and higher frequency regions.

A Microstrip Patch Antenna[8] with single band frequency operation is discussed in this paper. Direct strip line feed is compared with coaxial line feed technique. Comparison in the paper provides a clear understanding that coaxial feed is better as using this provides better gain, lower values of return loss. Bandwidth comparison is also done for both the feeding techniques and results shows that coaxial fed antenna gives better bandwidth over direct strip line feed antenna.

First two basic geometries [9] used in microstrip patch antenna design is rectangular and circular shapes. The reason behind keeping geometry simple is ease of fabrication there for mostly for the application these antennas are used. Different characteristics offered by these antennas like dual band operation, frequency agility, feed line flexibility, beam scanning in the desired angles is the advantages of these Microstrip Antennas. Generally the directivity of the circular patch antennas are rather better than the rectangular Patch Antennas, therefore circular shape Patch radiators are used widely.

An inset[10] feed Microstrip Patch Antenna is designed for dual frequency operation .Impedance matching is obtained using the standard smith chart method. Impedance matching is done to improve the power transfer to the antenna at the input. Parameters of antenna like length, width and inset depth are tweak to obtain the desired range of frequency for many applications. Antenna width decides the operational frequency whereas the length of the antenna is a controlling parameter for the resistance value. A gain of 7.2 dBi is measured with a decent bandwidth of 1.4 GHz.

In this paper[11] design of an aperture coupled antenna is presented for a frequency lying in X-band range therefore can be used for wireless communication applications. Paper describes the design consideration for the aperture coupled antenna. An aperture coupled antenna consists of two substrate layers with different heights. Here for ease of design same substrate is used in both the layers with two different heights of 0.762 mm and 0.508 mm. Dielectric constant for the substrate used is 3.2.Simulation the antenna design on the software platform giving a Gain of 7.3 dBi. Parametric variation is performed to enhance the bandwidth of the antenna.

This paper [12] represents comparison of a simple aperture coupled antenna and another antenna with fractals on it. These antennas are design for a frequency range of almost 5.7 GHz to 5.875 GHz. Two different substrates of heights h1=1.6 mm and h2=0.8 mm is used. Dielectric constants for the two substrates are 4.3 and 2.2. Designed structure is then simulated on CST Microwave Studio software and a gain of 5.7 dBi is obtained with a size reduction of 22.9 %. Therefore, size miniaturization is claimed in the paper. Frequency of operation is around 5.8 GHz therefore antenna can be used in the RFID applications.

A simple aperture coupled antenna is presented [13] in this paper. Later parametric simulation is performed to enhance the performance parameters of the antenna. Antenna is designed for a frequency of 2GHz.Rectangular geometry for the radiating patch is preferred with a dimension of 48 mm width and 66 mm height. Two substrates are used with the dielectric constants of 1.07 and 4.4 with two different thicknesses as 1.58 mm and 1.7 mm. Simulation the design on the CST Microwave studio provides a main lobe gain of 8.185 dBi. Different parameters are to be tweaked to get the desired performance parameters.

This paper presents [14] design of an aperture coupled antenna with substrate having dielectric constant 3.5, ROGERS RT6035.Radiating and parasitic patches are kept at heights of 1 mm and 3 mm respectively with the reference of the plane which consist the feed line. Input impedance of the antenna is optimized to a value of 50 Ώ. The structure is supported using foam in the bottom. Operational frequency is at 14 GHz. Therefore, the designed antenna can be used in the satellite communication application. A gain of 8.2 dBi is observed with a fractional bandwidth of 33.2 %.

Proposed antenna [15] is an array of 2 X 1. It consists of two aperture coupled antennas with an Wilkinson power divider network. Designing of the antenna is having two substrate model of the aperture coupled antenna. Bottom layer substrate is Rogers 4003C with a height of 0.508 mm and bottom side layer of the antenna uses the standard substrate of Rogers 5880 with a height of .508 mm. Dielectric constant of both the dielectric is not same and which is having a value of 4.4 and 2.2 respectively. Designed antenna is a very low-profile antenna because of the height values taken for the antenna. Because of this feature of antenna, it can be used in the defense applications. Antennas elements are connected using basic Wilkinson power divider.

This paper [16] describes the design and discuss the simulation results of an aperture coupled antenna with defected ground structure for wireless applications. A microstrip line of quarter wavelength is being used for the feeding purpose. Antenna operates at a frequency of 2.5 GHz. This type of technique for feeding is used to get higher impedance match at the input of antenna Defected ground structure is used for betterment of bandwidth achieved from conventional antenna. A improvement in bandwidth and a gain value of 7 dBi is obtained.

In this paper [17], an ideal triple frequency monopole antenna is designed and simulated. At the ground plane of the antenna a structure of dual L-shaped strips is etched. Antenna is fed by a crossed microstrip line. DGS on the ground plane provides additional resonance points in the return loss graph, or in the bandwidth of the antenna an improvement is observed and the gain of the antenna increases with the use of DGS. Antenna acquires an area of 20mm X 30 mm. It can be used in the ISM band frequency range of applications. When compared to conventional antenna the results measured in case of DGS are far better.

An antenna [18] with DGS is presented in this paper with enhanced bandwidth and gain. Antenna with a fractional bandwidth of 31% is designed. Designed antenna offers a double frequency operation. Antenna is simulated using CST Microwave Studio and tested with anechoic chamber and VNA.

This paper presents [19] an efficient design of an aperture coupled antenna with high front to back ratio and better polarization purity. From the conventional design, this antenna is different because it uses a quarter wavelength chock which is being added to the antenna to improve the front to back ration. Proposed antenna is occupying very small area therefore miniaturization is achieved in the antenna. Front to back ratio of 22 dB and cross polarization below -44 dB is obtained as the measured result of the antenna. When antenna without chock or conventional antenna is compared with the antenna with the chock added 27 % increase in bandwidth is obtained.

Objective of this paper [20] to make a clear understanding over the use of DGS in Microstrip Patch Antennas. DGS structures provides and effective and improved fractional bandwidth. For the application where double frequency operation is required defective ground structures are applied over the patch of microstrip patch antennas. Use of DGS enables polarization purity increment therefore; antennas with DGS structures can be used in transceivers applications.

4

DESIGN OF MICROSTRIP FED APERTURE COUPLED ANTENNA WITH DEFECTIVE GROUND

This Chapter describes the design methodology of micro-strip fed aperture coupled antennas with different defective grounds consisting of circular slot.

4.1 MICRO STRIP FED APERTURE COUPLED ANTENNA

Micro-strip fed aperture coupled antenna presented here, with defective ground possess a decent impedance matching. This antenna provides a worthy wide bandwidth over the frequency range from 6.1 GHz to 9.2 GHz which lies in the range of C and X band of standard classification. Above antenna can used for the application in radar, microwave relays etc. Software platform used for the antenna design used is Agilent ADS (Advanced design system tool). Micro-strip fed line of 50 Ω is designed using parameter variations in length and width of micro-strip line. Design of the antenna and effects of slots in the ground plane is discussed with the other parameters on the antenna performance.

4.1.1 ANTENNA DESIGN AND ITS WORKING PRINCIPLE

Fig.4.1 describe the design of proposed antenna. Substrate used for the antenna is FR-4 with a standard height of 1.6 mm. It is a multilayer design in which bottom layer of substrate having a thickness value of 1.6 mm consist of a copper patch on the top with dimensions of 20 mm length and width, both equal. Underneath a micro-strip line of 50 Ω is etched. This is the first layer of the design. In second layer same substrate with a height of 1.5 mm having a patch of length 15 mm and width 15 mm designed.

