Design and Development of Compact Millimeter Wave Microstrip Planar Antenna Using Defected Ground Structure for 5G Applications

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Thesis
Master of Technology in Electronics and Communication Engineering
(Specialization in Communication Systems)

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Department of Electronics and Communication Engineering

College of Technology and Engineering

Maharana Pratap University of Agriculture & Technology, Udaipur

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(Specialization in Communication System)

By

Suman Suthar

2018

COLLEGE OF TECHNOLOGY AND ENGINEERING

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE & TECHNOLOGY, UDAIPUR

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Date: 23/07/2018

This is to certify that **Suman Suthar** student of **Master of Technology in Electronics and Communication Engineering**had successfully completed the comprehensive/preliminary examination held on 12-10-2017 as required under the regulation for Post-Graduate Studies.

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CERTIFICATE – II

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This is to certify that this thesis entitled **Design And Development of Compact Milli-meter Wave Micro-strip Planar Antenna Using Defected Ground Structure for 5G Applications**submitted for the degree of Master of Technology in **Electronics and Communication Engineering** in the subject of **Communication Engineering** embodies bonafide research work carried-out by **Ms.Suman Suthar**under my guidance and supervision and that no part of this thesis has been submitted to any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 08/08/2017.

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CERTIFICATE – III

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This is to certify that this thesis entitled **Design And Development of Compact Milli-meter Wave Micro-strip Planar Antenna Using Defected Ground Structure for 5G Applications** submitted by **Ms.SumanSuthar** to MaharanaPratap University of Agriculture & Technology, Udaipur in partial fulfilment of the requirement for the degree of **Master of Technology** in the subject of **Electronics and Communication Engineering**after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination held on 1/10/2018 was found satisfactory; we therefore, recommend that the thesis be approved.

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This is to certify that**Ms.SumanSuthar** student of **Master Of Technology** in the subject of **Electronics and Communication Engineering** has made all corrections/modifications in the thesis entitled **Design And Development of Compact Milli-meter Wave Micro-strip Planar Antenna Using Defected Ground Structure for 5G Applications**which were suggested by the external examiner and the advisory committee in the oral examination held on 1/10/2018. The final copies of the thesis duly bound and corrected were submitted on 1/10/2018.

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Place: Udaipur

Date: 23/07/2018

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Suman Suthar

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1
INTRODUCTION

Chapter 2 1.1 Background

Over the last many years,there has been regular progress in the communication technologies. The communication revolution that started with the invention of telephones by Bell extended with the invention of the radio by Marconi. Currently,wireless communication is the most significant growing segment of the communication field. Now a day weight, size, cost, performance and ease of installation are major constraints for many governments and commercial applications such as mobile, radio, Satellite and Wireless communication.As well, in present time, demands of antennas technology which islow cost,compact in size, minimal weight and capable of maintaining high performance.

In the present era, we require a high data rate and compact size devices.Wireless technology is one of the most important areas of research in the world of communication systems in present time and a study of communication fields is incomplete without an understanding the details of the operationand fabricationof antennas in various fields. This was the main and important reason for selecting our project focused on this field.

Wireless communications have been rapidly increasing and developing every year and have reached a level of 4G networks till date, which has been designed to meet the requirements of wireless standards such as IEEE 802.16m and LTE-Advanced requirements. Main challenges for the future wireless system developers are the growing need for higher transmission rates and the increasing number of users. It is difficult to achieve higher transmission data rate because of the conventional wireless systems using frequencies up to 10 GHz due to limited bandwidth. A solution to achieve this high data transmission problem is the use of millimeter wave frequency technology that can provide large bandwidths.

5G network and system will new era in the world in the communication field. The 5G mobile system used for accessed different technologies at the same time and used in various field of technologies. This is agreed that the 5G network is high in speed than the 4G network. As compared to 4G and 5G, the 5G network should obtain the program capacity is 1000 times, 10 times the spectral efficiency, data rate and energy efficiency.5G antenna is smaller and compact size antenna that we will get more efficient results. Which may have offered 3G and 4G systems, and they will need more advanced steering and scanning techniques in an attempt to function well at mile meter wave frequencies.

There have been dynamic research activities round the world in advancing the next-generation 5G wireless systems. More than five billion dollars devices demand wireless contacts that working voice, data, and other applications in present day wireless networks. The amount of mobile data has expanded significantly throughout the years due to the availability of smart portable devices, which support high-speed wireless applications such as multimedia. The efficient deployment of the 5G systems requires the design of small yet efficient antennas. Presently there has been much interest within the antenna research community to develop effective antenna designs for the future 5G specifically designed to operate in 5G-frequency bands: 41GHz to 42.5 GHz band (Shubair et al., 2015).

Due to the shortage of worldwide bandwidth, Wi-Fi service carriers are in need to offer better performances for all of their clients and also they have to introduce new features for the necessities of mobile customers. on the grounds that wireless communication is advanced up to 4G, in future to address the traffic price, shortage of bandwidth and first-class of service 5G is added. Design a suitable antenna for 5G technology may be very vital at the same time as growing 5G cell telephones. Various parameters of an antenna have to be measured to test the suitability for 5G technology. The antenna is designed to operate on the mm-wave spectrum.

CMOS generation is used with this mm-wave antenna design. a few other strategies like MIMO and Adaptive beam forming are also used to improve the performances of mobile phones from 4G to 5G(Rappaport, 2013).

Recently micro-strip patch antennas are widely used often in antenna designs for their simplicity
and compatibility. Also, they are an attractive type of antenna due to their low cost, Conformability, and ease of manufacture (Garg et al., 2001) (Balanis, 2001).

Wireless technology has experienced an incredible progress and growth because of an ever-increasing demand of wireless devices in communication systems. In 4G LTE, several devices and networks are interconnected to provide an ultra-fast, efficient and high-speed communication for the users. With the massive up gradation of networks, the current spectrum assigned for wireless communication has theoretically reached its maximum system utilization. Millimetre-waves (MMWs) are anticipated as a promising candidate for the upcoming wireless solutions (Rappaport, 2013). Unused available spectrum at MMW frequencies has a potential to compete with the requirements of future 5G systems where high capacity and fast speed are the distinguishing features to achieve ((Rappaport, 2011),(Khan, 2011)). On the other hand, there are several critical limitations necessary to be resolved at MMW spectrum, such as the atmospheric attenuations and absorptions, which become more obvious at high frequencies. Developing a wireless network by integrating the advantages of MMW, while handling the limitations of the spectrum, is an immense task. In order to address these challenges, researchers are intensely focused to deal with shortcomings in developing a wireless architecture based on MMW frequencies.

Many current wireless systems operate at high frequency (3MHz to 30MHz), very high frequency (30MHz to 300MHz) and ultra-high frequency (300MHz to 3GHz) bands but there is need to go beyond these bands to meet higher transmission rate, larger bandwidth etc. The short wavelength of mm-wave is used to design the antenna that is easily fit in handheld devices.Recent studies show that millimeter wave frequencies could be used as a possible solution to future wireless networks congestion that only work in a frequency spectrum of 30 GHz –300 GHz. Millimeter wave antennas are also known as extremely high frequency (EHF) band and very high frequency band, which have high gain to counter the propagation losses issue in the free space.Currently, most of the research work is based on 28 GHz to 38 GHz band, 60 GHz band and E-band (71-76 GHz and 81-86 GHz).

In this trade of technology various demands of microwave and wireless communication systems in many types of applications resulting in an interest to improve antenna parameters performances. Therefore, the selection of micro-strip antenna is suitable and useful to apply in various fields such as medical application, telecommunication, satellite and, military system (Tariqul et al., 2009).

One of the popular and large scales used antenna in the wireless field is micro-strip patch antennas. Micro-strip antennas are widely used for its low profile, easily manufactured, simple structure, Omni directional radiation patterns and low fabrication cost (Balanis et al, 1997).These types of features of patch antenna provide a great advantage over the traditional ones. But the drawback of this kind of antenna also sometimes confines their applications, especially the narrow bandwidth(Arya et al., 2013).

Chapter 3 1.2 AntennaTheory

The smart antennas play an important role in today's wireless communication, such as Mobile and satellite communication,Global Positioning System (GPS), WiMAX, Radio Frequency Identification (RFlD), Wireless Local Area Networking(WLAN) and medicinal applications. The requirements of the antenna for Wireless communication applications are small,low cost, and low profile. Micro-strip patch antenna meets all this requirements.So most antenna designers preferred micro-strip patch antenna for various wireless communication applications according to C.A.Balanis (Balanis, 1997). Today Micro-strip patch antennas are the widely used type of the antennas due to their advantages such as low volume, low cost, light weight, and compatibility with integrated circuitsand easy to install on the rigid surface(Marotkar et al., 2015).

Electromagnetic waves are formed due to acceleration and deceleration of electrons in the conductor called antenna. The antenna is connected to a transmitter which is designed to output current as a function of time. This current is an electromotive force (EMF) which forces free charges in the conductive element of the antenna to travel back and forth along the transmitting antenna. So when we use the antenna as a transmitter, it excites with the electrical quantity which generates electromagnetic waves. The same structure is capable of receiving electromagnetic waves. That means when the EM waves are incident on the antenna, it will produce current at the terminals of the antenna. Usually, there is a long distance between the transmitting antenna and the receiving antenna, that movement of charge in the receiving antenna is much smaller than the quantity of charge and movement in the transmitting antenna. The small and somewhat distorted signal is then amplified by the amplifier. In order to understand the basics of antenna principle, there are some parameters which have been taken into account.

1.2.1 Radiation pattern

The radiation pattern or antenna pattern is the graphical representation of the energy from the antenna (Balanis, 2009).The radiation source of electric region at the edge space of Micro-strip component and the surface plane is the key factor to perfect computation for patch antenna pattern.The antenna pattern explains how the antenna is radiating energy out in of space (or how it receives energy in of space). the antenna radiates energy in all directions, so the pattern is Known as three-dimensional, as shown in fig. 1.1.the 3D radiation pattern is important for the finding the radiating energy in all direction. It is natural to explain this 3D pattern with two planar patterns, it is called the principal of the plane pattern. These principal plane patterns are commonly known as the antenna patterns.