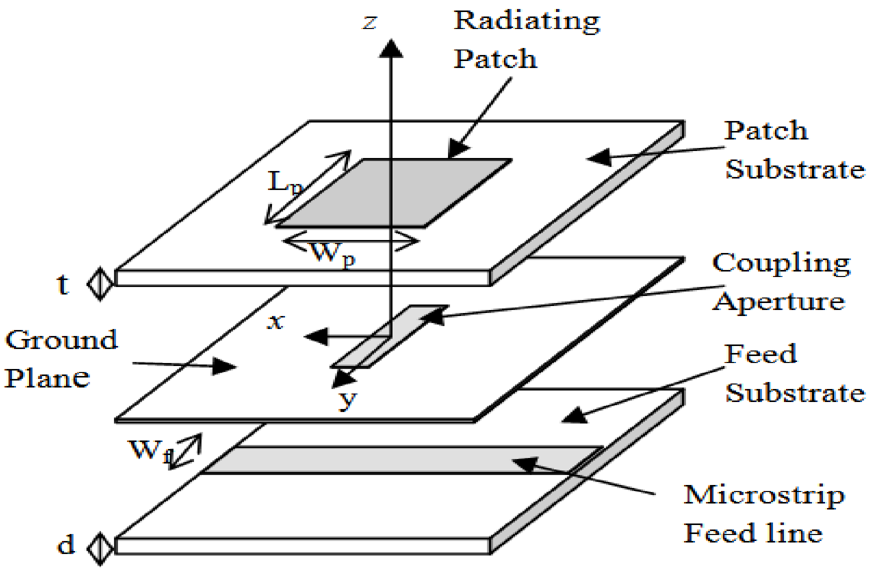

Fig.4.1 Basic structure of aperture coupled antenna

Physical parameters (Length and Width) of micro-strip line which is being used underneath the first substrate layer to feed antenna with an impedance of 50 Ω is obtained from a software utility provided in Agilent ADS. Feed line is used to provide an impedance matching of 50 Ω such that an optimum amount of power can be fed into the antenna for higher power requirement applications. A standard height of substrate of 1.6 mm from ADS directory is used. Above this substrate a patch of length of 20 mm and width of 20 mm is etched with a thickness of 35 micron. This patch layer of a suitable conducting material like copper is referred as ground for the antenna structure and excitation to antenna is setup taking this plane a reference. For second layer, same substrate is used with a height of 1.5 mm. Top of this substrate consist of a patch of good conducting material of square dimensions of 15 mm. Dimensions parameters of patch decides operating frequency, radiation resistance, therefore for a frequency of operation, appropriate dimensions are calculated from formulas. An aperture in the ground plane is cut of rectangular geometry. Shape of aperture is kept rectangular for ease of calculations of frequency and bandwidth.

4.2 DESIGN OF COVENTIONAL APERTURE COUPLED ANTENNA

Feed line parameters as length L_f width W_f obtain an optimum value of 24.4 mm and 2.262mm. Stub length is kept as 3.8 mm. Stub length is usually kept as $\lambda/4$.Therefore for antenna operating at a frequency of comes out as above value. Ground plane is kept in square shape and dimension is kept as 20 mm for length and width. An aperture with rectangular geometry is cut into the ground plane with a length of 7.2 mm and width of 1mm.

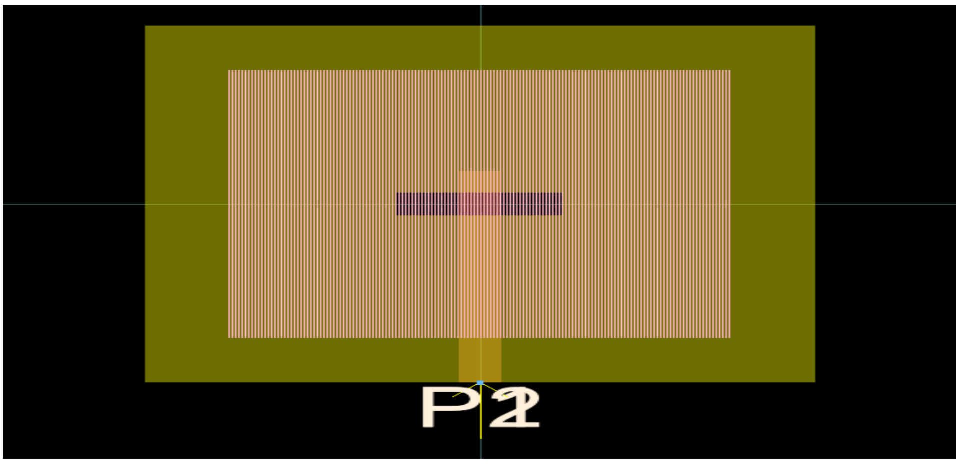

Fig 4.2 Design of conventional aperture coupled antenna

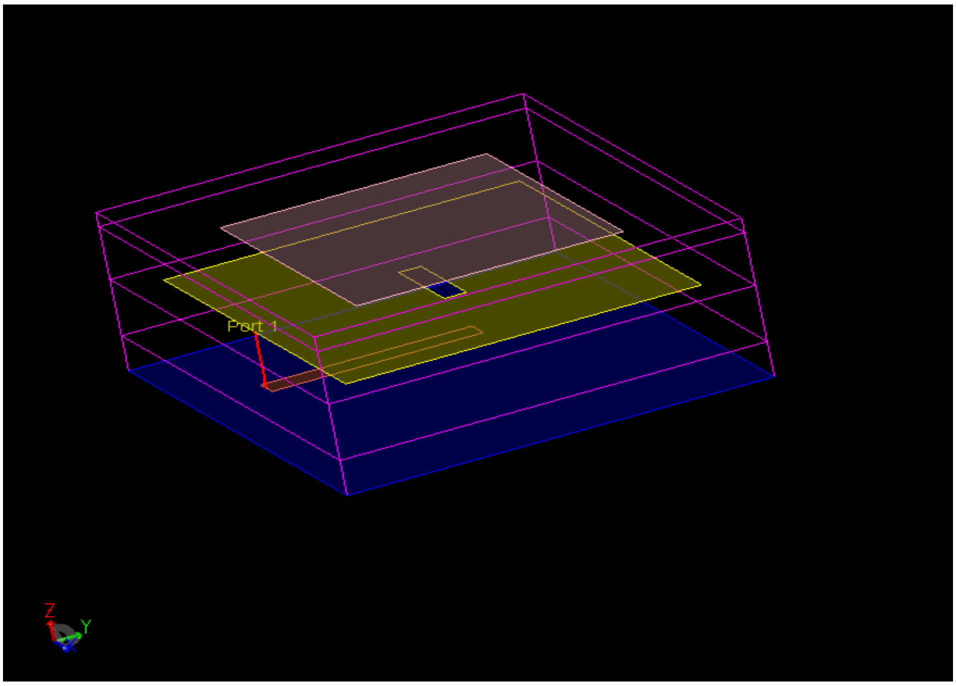

Fig4.3 3D view of conventional aperture coupled antenna

In conventional aperture coupled antenna input is excited through a microstrip feed which is at the bottom of the lower substrate layer. On the top of this layer a conductor plane with an aperture is etched, which is called ground plane for the structure. A view of substrate layers and conductor layers is being shown in the figure below.

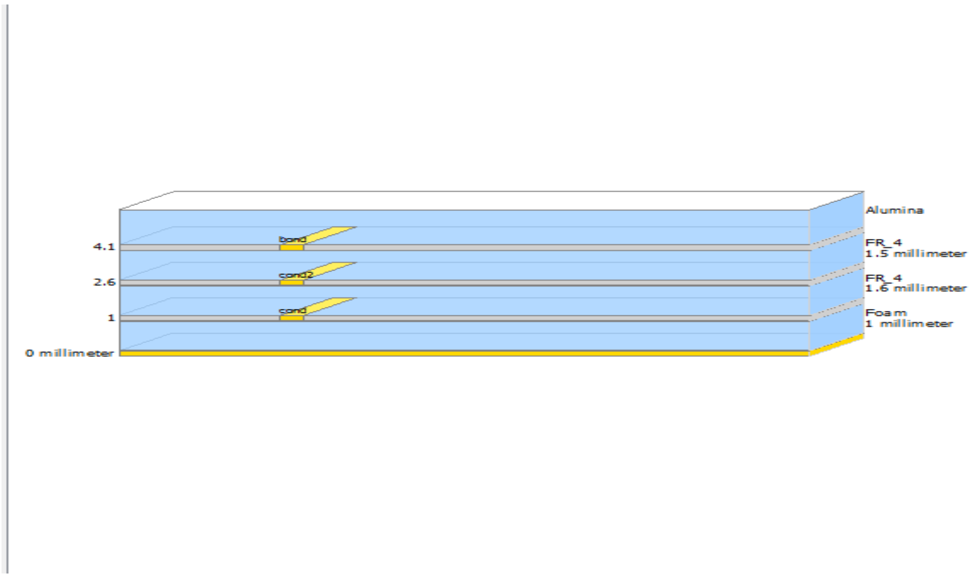

Fig4.4 Substrate view for proposed antenna

4.3 DESIGN OF APERTURE COUPLED ANTENNA WITH DGS

Fig.4.1 describe the design of proposed antenna. Substrate used for the antenna is FR-4 with a standard height of 1.6 mm. It is a multilayer design in which bottom layer of substrate having a thickness value of 1.6 mm consist of a copper patch on the top with dimensions of 20 mm length and width, both equal. Underneath a micro-strip line of 50 Ω is etched. This is the first layer of the design. In second layer same substrate with a height of 1.5 mm having a patch of length 15 mm and width 15 mm designed. parameters (Length and Width) of micro-strip line which is being used underneath the first substrate layer to feed antenna with an impedance of 50 Ω is obtained from a software utility provided in Agilent ADS. Feed line is used to provide an impedance matching of 50 Ω such that an optimum amount of power can be fed into the antenna for higher power requirement applications.

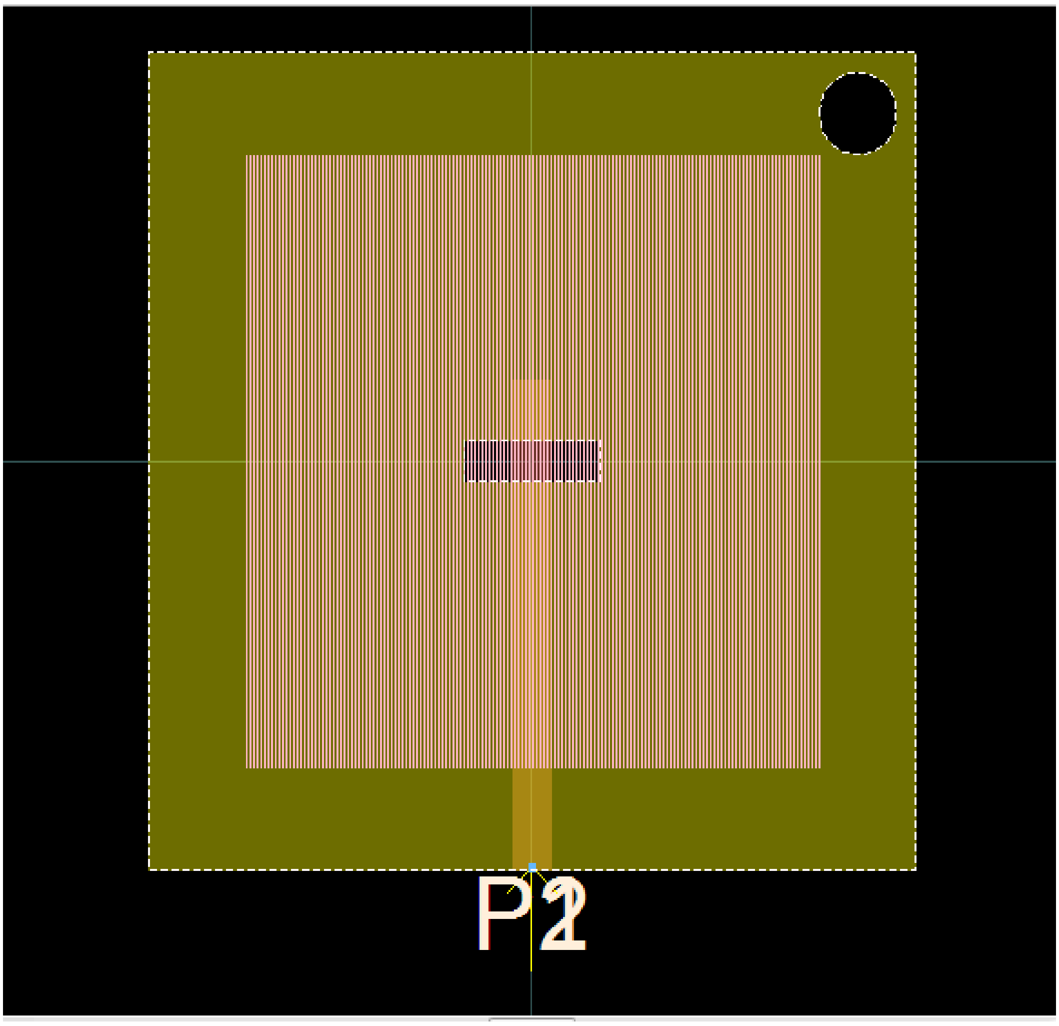

Fig4.5 Aperture coupled Antenna with DGS (single circular slot)

A scaled view of the Aperture Coupled Antenna with single circular slot is being shown below. Both the layers of substrate is having a dielectric constant of 3.2 but are of different heights.

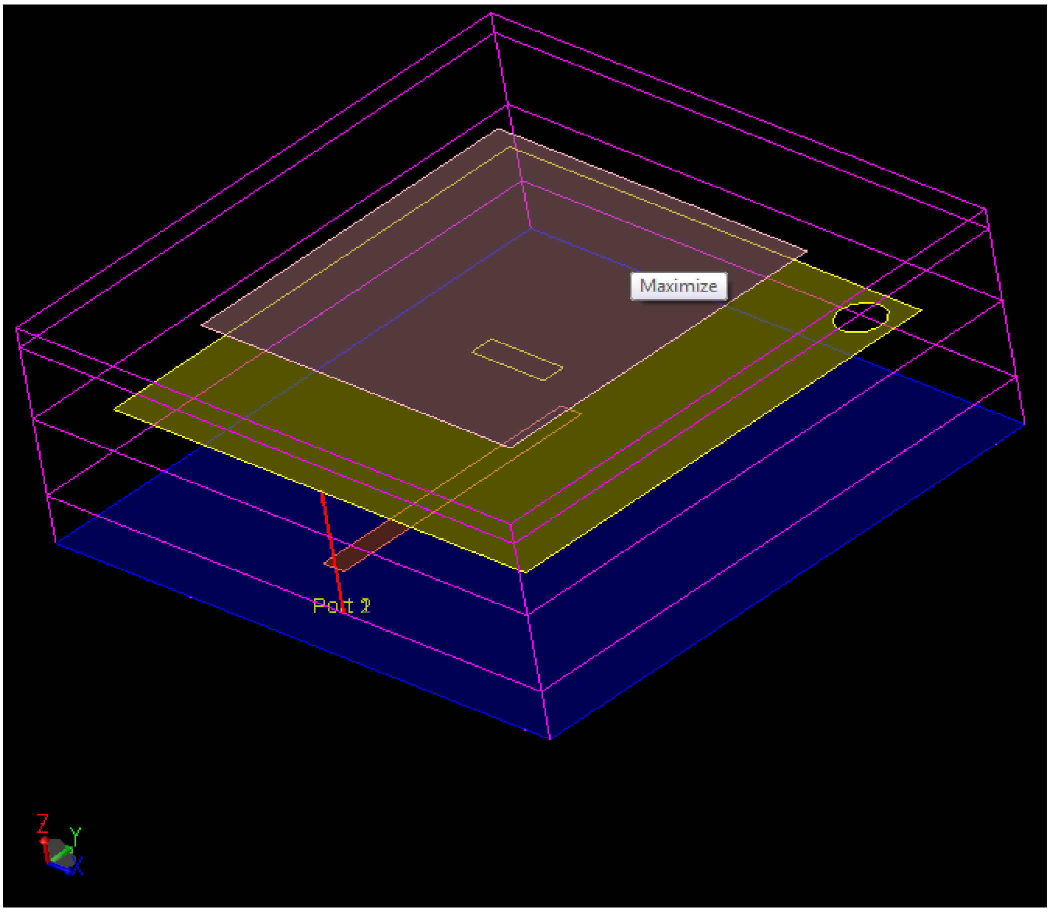

Fig4.6 Aperture Coupled Antenna with DGS (single slot)

Defective ground structure is used in the Microstrip Patch Antennas to improve the performance parameters of antenna like bandwidth, gain. Therefore, above Aperture Coupled Antenna is having a circular slot in its ground plane at a location 1 mm away from its both the edges.

4.4 APERTURE COUPLED ANTENNA WITH DOUBLE CIRCULAR SLOT

An Aperture Coupled Antenna is designed using the same dimensions and other physical parameters but with double circular slots. Circular slots are created in the ground plane with a radius of 2 mm and they are on the diagonally opposite of the rectangular radiating patch. Creating the slots on the ground plane at diagonally opposite locations improve the bandwidth of the antenna which will be discussed in the next chapter.