In discussions of antenna patterns orprincipal plane patterns, the terms azimuth and elevation plane pattern are frequently used. The azimuth is normally found in reference of “the horizontal” or “the horizon” whereas the elevation is normally refers to “the vertical”. The azimuth plane pattern is measured by traversing the entire x-y plane around the antenna. The elevation plane is the plane orthogonal to the x-y plane (Francis Jacob, 2008).Azimuth plane and elevation planes are shown in fig. 1.2. (Radio-electronics.com)

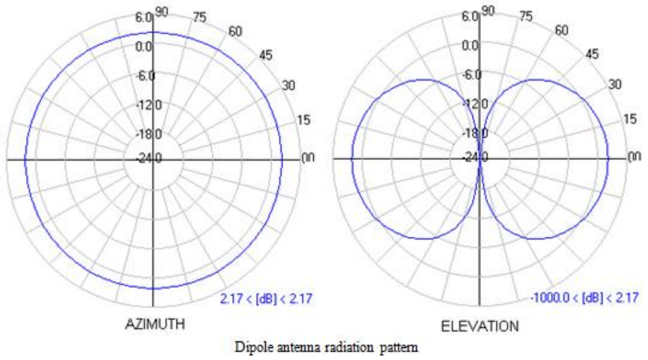


Fig. 1.1: Radiation pattern of half-wave dipole antenna

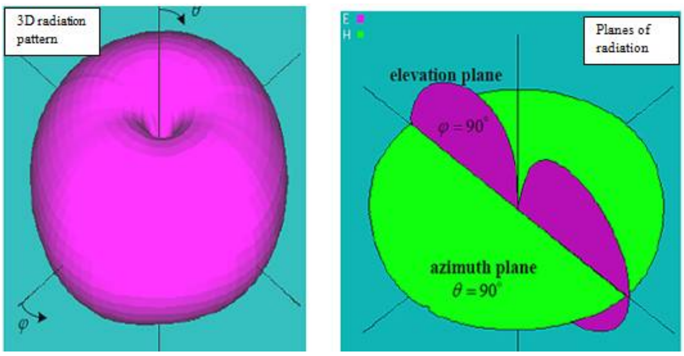


Fig. 1.2:Planes of radiation pattern

On the basis of radiation pattern, antennas are classified as:

- **Isotropic:**An antenna is isotropicif the radiation pattern is the uniform in all the directions. Antennas with isotropic radiation patterns don't exist in practice, but it is taken as the reference antenna for the measurement of gain. Fig. 1.3 shows the radiation pattern of a hypothetical isotropic antenna. Omni-directional patterns are normally desirable in mobile and hand-held systems.

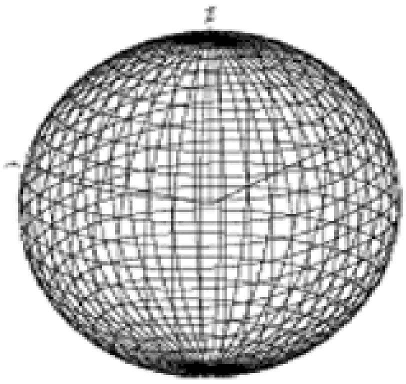


Fig. 1.3: Radiation pattern of an Isotropic antenna

- **Omni-directional:**An antenna is said to be Omni-directional, if the radiation pattern is isotropic in a single plane, i.e. those antennas whichradiate uniformly in all directions in one plane(Balanis, 2009).Examples of Omni-directional antennas are the dipole antenna and the many other antennas.Fig. 1.4 shows the radiation pattern of a hypothetical isotropic antenna.

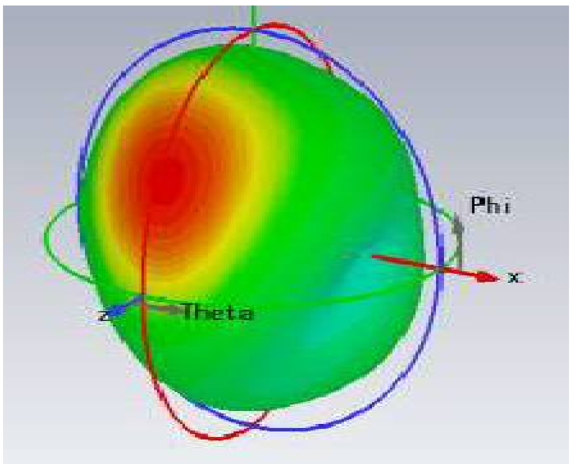


Fig. 1.4: Radiation pattern of an Omni-directional antenna (Soni, 2017)

- **Directional:** Those antennas which do not have symmetric in the radiation pattern are called directional antennas.In the directional antenna usually, have a one peak direction in the radiation pattern; in this direction the bulk of the power is more radiated. Examples of antennas having high directional radiation patterns such as dish antenna, slotted waveguide and, the sector antenna.An example of a directional radiation pattern is shown in Fig. 1.5.

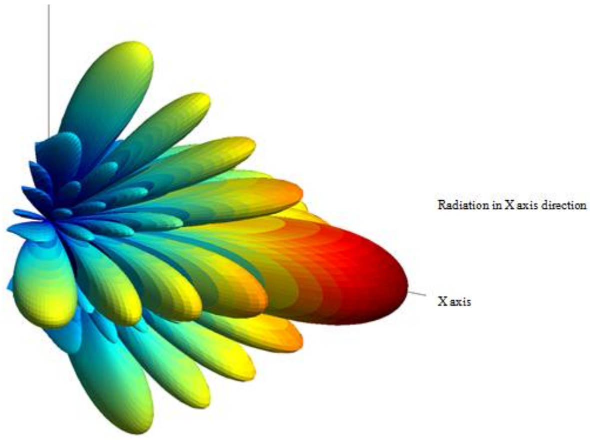


Fig. 1.5: Radiation pattern of a directional antenna

1.2.2 Bandwidth

Bandwidth can be said as the frequencies on both the sides of the Centre frequency in which the characteristics of an antenna such as the input impedance, polarization, beam width, radiation pattern etc. are almost close to that of this value (Ruchi et al., 2011). Bandwidth is a range of frequencies (maximum and minimum frequency) besides radiating frequency where the features or characteristics of micro-strip patch antenna such as return loss, gain, directivity, radiation pattern etc. is almost close to that of this value. Since the explanation goes "the range of appropriate frequencies where antenna performance, with respect to some feature, conforms to inexact standard". Bandwidth is the ratio of the higher frequency and lower frequencies of the process.

Bandwidth is a key factor for choosing the correct antenna. Antennas with a narrow bandwidth cannot be used for wideband operations. Bandwidth is typically quoted in VSWR (Voltage Standing Wave Ratio). For example, an antenna may be described asoperating at 100-400 MHzwith a VSWR<1.5, similarly, we can measure bandwidth by restricting return loss, isolation parameter etc. When the reflection coefficient is less than 0.2 across the quoted frequency range. Hence, only 4% of the power is reflected back to the transmitter (Francis Jacob, 2008).

1.2.3 Antenna gain

The Gain represents the maximum directivity. In other words, it can be defined as the ratio of radiation intensity of a practical antenna with respect to radiation intensity of the ideal antenna. The Gain is usually used to measure the performance of the antenna and the efficiency of the antenna.Antenna gain is defined as the ratio of the output power of the antenna and the total input power of the antenna.

$$G = \frac{P_{out}(\text{output power of the antenna})}{P_{total}(\text{total input power of the antenna})} \qquad \ldots 1$$

The Directivity of the antenna is known as how much the antenna is to concentrate energy in one particular direction in preference to the radiation in other direction. Gain combines both the efficiency with its directivity into a single figure. In case of transmission, the gain has to deal with how effectively an antenna can convert its input signal to radio waves heading to aspecific direction. On the other hand, during reception, ittells about how effective the antenna is in case of converting received waves into electrical signal. Gain is given by the following formula (Bala et al., 2010).

$$G = \epsilon_r D \qquad \ldots 2$$

Where, ϵ_r is the efficiency and D is the directivity.

1.2.4 Polarization

It is the plane where the electric field differs. The fundamental patch coated thus it is linearly polarized because electric field differs in only single direction. It can be something between vertical and horizontal depend on the direction of the patch. An antenna will generate an electromagnetic wave (EM waves) that varies in time as it travels through space. Fig. 1.7(Balanis, 2009) shows the locus of a linearly polarized wave at the origin.

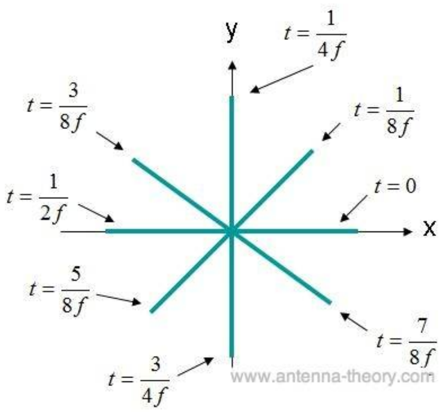


Fig. 1.6: E-field strength at (x,y,z) = (0, 0, 0) for field of a circularly polarized wave