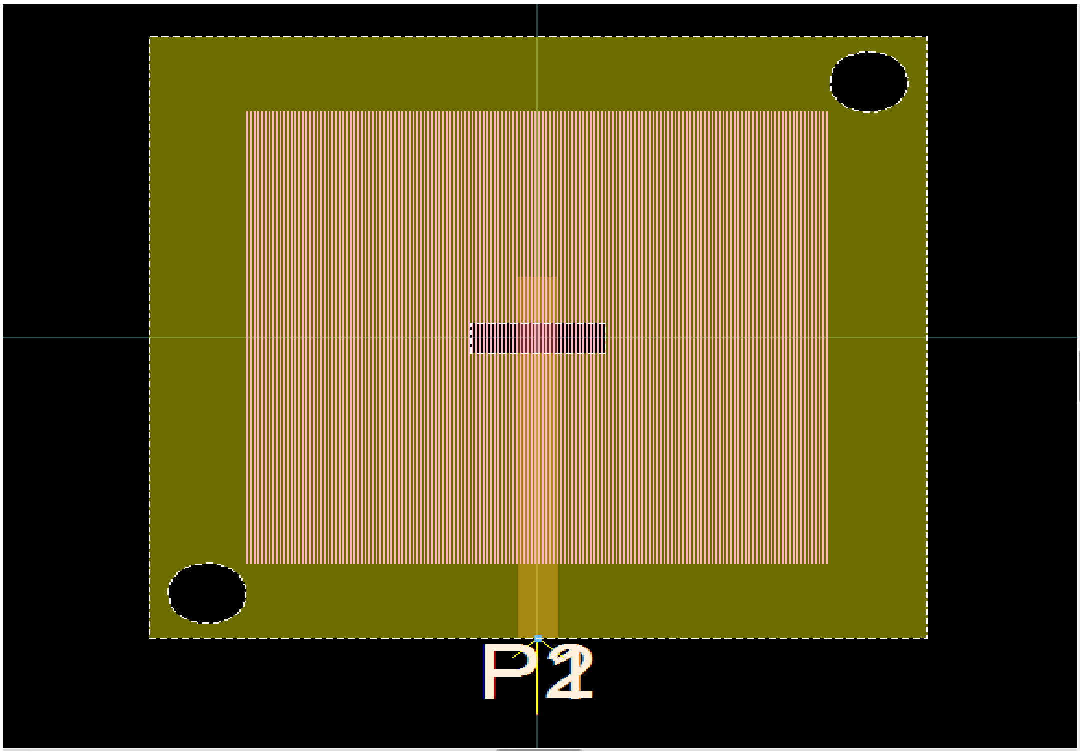

Fig 4.7 Aperture Coupled Antenna with double slot

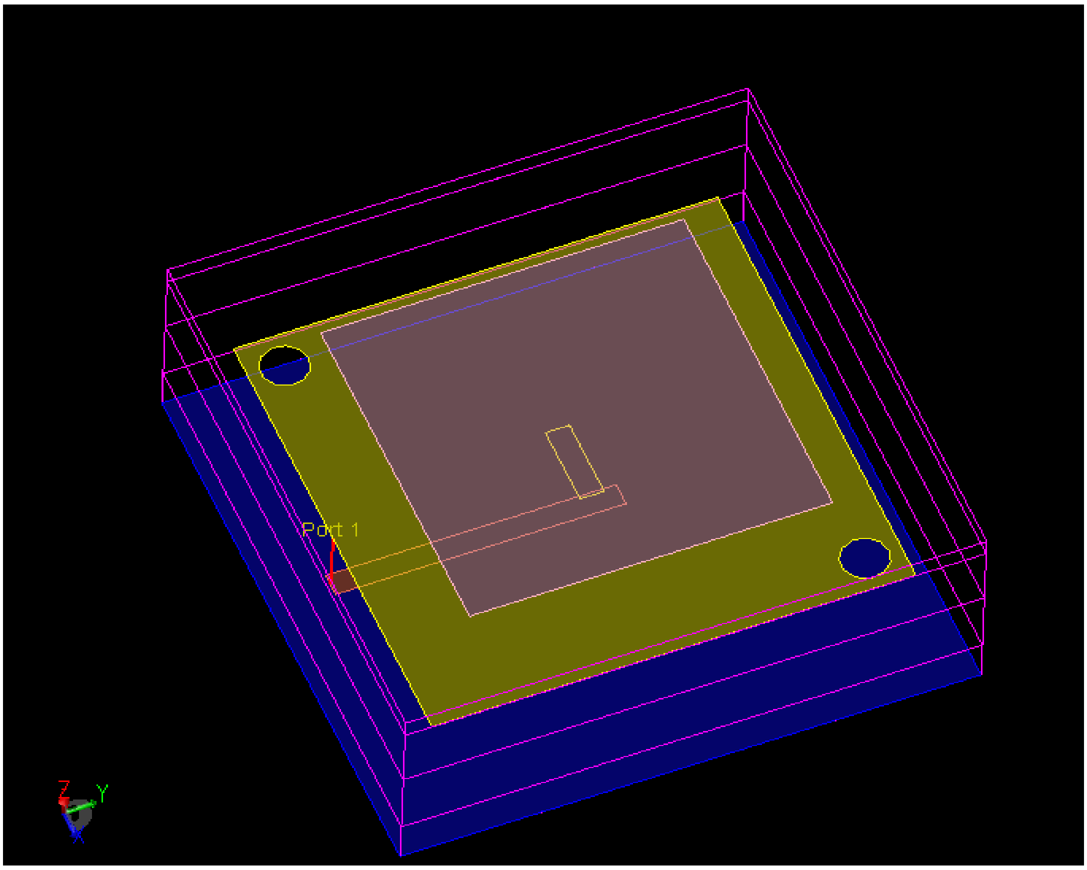

Fig 4.7 Aperture Coupled Antenna with double slots

4.5 APERTURE COUPLED ANTENNA WITH FOUR SLOTS

An Aperture Coupled Antenna is designed using the same dimensions and other physical parameters but with double circular slots. Circular slots are created in the ground plane with a radius of 2 mm and they are on the diagonally opposite of the rectangular radiating patch. Creating the slots on the ground plane at diagonally opposite locations improve the bandwidth of the antenna which will be discussed in the next chapter.

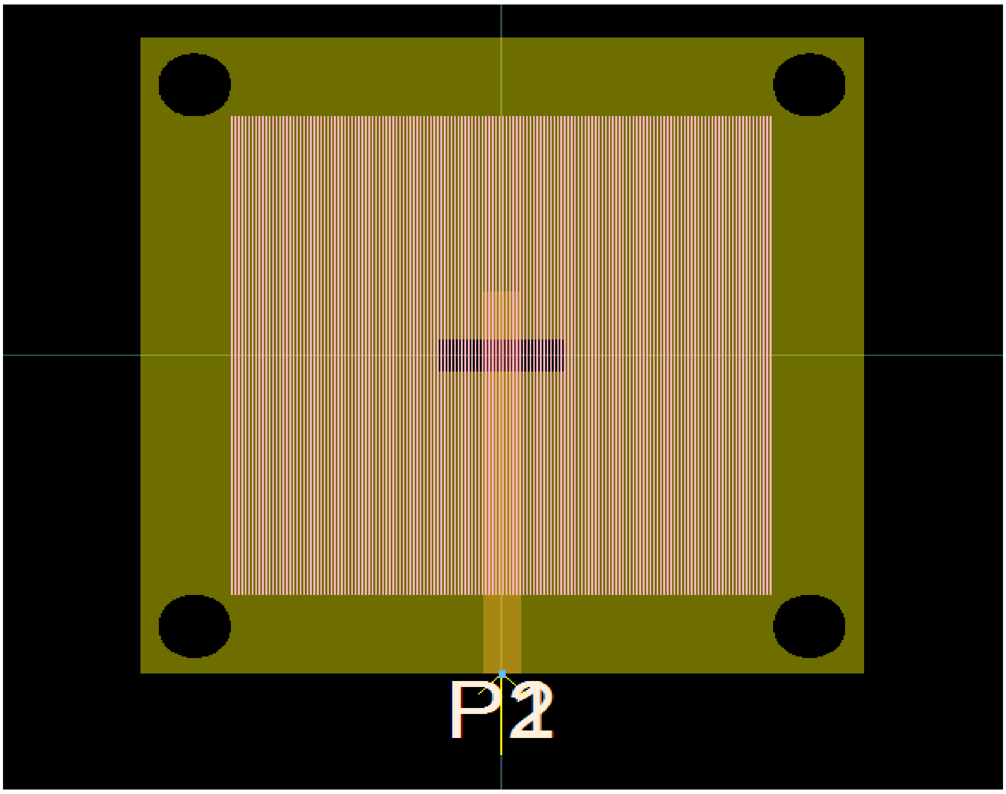

Fig 4.8 Aperture Coupled Antenna with four slots

A standard height of substrate of 1.6 mm from ADS directory is used. Above this substrate a patch of length of 20 mm and width of 20 mm is etched with a thickness of 35 micron. This patch layer of a suitable conducting material like copper is referred as ground for the antenna structure and excitation to antenna is setup taking this plane a reference. For second layers, same substrate is used with a height of 1.5 mm. Top of this substrate consist of a patch of good conducting material of square dimensions of 15 mm. Dimensions parameters of patch decides operating frequency, radiation resistance, therefore for a frequency of operation, appropriate dimensions are calculated from formulas. An aperture in the ground plane is cut of rectangular geometry. Shape of aperture is kept rectangular for ease of calculations of frequency and bandwidth. Feed line parameters as length Lf width Wf obtain an optimum value of 24.4 mm and 2.262mm. Stub length is kept as 3.8 mm. Stub length is usually kept as $\lambda/4$.Therefore for antenna operating at a frequency of comes out as above value. Ground plane is kept in square shape and dimension is kept as 20 mm for length and width.

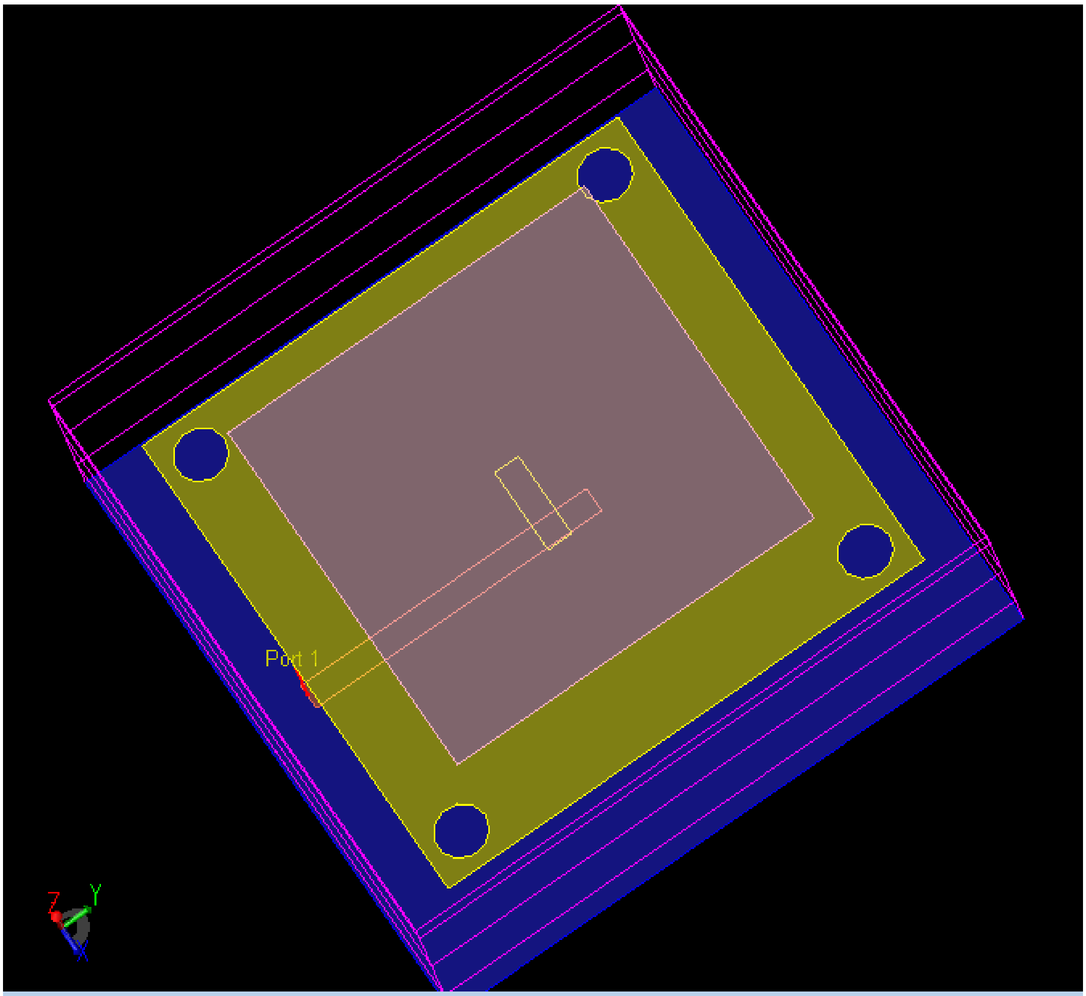

Fig 4.9 Aperture Coupled Antenna with four slots

An aperture with rectangular geometry is cut into the ground plane with a length of 7.2 mm and width of 1mm.Defective ground structure is used in the Microstrip Patch Antennas to improve the performance parameters of antenna like bandwidth, gain. Therefore, above Aperture Coupled Antenna is having a circular slot in its ground plane at a location 1 mm away from its both the edges.

5

RESULTS AND DISCUSSION

5.1 RESULT DISCUSSION OF APERTURE COUPLED ANTENNA WITH DGS

Simulation Results

5.1.1 S-parameters (simulated and measured)

Antenna is simulated using software platform Agilent ADS. Simulated return loss(S-parameter) are shown for the conventional designed antenna.

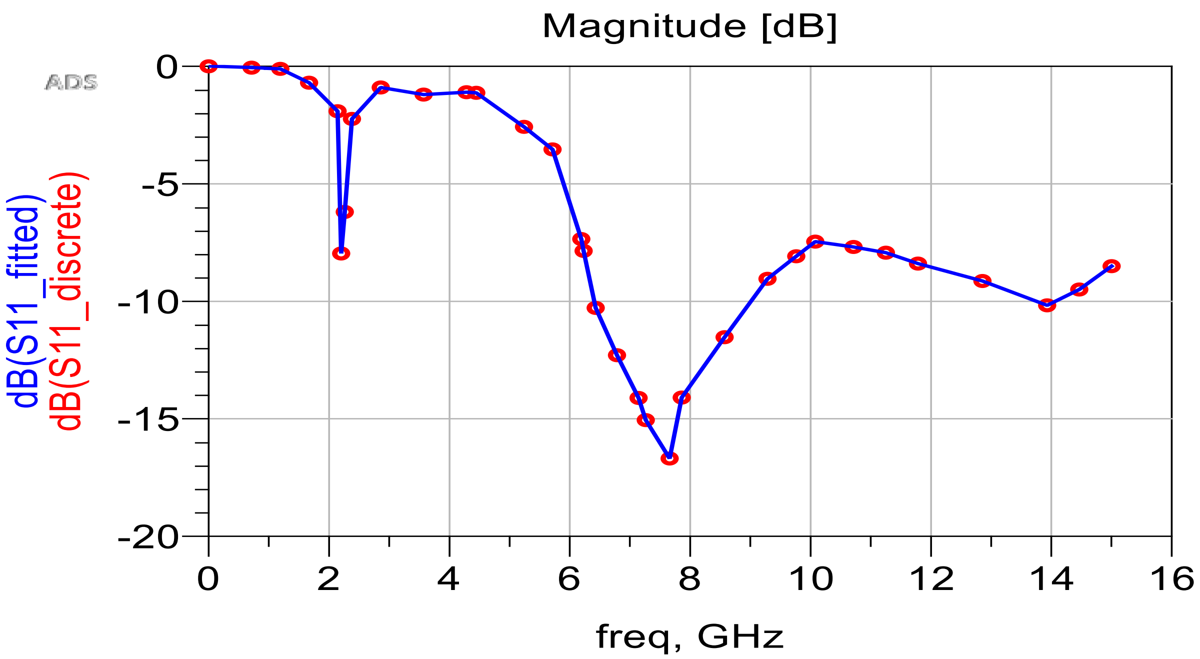

Fig5.1 S-parameter of conventional Aperture Coupled Antenna

Here conventional Aperture Coupled Antenna is simulated and a return loss value of -17.22 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 0.84 GHz. Antenna is simulated using Agilent ADS software.