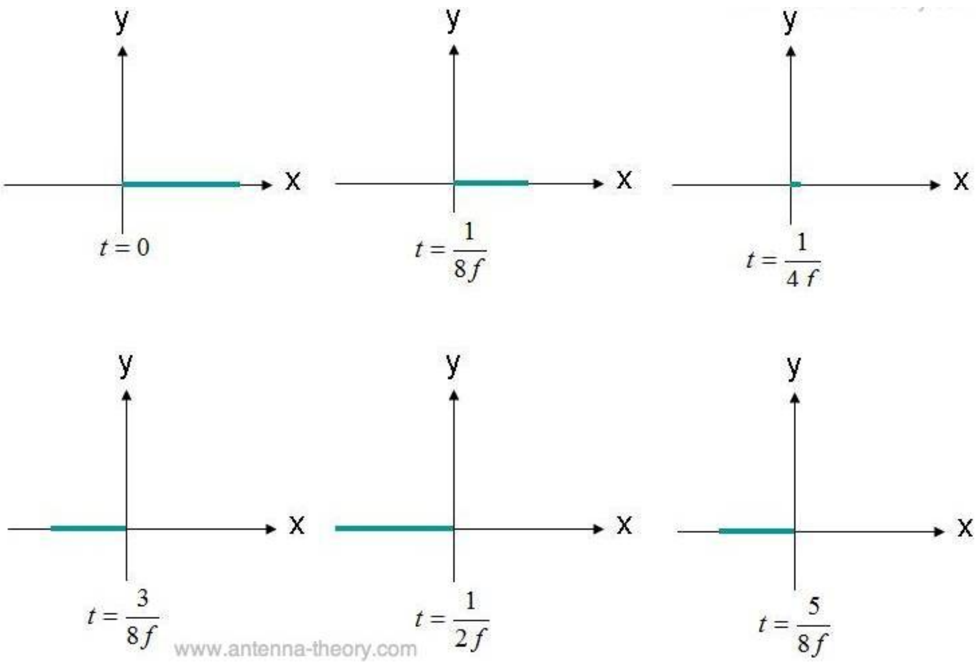


Fig. 1.7: E-field strength at (x,y,z) = (0, 0, 0) for field of a linearly polarized wave

If the wave rotates or "spins" in time as it travels through space, the wave is said to be elliptically polarized. As a special case, if the wave spins out in a circular path, the wave is circularly polarized. This implies that certain antennas are sensitive to particular types of electromagnetic waves. Circularly polarized wave is shown in fig. 1.6.

The practical implication of this concept is that antennas having the same polarization provide the best transmission/reception (Jacob, 2008). A horizontally polarized antenna can't communicate with a vertically polarized antenna. Due to the reciprocity theorem, the antennas receive and transmit the signal in an exactlythe same manner. Hence, a vertically polarized antenna transmits and receives only vertically polarized fields. In general, if two linearized polarized antennas are rotated from each other by an angle φ, then the power loss due to this mismatch polarization will be explained by the Polarization Loss Factor (PLF). (Likul et al., 2003).

$$PLF = cos^2\varphi \qquad \ldots 3$$

Hence, if both antennas have the same polarization and the angle between their radiated E-fields is zero then there is no power loss due to polarization mismatch. If one antenna is vertically polarized and the other antenna is horizontally polarized then the angle is 90º than no power will be transferred. If two antennas that are both circularly polarized, communicate with each other than they do not suffer signal loss due to polarization mismatch.

1.2.5Voltage Standing Wave Ratio (VSWR)

The VSWR is basically a measure of the impedance mismatch between the Transmitter and the Receiver of the antenna. VSWR is a function of the reflection coefficient which explainsthe power initiated from the antenna. It is constantly actual and positive number for an antenna. The minimum the VSWR, which corresponds to a perfect match. When the VSWR is smaller than the antenna is better matched to the transmission line and the more power is delivered to the antenna. And when the VSWR is higher or greaterthan the antenna is mismatched in these conditions the more power is reflected back toward the transmitter. The Least VSWR is 1.0 VSWR. In this case, no power is reflected from an antenna, which is an ideal condition. The impedance of the antenna varies based on many factors including the antenna’s numbers of ports, natural resonance at the frequency being transmitted, the antenna's height above the ground, and the size of the conductor. Interaction of these reflected waves and forward waves causes standing wave patternsVoltage standing wave ratio (SWR) is the ratio of the amplitude of a partial standing wave at an anti-node (maximum) to the amplitude at an adjacent node (minimum), in an electrical transmission line. Table 1.1 shows the fraction of transmitted power with VSWR:

Table 1.1: Percentage of power transmitted with VSWR

VSWR	Power transmission
1.00	100%
1.10	99.8%
1.50	96.0%
2.10	88.9%
3.01	75.0%
8.72	36.5%

1.2.6Directivity

Directivity is can be defined as the ratio of radiation intensity within a specified way from the antenna to average radiation intensity in every direction. And the gain may be identified as ratio among the number of energy propagated in these ways to the energy, if there is an Omni-directional antenna then it will be propagating. The antenna directivity depends upon radiation pattern form.Directivity is measure how “directional” an antenna’s radiation patterns”.

1.2.7 Return loss

Return loss is the measure of how much small the power is "return" or "reflected". Small return loss is bad for an antenna, it means less energy is going in our antenna and better and more return loss is good for an antenna, it means more energy is going in our antenna. When the return loss is poor then the antenna cannot radiate.

The 10dB of return loss is considered as the reference level in antenna designing. When the return loss is below 10dB then the result for antenna considered good.Return Loss 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. This Return Loss is determined in dB as follows:

$$R_L = -20 \log_{10}|Reflection\ coefficient| \quad ...4$$

Or

$$R_L = -10 \log_{10}|S_{11}| \quad ...5$$

Where $S_{11} = \frac{reflectedvoltageatportone}{incidentvoltageatportone}$

Chapter 4 1.3 Defected Ground Structure:

Defected ground structure (DGS), commonly used for enhancing the performance of printed circuits and antennas, has been relatively a new area of research. Single or multiple defects are usually created on the ground plane (GP) to perturb the current distribution and to introduce resonant properties which are modelled using an equivalent L-Ccombination (Yablonovitch et al., 1987).

Means of this method is Defect has been etched off in the ground plane. DGS comprising of any asymmetrical shape slot in earth has been accessible to enhance the bandwidth, compact the antenna size and also reduced the other parameters of Micro-strip Patch antenna. The parameters for instance Return loss; VSWR and Bandwidth are greatly enhanced in the projected antenna. CADFEKO Simulation tool has been used for the designed antenna.

In Present time, there have been many novel ideas applied to disperse microwave circuits. One of them is DGS that is significantly Known as Defected Ground Structure. In this Technique, the back side of radiating patch that means ground has to go with some amendments, these amendments could be of any shape or size.

In this technique, a defect or cut is used in the ground plane to modify the radiation characteristic of the whole antenna, this defect made in the ground will further change the behaviour of the radiation of the patch antenna.

Defected Ground Structure (DGS) is one of the methods, which are used to miniaturize the size of micro-strip antennas, DGS consist etching of a simple shape in the ground plane, or sometimes by a complicated shape for the better performance. Fig. 1.8 shows the example of DGS specific shapes etched on the ground plane of micro-strip circuits (Aris et al., 2015).

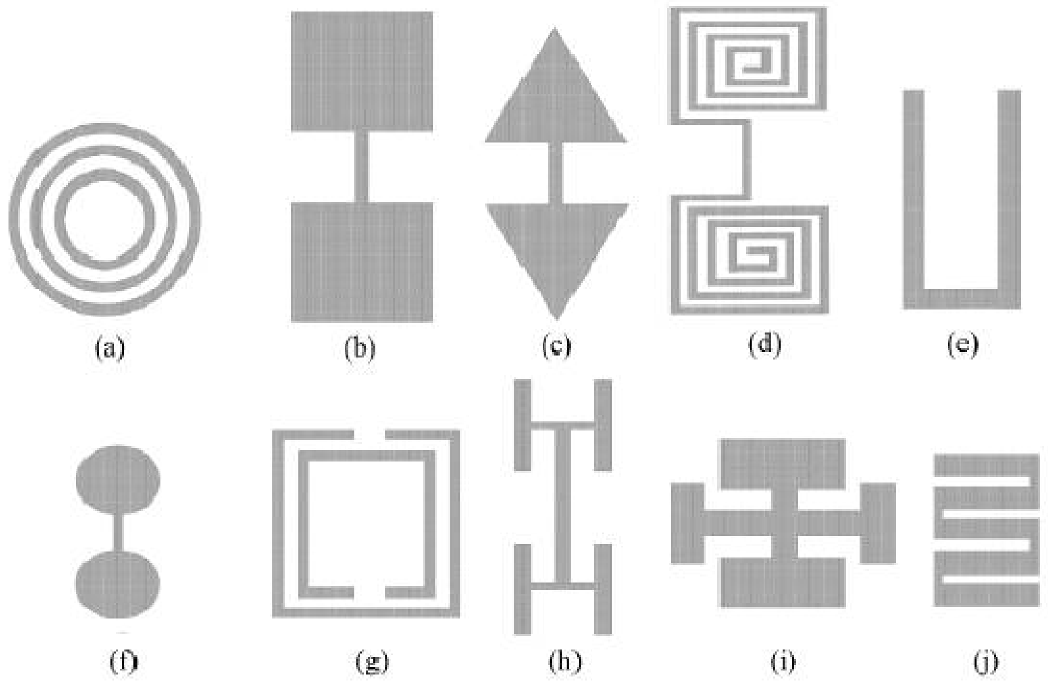


Figure 1.8: Different DGS geometries: (a) Dumbbell-shaped (b) Spiral-shaped (c) H-shaped (d) U-shaped (e) Arrow head dumbbell (f) Concentric ring shaped (g) Split-ring resonators (h) Meander line (i) Cross-shaped (j) Circular head dumbbell

Defected Ground Structure understands by introducing a symmetrical or non-symmetrical cut and defect on the ground plane of the Micro-strip patch antenna, this introduction changes the current distribution in the ground plane and significantly may increase the number of radiation frequencies.

As the antenna is radiating to the applied frequency there have to be some losses in the antenna, these losses are return losses and transmission losses, which arises when radiating waves enter in the substrate. The losses during the ground wave's excitation will origin reduce in the effectiveness, bandwidth and, gain of the patch because when ground wavearise, it can take out whole present radiation power to space wave.

Therefore, the micro-strip patch antenna lacking DGS, the return loss may be high and bandwidth may be low. Whereas, if DGS incorporated on the ground surface of the antenna then, it will modify the characteristic of the antenna basically the return loss and bandwidth without adding any further circuitry to the antenna.

The DGS can be designed by using an equivalent L-C resonator circuit. The value of the inductance and capacitance depends on the size and the area of the shape. By varying the various dimensions of the etched shape and etched defect, then the desired resonance frequency can be achieved.