S-parameters measured

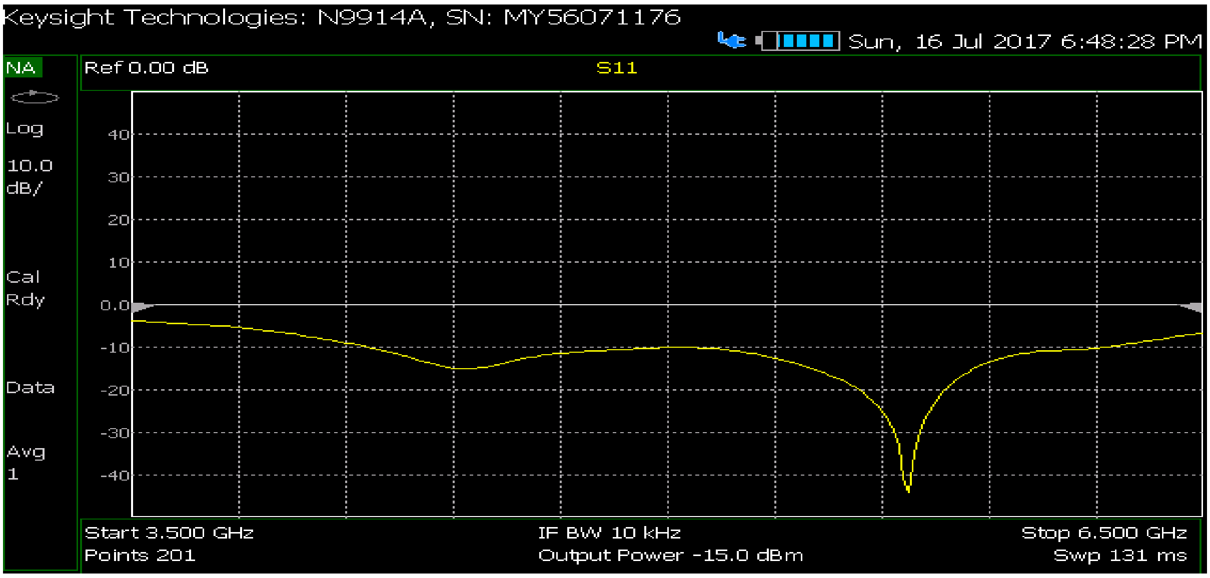

Fig 5.2 S-parameter of conventional Aperture Coupled Antenna (Measured)

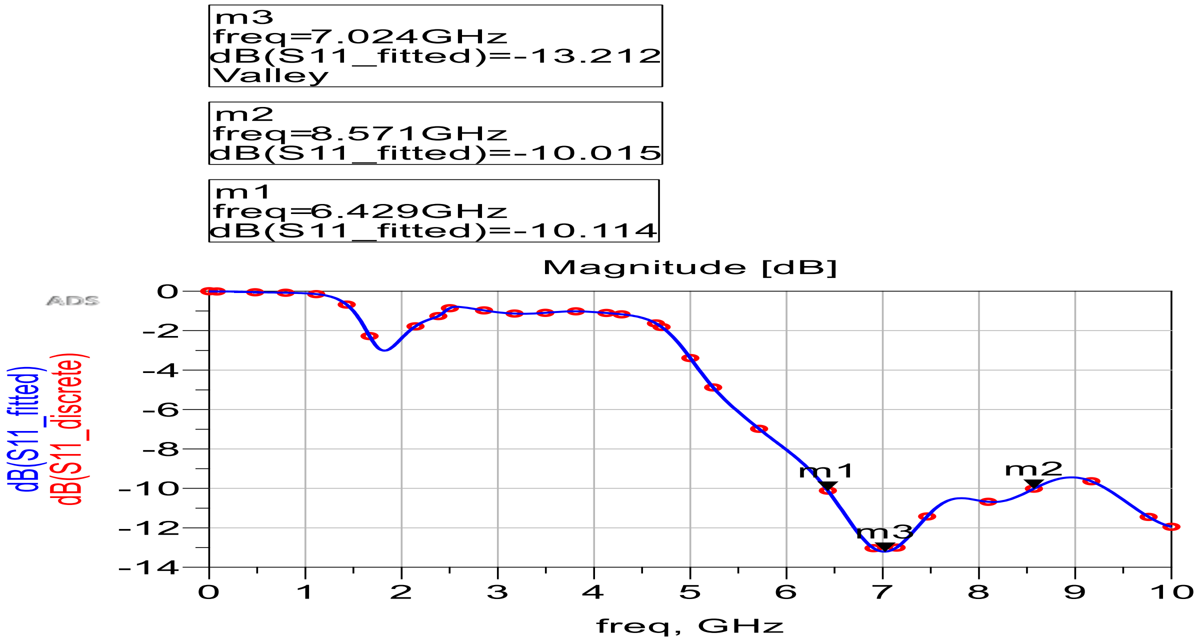

Fig 5.3 S-parameter of Aperture Coupled Antenna with single slot

Here Aperture Coupled Antenna with single circular slot is simulated and a return loss value of -13.44 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 1.01 GHz. Antenna is simulated using Agilent ADS software.

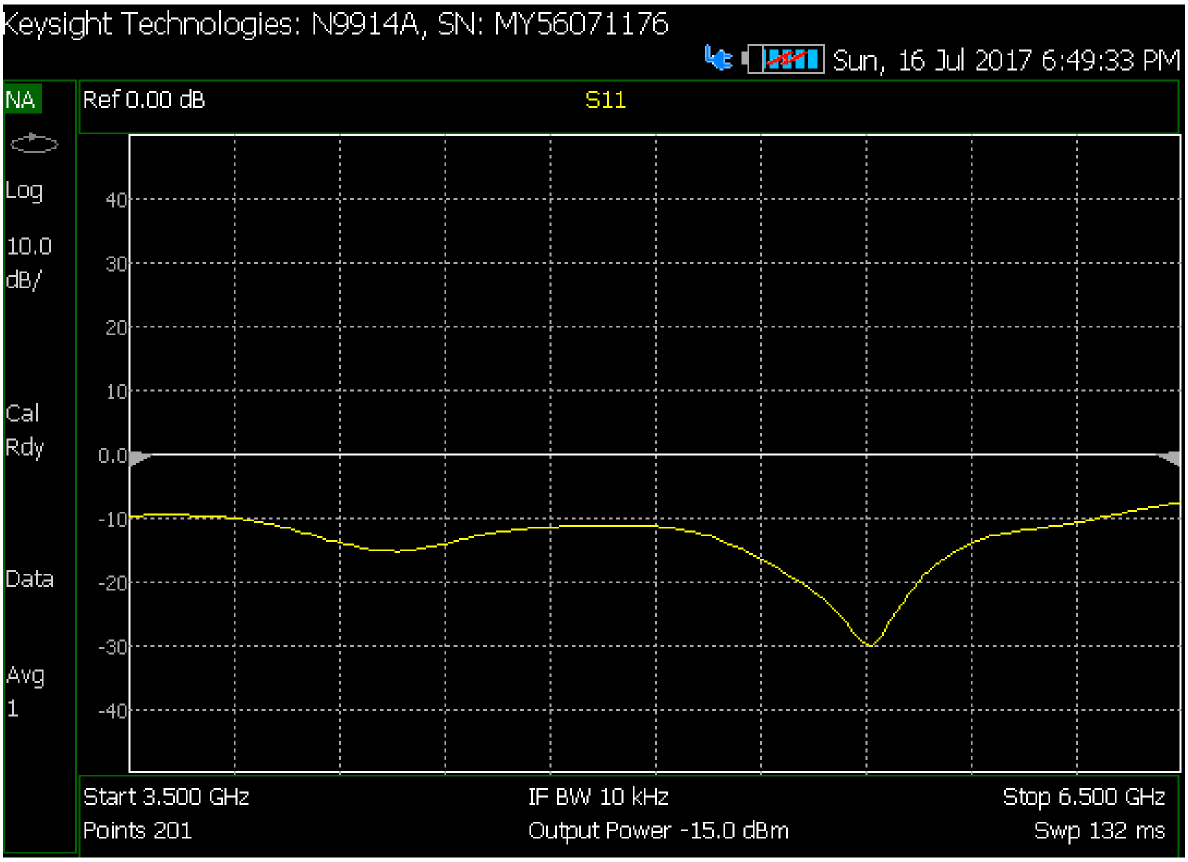

Fig5.4 S-parameter of Aperture Coupled Antenna with single slot(Measured)

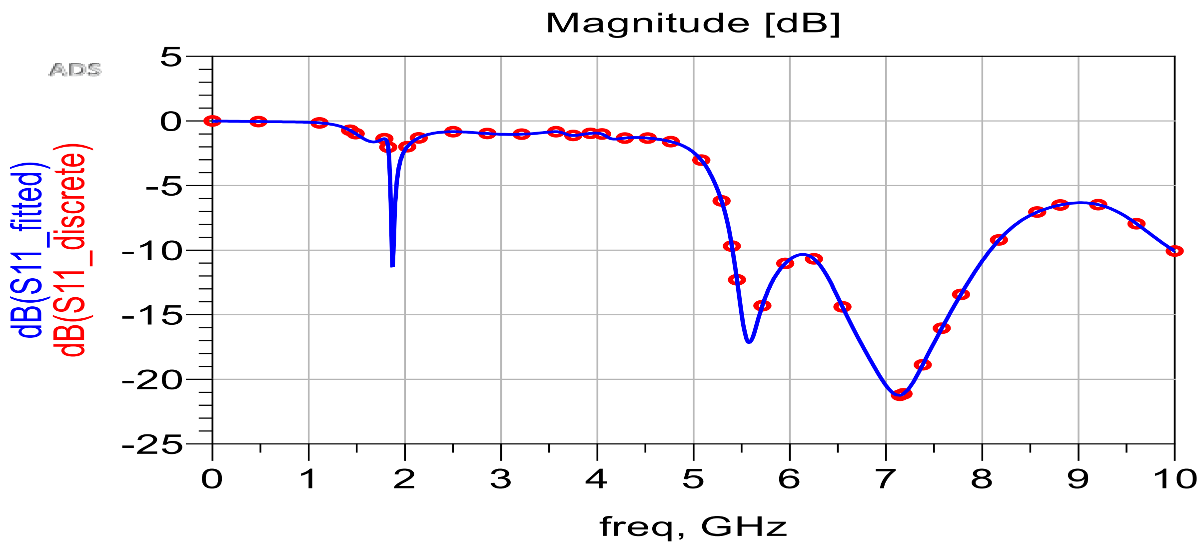

Fig5.5 S-parameter of Aperture Coupled Antenna with double slot

Here Aperture Coupled Antenna with single circular slot is simulated and a return loss value of -22.5 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 1.57 GHz. Antenna is simulated using Agilent ADS software.

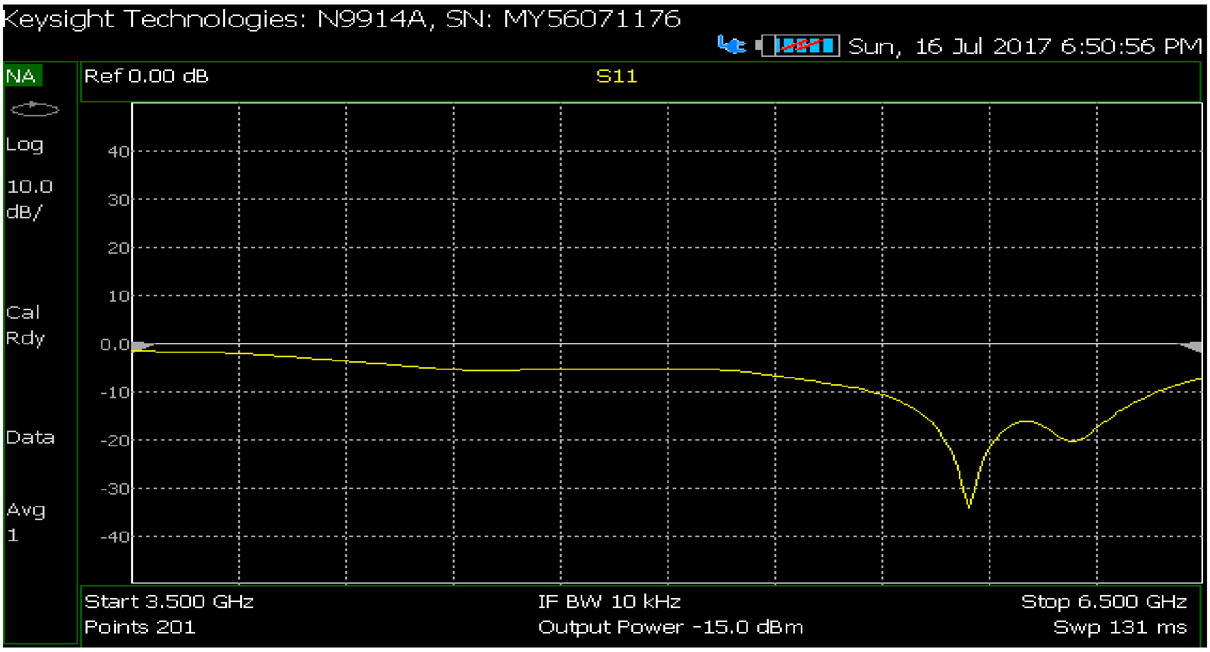

Fig 5.6 S-parameter of Aperture Coupled Antenna with double slot(Measured)

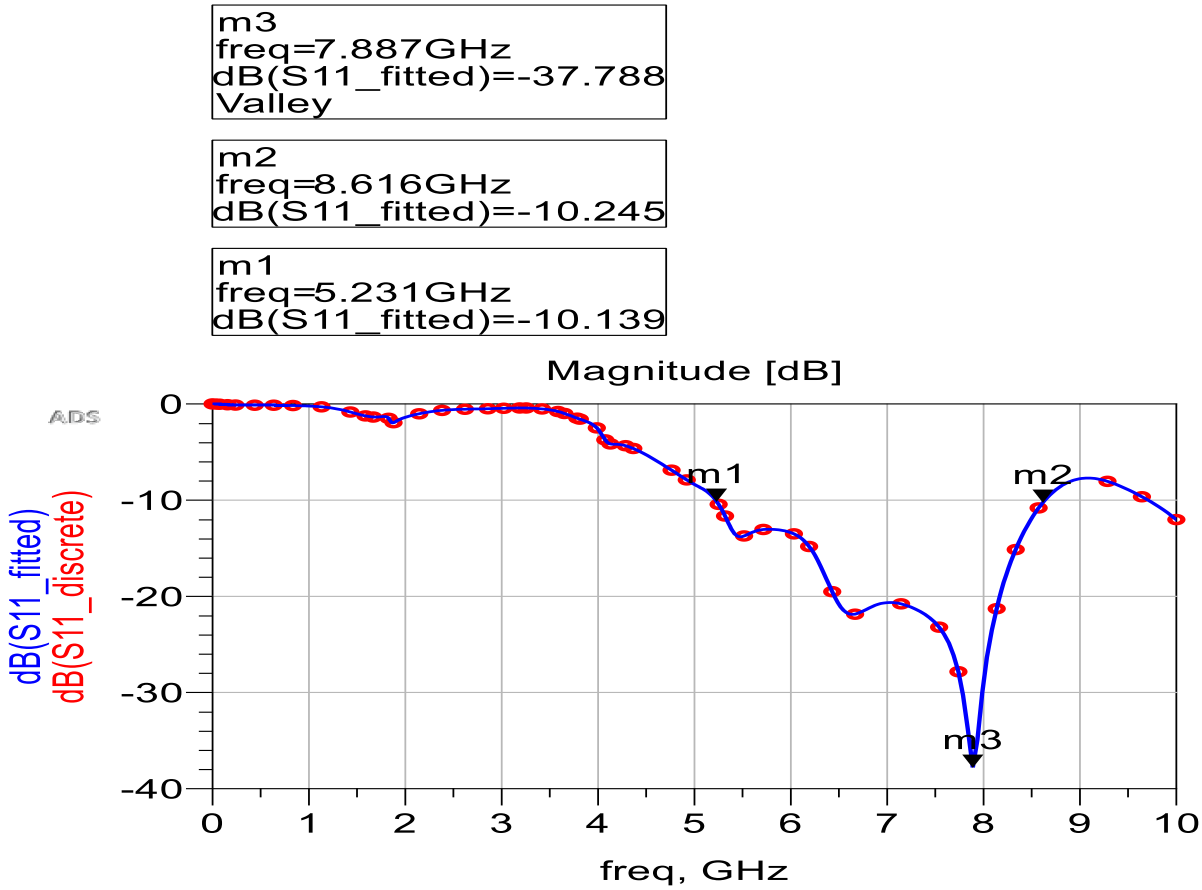

Fig 5.7 S-parameter of Aperture Coupled Antenna with four slots

Here Aperture Coupled Antenna with single circular slot is simulated and a return loss value of -35.44 dB is obtained. Bandwidth observed in the frequency range of 6-8 GHZ is around 3.2 GHz. Antenna is simulated using Agilent ADS software.