1.3.1 Applications of DGS:-

1. Delay lines: -Placement of the DGS resonator along the transmission line introduces changes in the propagation of the wave along the line.
2. Filters: -Different shapes of DGS have been explored to design bandpass and band-stop planar filters.
3. Amplifiers:-DGS is used for improving the efficiency of the power amplifier.
4. Antennas:-DGS has been used for improving the various parameters of the planar antenna.

Chapter 5 1.4 Fields of an Antenna

The fields of an antenna are divided into three principle regions as follows-

1. Far Field or Fraunhofer Region
2. Reactive Near Field
3. Radiating Near Field or Fresnel Region

1.4.1 Far Field (Fraunhofer) Region

As the name suggests, the far field is the region far from the antenna. The far field region is the most important because this determines the antenna's radiation pattern. Also, antennas are used to communicate wirelessly for long distances, so this is the region of operation for most antennas. In this region, the radiation pattern does not change with distance (although the fields still die off as 1/R, the power density dies off as $1/R^2$). Also, this region is dominated by radiated fields such as the E- and H-fields orthogonal to each other and the direction of propagation as with plane waves(Likul et al., 2004).

If the maximum linear dimension of an antenna is D, then the following three conditions must all be satisfied to be in the far field region (Balanis, 2009):

$$R > \frac{2D^2}{\lambda} \quad \ldots 6$$

$$R \gg D \quad \ldots 7$$

$$R \gg \lambda \quad \ldots 8$$

The equation (7)and (8) ensures that the power radiated in a given direction from distinct parts of the antenna is approximately parallel. This helps to ensure the fields in the far-field region behave like plane waves.Also, near a radiating antenna, there are reactive fields that typically have the E-fields and H-fields die off with distance as $1/R^2$ and $1/R^3$. The equation (9) ensures that these near fields are gone, and we are left with the radiating fields, which fall off with distance as$1/R$.

1.4.2 Reactive Near Field Region

The reactive near field is in the immediate vicinity of the antenna. In this region, the fields are predominately reactive fields, which mean the E- and H- fields are out of phase by $90^0$to each other, while for propagating or radiating fields, the fields are orthogonal but are in phase.The boundary of this region is commonly given as(Balanis, 2009):

$$R < 0.62\sqrt{\frac{D^3}{\lambda}} \quad ..9$$

1.4.3 Radiating Near Field (Fresnel) Region

The radiating near field or Fresnel region is the region between the far and near fields.This regiondoes not contain reactive field components from the source antenna, because it is so far from the antenna. Back-coupling of the fields becomes out-of-phase with the antenna signal and thus cannot efficiently store and replace inductive or capacitive energy from antenna currents or charges. The energy in the radiating near field is thus all radiant energy, although its mixture of electric and magneticcomponents, still different from the far-field. Further out into the radiating near field (one half wavelength to one wavelength from the source), the**E**and**H**field relationship is more predictable, but the**H** to**E**relationship is still complex, since the radiating near field is still part of the near-field, there is potential for unanticipated (or adverse) conditions(Likul, 2004).The region is commonly given by:

$$0.62\sqrt{\frac{D^3}{\lambda}} < R < \frac{2D^2}{\lambda} \quad ..10$$

Depending on the values of R and the wavelength, this field may or may not exist.Fig. 1.8 gives a pictorial representation of near and far field regions for an antenna.

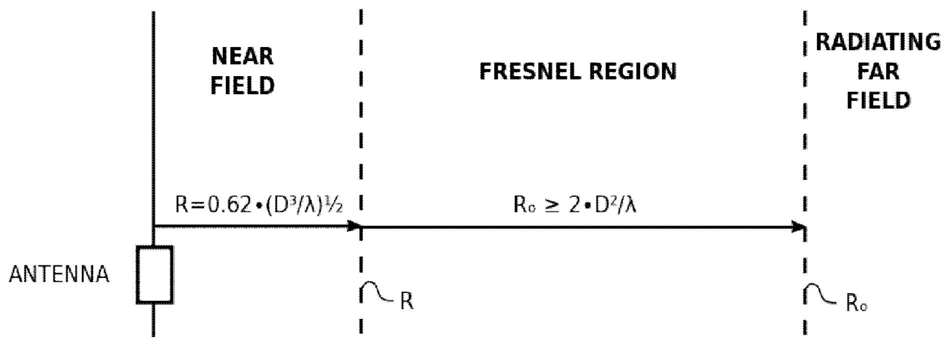


Fig. 1.9: Field distribution for an Antenna

Chapter 6 1.5Micro-Strip Patch Antennas

Micro-strip or patch antennas are very useful because they can be printed directly onto a circuit board. Micro-strip antennas are becoming very popular because of features like low profile,low cost and easy fabrication.

The normally geometry of a microstrip patch antenna (MPA) consists of a radiating patch on one side of the dielectric substrate and ground plane on another side so it is kind of semiconductor material. Micro-strip patch antenna is also known as a printed antenna. This antenna is mainly used at microwave frequencies. Normally a single patch antenna provides a Maximum gain is around 6 to 9dBi. It is easy to fabricate and comfortable on the curved surface. Its installation is very easy due to light weight, small size and low cost. Micro-strip patch antenna is various shapes such as the rectangle, circle, annular-ring, square, triangular and round shape. The patch antenna idea was first proposed in the early 1950s, but it was not until the late 1970s that this type of antenna attracted serious attention of the antenna community.

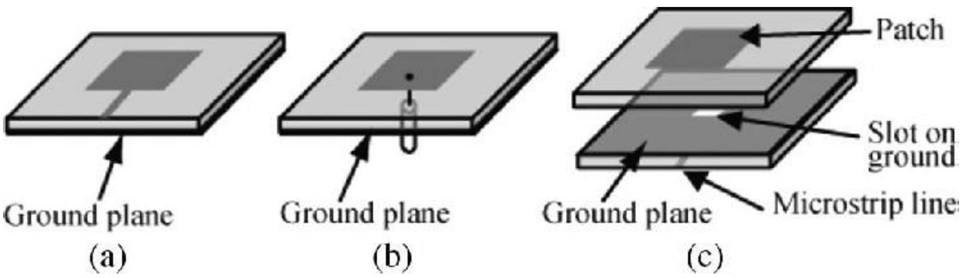


Fig. 1.10: Plane of Patch antenna(a), (b) and (c)

While designing airplane, missile and satellite, spacecraft etc. designing the dimension, mass, effortless installation, charge and aerodynamic outline are the limitations, and small shape antennas are needed. The microstrip patches antenna consistence too non-planar and planar ground, easy and economical to fabricate by current printed-circuit tools.

The Micro-strip patch antenna is very popular and useful patch antenna for small charge and solid design for RF uses and Wi-Fi systems. In Wi-Fi cellular phone call and satellite uses, micro-strip patch antenna has magnetized a lot interest because of less dimension, cheap on mass production, less burden, short profile and simple incorporation with other parts.

Micro-strip antenna is shown in fig. 1.11. The patch antennaand the ground planes are made up of highly conductive metal material (typically copper) plate. The patch is of length 'L'and width 'W'sitting on top of a substrate, which is a dielectric circuit board of thickness'h' with permittivity '$\in_r$'. The thickness is not critically important for the ground plane andpatch. Typically the height 'h' is much smaller than the wavelength of operation, but not much smaller than 0.05 times the wavelength.

The frequency of operation of the patch antenna is determined by the length of patch. The center frequency will be approximately given by (antennatheory.com):

$$f_c = \frac{c}{2L\sqrt{\in_r}} = \frac{1}{2L\sqrt{\in_0 \in_r \mu_0}} \quad ..11$$

Where

$\in_0$ = absolute permittivity and

μ_0= absolute permiablility.

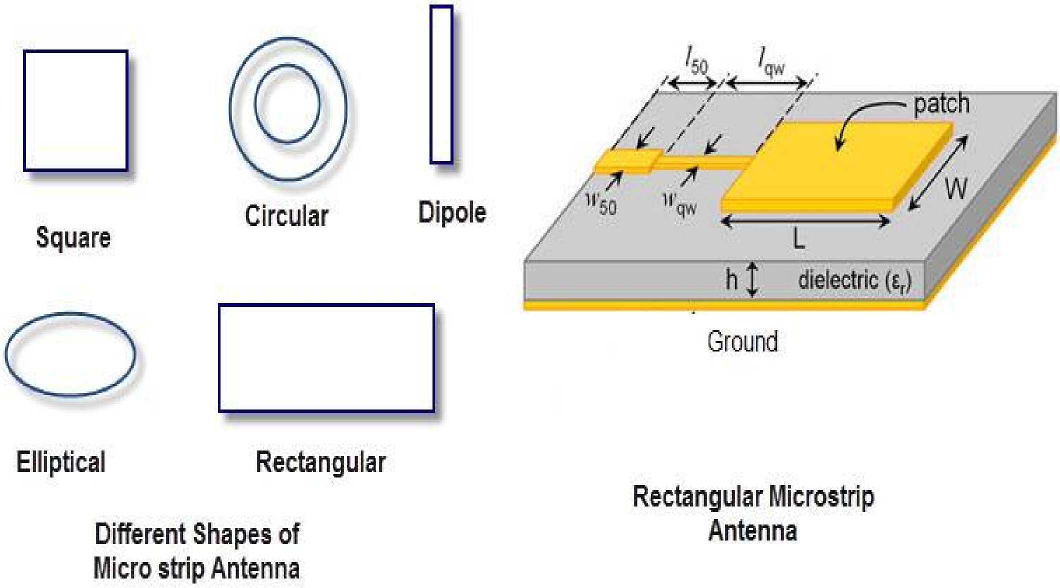


Fig. 1.11: Pictorial Representation of a Micro-strip Patch Antenna

1.5.1 Types of Micro-strip patch antenna

1. **Half Wave Antenna**

   It is substituted with a shorting plane to make micro-strip antenna of quarter-wavelength. This is also named half-patch. It has one main lobe of radiation pattern which is lesser than the antenna directivity. Compared to half wavelength full patch impedance bandwidth is lesser as pairing between the radiating edges has been reduced. Micro-strip patch antenna influences both its impedance bandwidth and radiation model.

2. **Planar Inverted F Antenna(PIFA)**

   Planar Inverted F antennas admired because of its Omni directional pattern and small profile. It radiates in only a single plane. Its radiation in a plane decreases in dimension which reduces the resonance frequency. Habitually PIFA have several subdivisions to resonate at different bands of cellular.

3. **Folded Inverted Conformal Antenna (FICA)**

   The Folded Inverted Conformal Antenna has its position on cell-board and also its supply systems are related to those utilized presently for the huge greater part of cells with inside PIFA. FICA formation is created in sort of maintain three resonant forms that improved recycle the volume.

1.5.2 Basic Principle of Micro-strip Patch Antenna

The patch behaves like a transducer which contains resonant like cavity having its barriers like short circuit elements on front and back of the substrate. In a confined space or cavity there is only assured forms are permitted to be present, at unusual radiating frequencies. If frequency is applied to the antenna, a powerful ground is set up within cavity and a powerful current on the (base) ground of the patch. This generates important radiation (perfect antenna). This type of antenna is a very low cost and easy to fabricate and possess very large number of qualities. Micro-strip patch antenna converts the electromagnetic waved into the electrical signal at the time of receiving and do vice versa at the time of transmission of the signal.

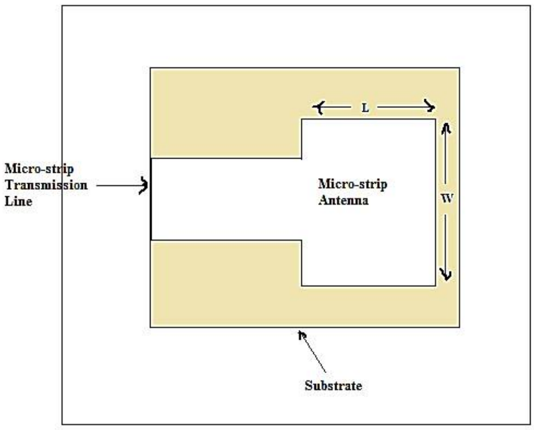


Fig.1.12: Principal of Micro-strip Patch Antenna

1.5.3 Working of Antenna

Antenna works as a transducer, which convert one from of energy into another. At the transmitter side it converts electrical energy into electromagnetic waves and at the receiving side it converts the electromagnetic waves into electrical energy.

Chapter 7 1.6Feed Technique

Micro-strip patch antenna could be excited by many techniques. These schemes could be distinguished into two sections - non contacting and contacting. In the former system, coupling is completed to move power among radiating patch and micro-strip line. In the contacting system, the RF power is supplied straightly to the radiating patch by a linking component for instance a micro-strip line. The five mainly admired feed methods are-

1. Micro-strip Line Feed
2. Coaxial Feed
3. Aperture Coupled Feed
4. Proximity Coupled Feed
5. Coplanar Waveguide Feeding

1.6.1Micro-strip Line Feed

In this Method, a micro-strip is linked straightly to the micro-strip patch border. This strip is lesser in thickness as equal to the patch and this kind of feed placement has the benefit that feed may be etched on equal substrate to offer a planar arrangement. For Good Impedance matching, we can vary the inset cut position. This is an easy fabrication technique and it provides the easy fabrication process and simplicity in modelling same as impedance matching(Bisht, 2014).

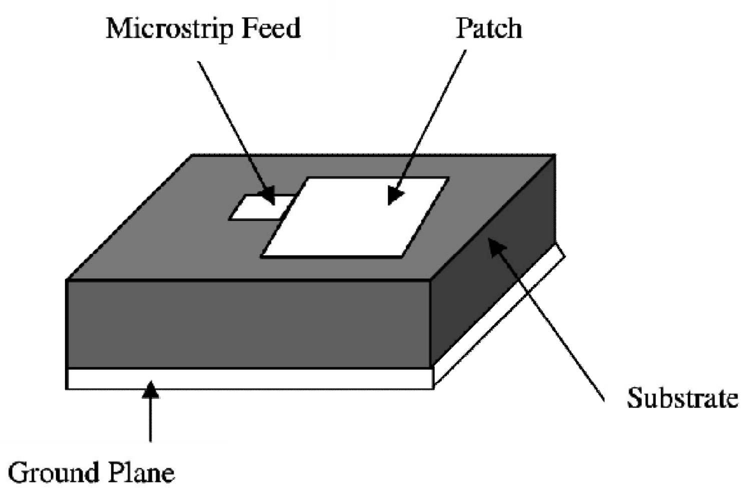


Fig. 1.13: Micro-strip Line Feed

1.6.2Coaxial Feed

It is also called probe feed. It is an extremely ordinary method utilized for supplying micro-strip patch antenna. The internal conductor of the coaxial connector widens throughout the dielectric and is linked to the radiating patch, while the other conductor is coupled to the surface pane.

The Major benefit of this sort of feeding method is that simple to manufacture and has small bogus radiation. Though, its main drawback is that it offers narrow bandwidth. In these techniques for impedance matching the feed can be placed at any desired position into the patch. This feed technique is easy to fabricate and have low radiation effect(Bisht, 2014).

1.6.3 Aperture Coupled Feed

In this scheme, the radiating patch and the micro-strip feed line are divided through the earth plane. Pairing between feed line and patch is prepared by an aperture in the surface plane.

The pairing aperture is generally cantered in the patch, directing to lesser cross polarization owing to symmetry of the arrangement. The quantity of coupling from supply line to the patch is resolute by the profile, dimension and position of the aperture.

The main drawback of this feed system is that it is complex to construct owing to numerous layers, which also enhances the antenna width. This feeding method also offers narrow bandwidth(Bisht, 2014).

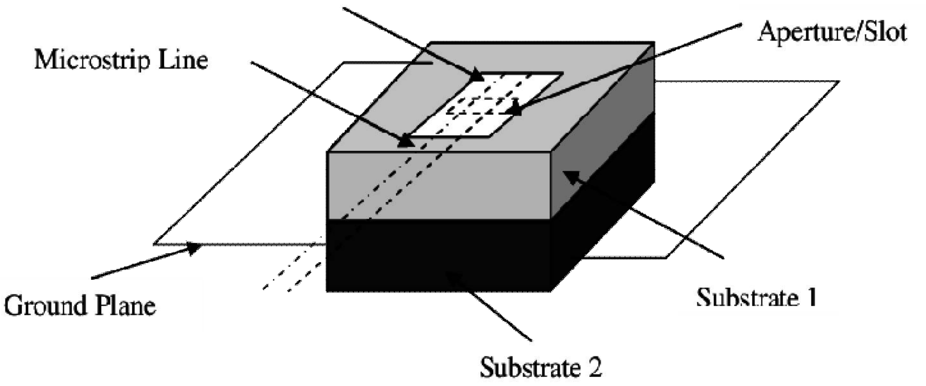


Fig. 1.14: Aperture Coupled Feed

1.6.4 Proximity Coupled Feed

In Proximity coupled feed, feed is implemented not on the above surface like we used to do in the micro-strip feed as well as not on the ground surface like coaxial feed, in this technique feed is applied between the substrate and the radiating patch.

The foremost problem of this scheme is that it is complicated to construct Micro-strip Line patch because of the two dielectric layers that require accurate arrangement. Moreover, there is the enhancement in the entire width of the antenna.

This technique is also known as electromagnetic coupling. In these techniques, the feed line is between the two dielectric substrates and the radiating patch is on the top of the upper dielectricsubstrate(Bisht et al., 2014).

The main advantages of this feed techniques is that it eliminates feed radiations and provides high bandwidth is about 13%. It provides the choice between the two dielectric media that is one for the patch and one for the feed line to optimize the individual's performance.

The main disadvantage of this technique is it is difficult to fabricate because having two dielectric layers and these layers need the proper alignment(Bisht et al., 2014).

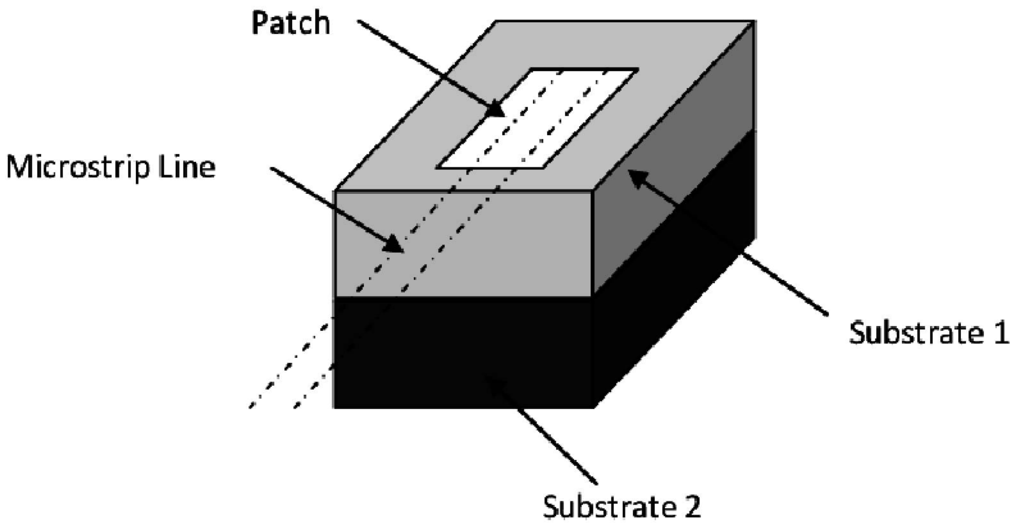


Fig. 1.15: Proximity Coupled Feed

1.6.5Coplanar Waveguide Feed

A CPW is the mainly given preference over other types of feeding technique for MMIC circuits (Microwaves Monolithic Integrated Circuits). Because micro-strip antenna and CPW both comes under the planar geometry. Therefore, for integrating micro-strip antenna with CPW. It is desirable to feed the micro-strip antenna with a CPW. The CPW fed antenna have been broadly utilized for Wi-Fi communications due to their numerous good features for instance broad bandwidth, easy arrangement of a solitary metallic layer, no soldering points, simple integration with MMIC, etc.