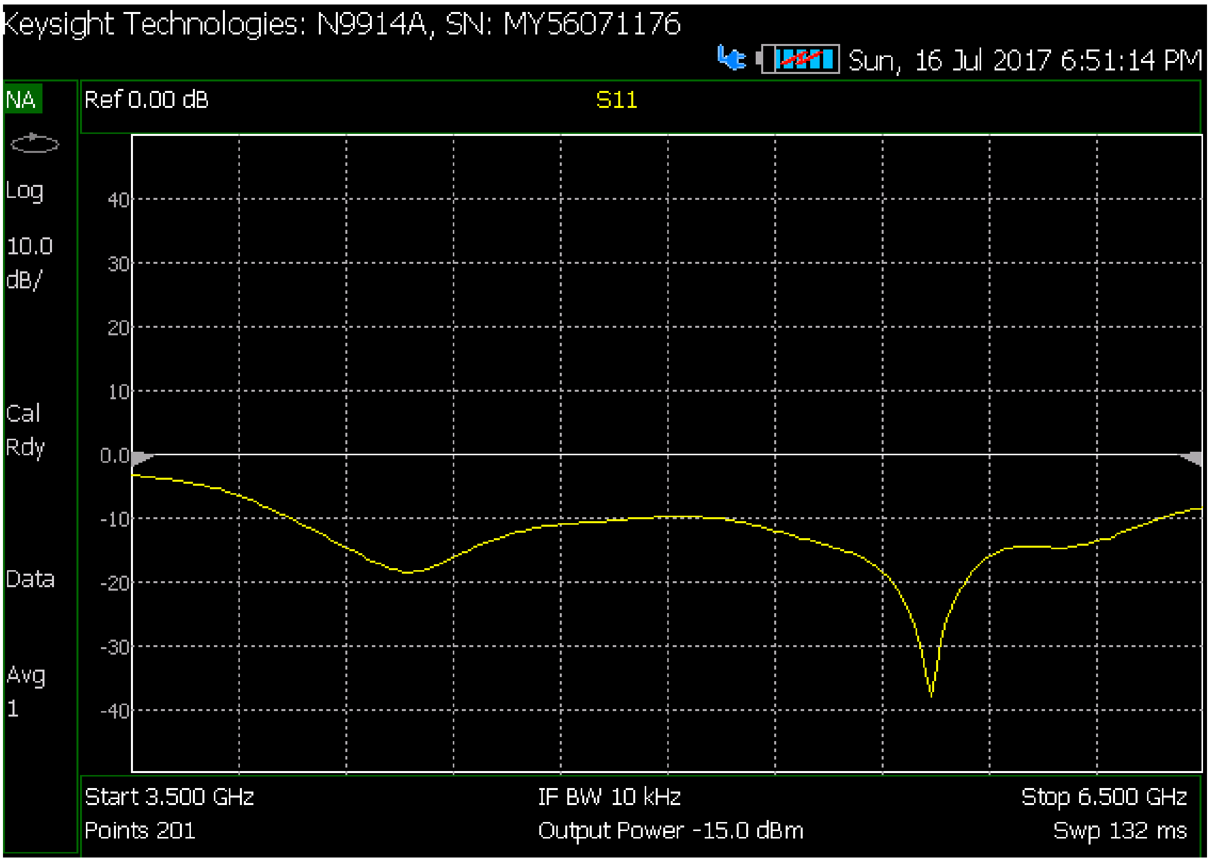

Fig 5.8 S-parameter of Aperture Coupled Antenna with four slot(Measured)

Fig 5.9 VNA measurement of fabricated antenna

5.2 COMPARATIVE ANALYSIS

Antennas with defective ground plane structure offer more bandwidth than the conventional Aperture Coupled Antenna. As can be from above graphs bandwidth is increasing with the presence of DGS.

5.3 ELECTRIC FAR FIELD

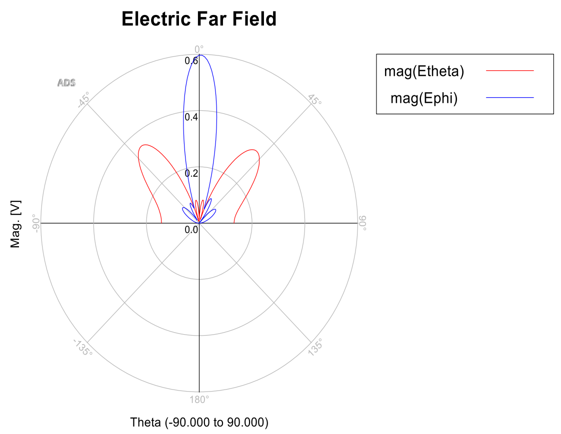

Fig 5.9 Far field for conventional design

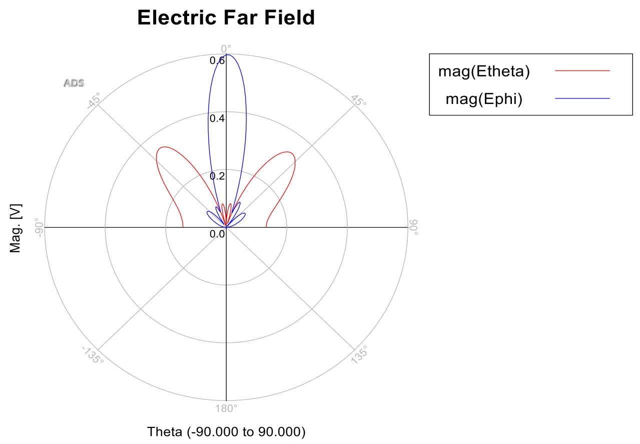

Fig 5.10 Far field for conventional design

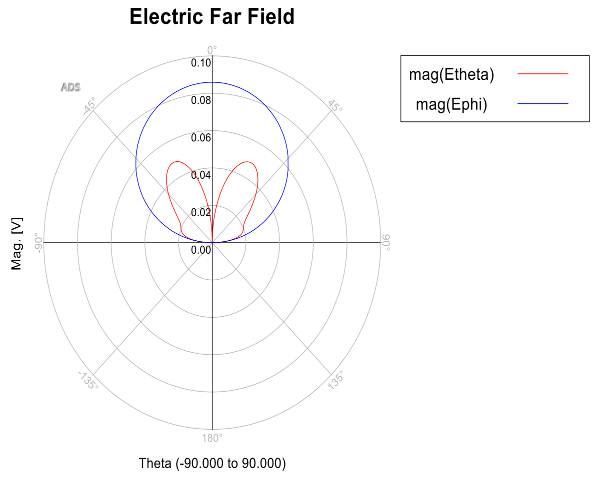

Fig 5.11 Far field for conventional design

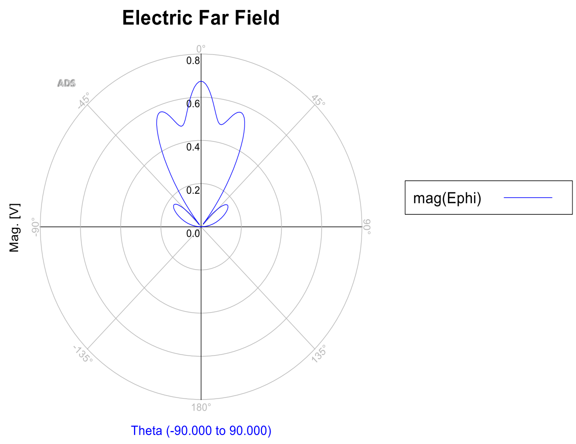

Fig 5.12 Far field for conventional design

When comparative study is done then it is observed that electric far field is better in case of Aperture Coupled Antenna with Defective Ground Structure.

6

CONCLUSION AND FUTURE SCOPE

This chapter sums up complete work done in the thesis, and then reaches to a conclusion which would help researchers in future to further improvements in the designed antennas.

Initially a conventional Aperture Coupled Micro-Strip Antenna is designed in the frequency range of 6 to 8GHz.Required dimension for designing were obtained using fundamentals of the patch antenna design. This antenna is consisting of two layers of substrates with heights of 1.6 mm and 1.5 mm with the same dielectric constants. The substrate is chosen to form the standard library of the Agilent ADS directory. Simulating this antenna gives s-parameter value of -17.44 dB.

Further in the later chapter Aperture Coupled Antennas are designed using the defective ground structure. Substrate chosen for designing of this antenna is same as the substrate chosen for the conventional Aperture Coupled Antenna. Dimension for the antenna are chosen from the required frequency range from the fundamentals of micro-strip patch antennas. Dimensions values are very small for these antennas therefore, miniaturization is obtained. A return loss values of -33.45 dB is obtained and fractional bandwidth improvement of 57% is obtained. A comparative analysis of the different Aperture Coupled Antennas is done as they are having single circular slot, double circular slot, and four circular slots.

Comparative analysis shows that presence of the DGS structure on the ground plane improves the antenna performance parameters. Fabricated antennas can be used in the applications like WLAN and in future mobile applications.

FUTURE SCOPE

Parametric variations of the physical parameters of the antenna are manually done but, this can be done using the software.

Shapes of the DGS structure is kept circular slots but in the future to enhance the performance parameters of the antenna more geometries on the ground plane can be etched.

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