Table 1.2: Comparison of the characteristics for different feed techniques (Bisht et al., 2014).

Parameters	**Micro-strip Line Feed**	**Coaxial Feed**	**Aperture Coupled Feed**	**Proximity Coupled Feed**
Feed Radiation	High	High	Low	**Less**
Reliability	Much Better	Poor	Average	Average
Impedance	Simple	Simple	Simple	Simple

Matching				
Bandwidth	2.5%	2.5%	2.5%	2.5%

1.7 Merits of Micro-strip Patch Antenna

Advantages of Micro-strip patch antenna are:

1. Light weight and low volume
2. Small fabrication charge therefore can be produced in huge quantities.
3. Sustains both, linear and circular polarization.
4. Can be simply incorporated with MICs.
5. Double and triple frequency functions.
6. Micro-strip Antenna is comparatively cheap to fabricate and plan because of the plain 2-D physical geometry.
7. Simple to make an array of patches on one substrate by lithographic schemes.

1.8 Demerits of Micro-strip Patch Antenna

It endures from additional problems correlate conventional antennas. Main drawbacks of it are following:

1. Small gain.
2. Small efficiency.
3. Small power handling capacity.
4. Narrow bandwidth.
5. Irrelevant radiation from junctions and feeds.
6. Plane wave excitation.
7. Fire antenna apart from tapered slot antennas.

1.9 Application of Micro-strip Patch Antenna

Applications of Micro-strip patch antenna are given below:

1. Radio altimeters.
2. Command and control system.
3. Remote sensing and environmental instrumentation.
4. Feed element in complex antennas.

5. Satellite navigation receivers.
6. Mobile Radio
7. Integrated antennas.
8. Doppler and other radars.
9. Used in biomedical applications such as hyperthermia.

CHAPTER 2

REVIEW OF LITERATURE

Chapter 8 2.1 Literature Review

Denidniet al. (1998) in this paper, broadband patch microstrip antenna is investigated. The goal is to meet the demands on wireless communication systems where there is a substantial need for new antennas, which are light, low profile and low cost. Micro strip patch antenna constitutes a best candidate in this area. However, these antennas are characterized by the limitation of their bandwidth that is of order 1–2%. In wireless system, this band is not enough sufficient for a high rate data transmission. To overcome this problem, a new antenna is presented in this paper.

Chung et al.(2003)this paper presents multifunctional micro strip transmission lines for designing a high port-isolation dual-frequency orthogonally polarized rectangular patch antenna and the antenna-integrated power amplifier. The proposed lines were realized through the integration of defected ground structures (DGSs) with conventional micro strip lines. A spiral-shaped DGS-integrated microstrip line enhances the port isolation of the antenna, while feeding the 2.0-GHz excitation to the antenna and filtering out the 2.5-GHz receiving signal from the other port. High-order harmonic signal suppression of the power amplifier at the 2.5-GHz port was accomplished by the dumbbell-shaped DGS, thereby improving the efficiency of the amplifier. Measurements show an improvement of 20 dB in port isolation and 3% in power-added efficiency relative to an identical RF front-end, but integrated with a conventional patch antenna. An image impedance of the DGS-integrated microstrip lines can be controlled by the integrated DGS geometries. Relatively high-impedances lines, i.e., 150 and 100, are effectively implemented using microstrip lines with 75- and 50 /spl Omega/ linewidths by incorporating the spiral- and dumbbell-shaped DGSs, respectively.

Biswas et al. (2013) Controlling higher order modes up to third harmonic of the fundamental operating frequency in a microstrip line-fed patch antenna has been successfully demonstrated. Harmonic rejection in the antenna has been achieved at its feed level using highly compact design of defected ground structure (DGS). Rejection characteristics have been improved adding an open stub to the feed line. All possible higher order modes occurring in between the fundamental and the 3rd harmonic have been identified. Relative suppression of radiated fields with and without DGS-control has been quantitatively measured and effective control of harmonics has been experimentally ensured. The area occupied by the proposed DGS has been compared with earlier designs and over 40–90% reduction in size has been documented.

Khandelwal et al. (2013) a wide band Micro strip antenna with defected ground plane structure is proposed for Ku Band applications. The design procedure is presented and characteristics of the antenna are analysed. A 50-ohm Micro strip line is used to excite he circular slot integrated in ground plane. The measured results demonstrate that the structure exhibits a wide impedance bandwidth of 56.67% ranging from 9.8 GHz to 17.55 GHz, which covers Ku-band and partially X-band. Within the band, stable radiation characteristics are observed. The designed antenna has a gain ranging from 5dBi to 12.1dBi in impedance bandwidth range. Isolation of about 20dB is observed between the co-polar and cross-polarization level.

Subbulakshmiet al. (2013) The modern mobile communication systems requires high gain, large bandwidth and minimal size antenna's that are capable of providing better performance over a wide range of frequency spectrum. This requirement leads to the design of Micro strip patch antenna. This paper proposes the design of 4-Element micro strip patch antenna array which uses the corporate feed technique for excitation. Low dielectric constant substrates are generally preferred for maximum radiation. Thus it prefers Taconic as a dielectric substrate. Desired patch antenna design is initially simulated by using high frequency simulation software SONNET and FEKO and patch antenna is designed as per requirements. Antenna dimensions such as Length (L), Width (W) and substrate Dielectric Constant (ε_r) and parameters like Return Loss, Gain and Impedance are calculated using high frequency simulation software. The antenna has been designed for the range 9-11 GHz. Hence this antenna is highly suitable for X-band applications.

Haraz et al. (2014) In this paper, a new dense dielectric (DD) patch array antenna prototype operating at 28 GHz for future fifth generation (5G) cellular networks is presented. This array antenna is proposed and designed with a standard printed circuit board process to be suitable for integration with radio frequency/microwave circuitry. The proposed structure employs four circular-shaped DD patch radiator antenna elements fed by a 1-to-4Wilkinson power divider. To improve the array radiation characteristics, a ground structure based on a compact uniplanar electromagnetic band gap unit cell has been used. The DD patch shows better radiation and total frequencies compared with the metallic patch radiator. For further gain improvement, a dielectric layer of a super state is applied above the array antenna. The measured impedance bandwidth of the proposed array antenna ranges from 27 to beyond 32 GHz for a reflection coefficient (S11) of less than 10 dB. The proposed design exhibits stable radiation patterns over the whole frequency band of interest, with a total realized gain more than 16 dBi. Due to the remarkable performance of the proposed array, it can be considered as a good candidate for 5G communication applications.

Mittal et al. (2014)Antenna is the most important part of wireless communication. The recent growth in this industry makes the antenna more advanced and reliable. In various fields we need the use of highly characteristics antennas and these characteristics are based upon some parameters like bandwidth, gain, directivity etc. As compared to other antennas micro-strip antenna can make possible to achieve the required characteristics for efficient communication because they are easily to fabricate and reduces the cost also. To make the micro-strip antenna more advanced it use defected ground structure (DGS). The DGS structures are introduce to improve the performance of planar array antenna in terms of return loss, gain, directivity and voltage standing wave ratio. The goal of this paper is to understand the mathematical terms of antenna and feeding techniques so that it possible to know how to make the Micro-strip antenna with DGS as more highly characterized antenna.

Arora et al. (2015) A Micro strip Patch Antenna is a type of radio antenna with a low profile, which can be mounted on a flat surface. It is a narrowband, wide-beam fed antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate such as a printed circuit board with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Its various applications are biomedical diagnosis, mobile radio, and remote sensing, wireless and satellite communications. A good impedance matching condition is required between the line and patch without any additional matching elements. This condition can be provided using various feeding techniques. In this paper, a comparative study between inset feed, micro strip feed and co-axial feed, on a rectangular micro strip patch antenna are done on the basis of S-parameter, Reflection gain, VSWR and Radiation Pattern using Hyperlynx IE3D EM software.

Ojaroudiparchin et al. (2015) The design of a 28 GHz phased array antenna for future fifth generation (5G) mobile-phone applications has been presented in this paper. The proposed antenna can be implemented using low cost FR-4 substrates, while maintaining good performance in terms of gain and efficiency. This is achieved by employing a new air-filled slot-loop structure as the radiator. A prototype array consisting of ten radiator elements has been designed for concept validation. Both the radiation and total efficiencies of the antenna array are higher than -0.5 dB(90%) for the scanning range between 0o to 50o, while the gains are higher than 13 dB. In addition, the simulated and measured results show that the antenna has the S11 response less than -10dB in the frequency range of 27 to 29 GHz.

Harazet al. (2015) In this article, a dual-band printed slot antenna for the future fifth generation (5G) mobile networks are proposed. The antenna is compact with size of $0.8\ \lambda_0 \times 0.75\ \lambda_0$ at 28 GHz. Matching between a sector-disk shaped radiating patch and the 50-Ω microstrip line is manipulated through aproximity-feed technique. An elliptically shaped aperture is etched in the ground plane to enhance the antenna bandwidth. A shunt stub is used to get more enhancement of the impedance bandwidth of the antenna. To reduce the interference between the 5G system and other systems, π-shaped slot is etched off in the feed line to create a notched band of 30-34 GHz. The simulated results show that the designed antenna has a dual band function at 28/38 GHz that covers future 5G applications. The proposed antenna provides almost Omni-directional patterns, relatively flat gain, and high radiation efficiency through the frequency band excluding the rejected band.

Kumar et al. (2016)in this paper, the dual-band slot antenna operating at 32 and 42 GHz for 5G mobile communication is presented. The presented design consists of an elliptical slot with sectored radiating patch to increase the antenna bandwidth and also to minimize the interference between 5G and other communication devices. The simulated result shows that the presented antenna has dual-band at 30.5-32 GHz and 40.5-42 GHz, which has a bandwidth of 1.5 GHz each for reflection coefficient less than -10dB. The simulated radiation patterns showed that the presented antenna is highly directional with VSWR less than 2 and achieved frequencies lie within the proposed 5G band. This antenna has been designed and simulated on HFSS using Neltec substrate with dielectric constant of 3.2.

Harazet al. (2016) In this paper, a broadband elliptical-shaped slot antenna for the future fifth generation (5G) wireless applications is proposed. The antenna has a compact size of $0.5\lambda_0 \times 0.5\lambda_0$ at 30 GHz. It consists of a circular shaped radiating patch fed by a 50-Ω micro strip line via proximity-feed technique. An elliptically shaped slot is etched in the ground plane to enhance the antenna bandwidth. A stub has been added to the micro strip line feed to achieve better impedance matching bandwidth of the antenna. Simulated results indicate that the proposed 5G antenna `yields a broadband impedance bandwidth larger than 67% (from 20 GHz to beyond 40 GHz) for S11 less than -10 db. The achieved bandwidth covers both future 5G bands (28/38 GHz). The proposed antenna provides almost Omni-directional patterns, relatively flat gain, and high radiation efficiency through the frequency band excluding the rejected band.

Jilani et al. (2016) This paper presents a T-shaped antenna at millimeter wave (MMW) frequency ranges to offer a number of advantages including simple structure, high operating bandwidth, and high gain. Defected ground structures (DGS) have been symmetrically added in ground in order to produce multiple resonating bands, accompanied by partial ground plane to achieve continuous operating bandwidth. The antenna consists of T-shaped radiating patch with a coplanar waveguide (CPW) feed. The bottom part has a partial ground plane loaded with five symmetrical split-ring slots. Measured results of antenna prototype show a wide bandwidth of 25.1-37.5 GHz. Moreover, simulation evaluation of peak gain of the antenna is 9.86 dBi at 36.8 GHz, and efficiency is higher than 80% in complete range of operation. The proposed antenna is considered as a potential candidate for the 5G wireless networks and applications.

Marotkar et al. (2016) This paper presents a Bandwidth enhancement of Rectangular micro strip patch antenna (RMPA) using defected ground structure (DGS). A simple RMPA is designed which works at 2.4 GHz frequency. This antenna is considered as reference antenna. This antenna has bandwidth of 67 MHz In this RMPA DGS technique is integrated. U shape DGS is inserted in a simple RMPA. Due to DGS, Bandwidth is improved compared to earlier antenna. Later this U shape DGS is modified to E shapes DGS. Later this E shape DGS is modified to Double E shapes DGS and finally into Psi shapes DGS. The bandwidth of simple RMPA was 67 MHz which got improved to 302 MHz at 2.4 GHz frequency of with Psi shape DGS. The bandwidth received is suitable for different applications of WLAN. Ansoft HFSS software is used for simulation of the designed structure.

Oktafianiet al. (2016) In this article, a printed patch antenna array for 37 GHz point-to-point wireless links is analyzed. The antenna array consists of five elements with rectangular patch and uniform distribution. It has a compact size of 30.25 × 9.5 mm with operating frequency at 37 GHz that covers future 5G applications. The designed antenna using a substrate with a relative dielectric permittivity of 2.2 and a thickness of 0.508 mm with 50 Ω Sub Miniature version A (SMA) connector as a feeding. The proposed antenna provides a wide bandwidth, directional radiation pattern and high gain.

Suvalka et al. (2016)A new wideband compact planar microstrip antenna with defected ground structure is presented. The compact size of antenna is 57 mm × 46 mm × 1.59 mm. Defected ground structure antenna has minimum return loss of -24.77 dB and -19.04 dB at operating frequency 5.57 GHz and 3.51 GHz respectively. This antenna provides percentage bandwidth of 52%, ranging from 3.4 GHz to 5.9 GHz with constant gain. This antenna is useful structure for lower ultra wideband (UWB) applications along with modern wireless communication systems such as WI-FI, WLAN and Wi-Max bands

Er-rebyiy et al. (2017) The concept of Defected Ground Structures (DGS) has been developed to improve the characteristics of many microwave devices. For this purpose the DGS is also used in the micro-strip antenna for some advantages such as antenna size reduction, mutual coupling reduction in antenna arrays etc... In this paper the defected ground structure (DGS) has been employed to miniaturize a micro-strip patch antenna and to shift the resonance frequency from an initial value of 10 GHz to a final value at 3.5 GHz, without any change in the dimensions of the original micro-strip patch antenna. This antenna is designed on a FR-4 substrate with dielectric constant 4.4 and thickness 1.6 mm and its size is 27 X 30 mm2. The antenna is designed, optimized, and miniaturized by using CST MW.

Jajere et al. (2017) A simple rectangular patch antenna operating in the unlicensed mille meter wave band is presented. The proposed antenna resonates at 38GHz with the corresponding return loss of -31dB, covering about 4GHz bandwidth which makes it a suitable candidate for the next generation (5G) wireless communication devices. The total profile of the designed structure is 5×4×0.64mm3; other parameters such as VSWR, gain, and radiation pattern are also discussed in this paper

Chapter 9 2.2 Overview of Literature Review

Table 2.1 gives an overview of literature review.

Table 2.1: Overview of literature review

Author	**Year**	**Title**	**Adopted index**
Denodni A.T. and Hotton M.	1998	Broadband micro-strip patch antenna for wireless applications	Investigation of Micro strip patch antenna
Chung Y.,Siek Jean S., Kim S.,Ahn D. , Choi J.K. and Itoh T.	2003	Multifunctional Micro-strip Transmission Lines Integrated With Defected Ground Structure for RF Front-End Application	Presents multifunctional micro strip transmission lines were realized through the integration of defected ground structures (DGSs)
Biswas S.,Guha D. and Kumar C.	2013	Control of Higher Harmonics and Their Radiations in Micro-strip Antennas Using Compact Defected Ground Structures	Defected Ground Structure
Khandelwal M.K., Dwari S. and Kanaujia B.K.	2013	Design and analysis of micro-strip DGS patch antenna with enhanced bandwidth for Ku Band applications	Defected Ground Structure for Ku Band

Subbulakshmi P. and Raj Kumar R.	2013	Design and characterization of corporate feed rectangular micro-strip patch array antenna	The Design of 4-Element micro strip patch antenna array which uses the corporate feed technique for X Band.
Haraz O. M., Elboushi A., Alshebeili A.S. and Sebak A.R.	2014	Dense Dielectric Patch Array Antenna With Improved Radiation Characteristics Using EBG Ground Structure and Dielectric Superstrate for Future 5G Cellular Networks	New dense dielectric (DD) patch array antenna prototype operating at 28 GHz for future fifth generation (5G)
Mittal A. and Khullar R.	2014	Micro strip Planar Array Antenna with DGS.IJSRD - International Journal for Scientific Research & Development	Defected Ground Structure
Arora A.,Khemchandani A., Rawat Y.,Singhai S. and Chaitanya G.	2015	Comparative study of different Feeding Techniques for Rectangular Micro-strip Patch Antenna	Feeding techniques of Micro strip Patch Antenna
Ojaroudiparchin N., Shen M.,and Pedersen G.F.	2015	A wavelet-chaos methodology for analysis of EEGs and EEG sub-bands to detect seizure and epilepsy	Micro Strip Patch Antenna for 5G applications
Haraz O., Ali M.M.M., Alshebeili S. and Sebak A.R.	2015	Design of a 28/38 GHz Dual-Band Printed SlotAntenna for the Future 5G Mobile Communication Networks.	dual-band printed slot antenna for the future fifth generation (5G) mobile networks through proximity feed techniques
Kumar A. and Kapoor P.	2016	Design and Performance Evaluation of a Dual-Band Antenna for the 5G Mobile Communication	Dual Band Slot antenna for 5G Mobile communication

Haraz O., Ali M.M.M., and Alshebeili S.	2016	Broadband printed slot antenna for the fifth generation (5G) mobile and wireless communications	Elliptical shape Patch antenna for 5G Mobile Application
Jilani S.F. and Alomainy A.	2016	Millimeter-wave T-shaped antenna with defected ground structures for 5G wireless networks	Defected Ground structure using Coplanar waveguide feed
Marotkar D.S., Zade P. and Kapur V.	2016	Chapter 10 Bandwidth enhancement of micro strip patch antennausing defected ground structure	Bandwidth enhancement of micro strip patch antennausing defected ground structure
Oktafiani F. and Wijayanto N. Y.	2016	Analysis of printed patch antenna array for 37 GHz point-to-point wireless links	Printed Patch Antenna array for 37GHz Point to Point Communication using SMA connecter as feeding.
Suvalka R., Agrahari S. and Rathi A.	2016	Design Planar Micro-strip Antenna for Wireless and Lower UWB Applications Using DGS	Compact Planer micro strip patch antenna using Defected Ground structure
Er-rebyiy R., Tajmouati A. , Latrach M. , Errkik A. and El Abdellaoui L.	2017	A New Design of a Miniature Micro-strip Patch Antenna Using Defected Ground Structure DGS	Defected Ground structure
Jajere A.M.	2017	Millimeter Wave Patch Antenna Design Antenna for Future 5g Applications.	Simple Micro strip patch antenna

2.3 Summary of Review of Literature

I have studied all paper on millimeter wave in the frequency range of 20-50 GHz.in this studying. I have searched for papers in my field much old and the new research paper. And all this studying did then I am selected my paper on 5G upcoming technology. My research work is on 5G Mobile technology. In millimeter wave, the frequency range is 30-300GHz.Millimeter wave antennas are designed at millimeter wave frequency spectrum, also known as extremely high frequency (EHF) band. In all research paper patches, the antenna is designed for various ranges of frequency but I chose my frequency range is a 41-42.5GHz 5G band. In many papers, different frequency and techniques are used for different antenna parameters such as VSWR, Gain, Reflection coefficient and Bandwidth. On low-frequency bands, the size of the antenna is large so for compact size antenna we used the millimeter wave frequency. In my literature review chapter, most of the papers are on Defected ground structure techniques but that’s used for low frequency and designs a rectangular patch antenna with compact size and gets better performance parameter on the high-frequency range.

CHAPTER 3
MATERIAL AND METHODS

The designs of 5G patch antenna for Mobile application were simulated. Defected ground structures (DGS) have been symmetrically added in ground in order to produce multiple resonating bands, accompanied by partial ground plane to achieve continuous operating bandwidth. First design uses a simple L slot structure and rectangular ground plane. But it was having very low gain, return loss and VSWR parameter. To improve gain, return Loss and VSWR we used Defected Ground Structure (DGS) techniques.
In order to reduce experimental cut and try design cycles, the simulation software EMSS FEKO v 7.0 is used to guide fabrication.

3.1Antenna Design Methodology:

This section contains the research methodology used in this thesis objective of DGS antenna. For this purpose following steps are followed.

Input design parameters

Software based design

Simulation

Redesign

NO

If the design meet the

Candidate antenna requirement?

YES

Chapter 11 3.2 Basic Antenna design:

A Micro strip patch Defected Ground Structure antenna is designed by followings Formulas.

Now for Design Of patch Antenna we used followings Equations:-

1.) Calculation of Width:-

$$\text{Width} = \frac{3*10\text{^}8}{42*10^{9\sqrt{\in r+1}}/2}\text{m}$$

2.) Calculation of Effective dielectric constant ($\in eff$)

$$\in eff = \frac{\in r+1}{2} + \frac{\in r-1}{2}\sqrt{[1+\frac{12h}{w}]}$$

3.) Calculation of Effective Length (Leff)

$$\text{Leff} = c/\ (2+\sqrt{\varepsilon_{eff}})$$

4.) Calculation of Length Extension

$$\Delta L = 0.41\ 2h\ [\ (\varepsilon_{eff} + 0.3)(\frac{w}{h} - 0.264)/(\varepsilon_{eff}\_0.258)(\frac{w}{h} - 0.8)]$$

5.) The actual length of patch

$$L = \text{Leff} - 2\Delta L$$

Where –

$\in r$ – Relative Permittivity

W - Width of patch antenna.

$L_e$ff - Length of patch antenna

C - Speed of Light

Chapter 12 3.3 Design of DGS Antenna:

Slots or defects integrated on the ground plane of microwave planar circuits are referred to as Defected Ground Structure. DGS is adopted as an emerging technique for improving the various parameters of microwave circuits.Let the T patch and L slot , which will be placed on the top side of the FR4 block, and other side will be rectangular ground plane .Excitation is provided by micro strip feed line, by which good impedance matching and circularly polarized radiation pattern can be easily obtained.

T-shaped antenna is designed on top of substrate and a partial ground plane with symmetrical placement of u slots is constructed at the bottom of substrate.

The antenna designing is initiated with a simple T shaped radiating patch on L slot provided with Line Feeding and capable of resonating at single frequency. The bottom ground of the antenna is then modified with a partial ground plane for bandwidth improvement. U slots is constructed in the bottom ground plane.

3.3.1 Theoretical calculation for antenna Design:

1.) Calculation of Width:-

- Width $=\frac{3*10\wedge 8}{42*10^{9\sqrt{\epsilon r+1}}/2}$m

$$\in r = 2.2$$

- Width = 0.00283m ≅2.83 mm.

2.) Calculation of Effective dielectric constant ($\in eff$) :-

$$\in eff = \frac{\in r+1}{2} + \frac{\in r-1}{2}\sqrt{[1+\frac{12h}{w}]}$$

$\in eff$= 2.31

3.) Calculation of Effective Length (Leff):-

Leff = c/ $2fr\sqrt{\varepsilon_{eff}}$)

Leff = 2.36mm

4.) Calculation of Length Extension:-

$$\Delta L = 0.412h\,[\,(\varepsilon_{eff} + 0.3)(\frac{w}{h} + 0.264) / (\varepsilon_{eff} - 0.258)(\frac{w}{h} + 0.8)]$$

ΔL = .204

5.) The actual length of patch:-

$L = L_{eff} - 2\Delta L$

L = 1.96mm

3.4 Schematic View of Designed Antenna

The Designed DGS antenna is shown in fig. 3.1 and 3.2 and it is analyzed using software CADFEKO Suite 7.0 which is based on electromagnetic (EM) simulation. In the designing of antenna FR4 substrate is used. The designed is divided into four parts-

Firstly “T” Shape patch is creating on rectangular substrate.

Secondly “L” Shape slot is cut on the radiating patch.

Thirdly Partial ground plane along with micro-strip feed line.

Fourth create the defected slot on the ground plane.

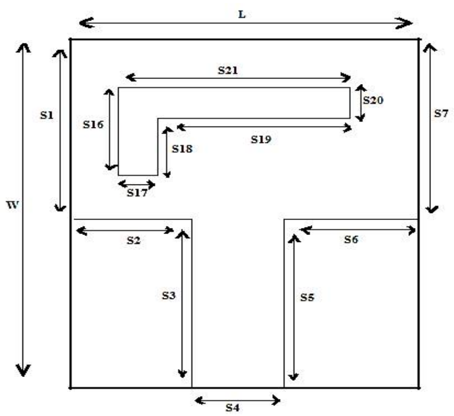


Fig.2.1:Designed antenna Front view (Schematic View)

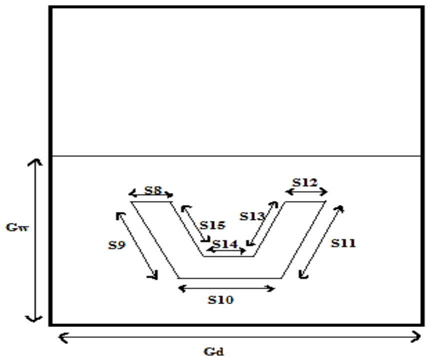


Fig. 3.2:Designed antenna back view (Schematic View)

The Dimensions for complete DGS antenna design are tabulated in table no 3.1.The designed antenna has 3x2.5mm^2. In this design antenna has a partial ground of width 0.92mm and the depth is 2.5mmwith U slot.

Table 3.1: Optimized dimension for designed antenna

S. No.	Parameter	Dimension (mm)
1	W	3
2	L	2.5
3	S1	1.55
4	S2	1
5	S3	1.45
6	S4	0.5
7	S5	1.45
8	S6	1
9	S7	1.55
10	Gw	0.92
11	Gd	2.5
12	S8	0.1
13	S9	0.2
14	S10	0.35
15	S11	0.2
16	S12	0.05
17	S13	0.1
18	S14	0.3
19	S15	0.1
20	S16	1.1
21	S17	0.1
22	S18	1
23	S19	1.8
24	S20	0.1
25	S21	1.9

Chapter 13 3.5Defected Ground Structure Design using FEKOSoftware:

3.5.1Antenna Design

The DGS antenna for Mobile application is designed using a thin copper sheet. To design a rectangular patchantenna.Figure (front view and back view) showing structure having inner radius 3 X 2.5mm^2. The antenna is using feed line.

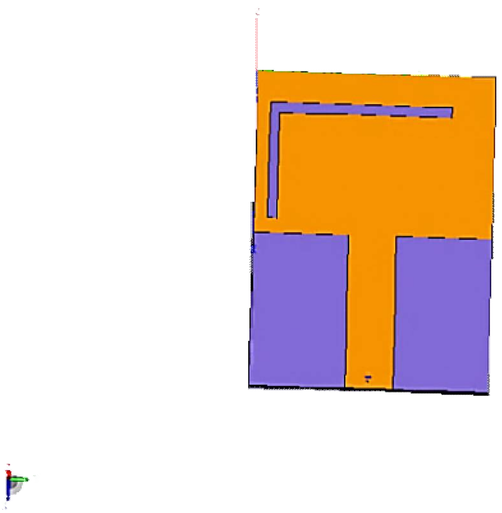


Fig. 3.3: SimulatedDGS Antenna (Front view)

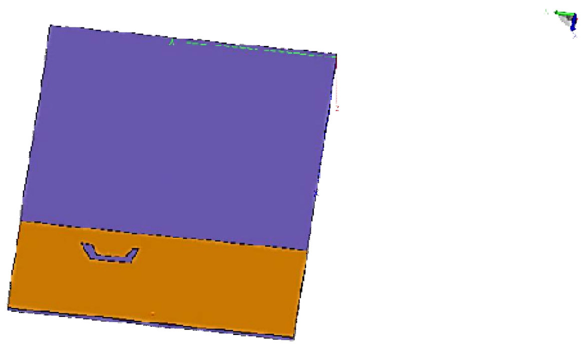


Fig. 3.4: Simulated DGS Antenna (Back view Ground)

3.5.2 Design parameters for simulation

- $\varepsilon_r = 2.2$

- tan δ=0.001
- Simulation frequency: 41 to 42.5GHz
- Thickness of dielectric substrate : 0.1 mm

Chapter 14 3.6 FEKOSoftware introduction

The elementary antenna is designed and simulated using EMSS FEKO v 7.0. The software has different modules for designing and result analysis. CADFEKO is used for designing of the antenna and POSTFEKO is used to view the simulation results. Fig. 3.5 shows information about FEKO version.

Fig. 3.5: FEKO suit version 7.0-238289

The name FEKO is an abbreviation derived from the German phrase **FE**ldberechnung bei **K**örpern mit beliebiger **O**berfläche, which means Field computations involving bodies of arbitrary shape. As the name suggests, FEKO can be used for various types of electromagnetic field analyses involving objects of arbitrary shapes.

3.6.1 EMSS FEKO

FEKO is a comprehensive electromagnetic simulation software tool, based on state of the art computational electromagnetics (CEM) techniques. It enables users to solve a wide range of electromagnetic problems.

The multiple solution techniques available within FEKO make it applicable to a wide range of problems for a large array of industries. Typical applications include:

- Antennas: analysis of horns, micro-strip patches, wire antennas, reflector antennas, conformal antennas, broadband antennas, antenna array.

- Antenna placement: analysis of antenna radiation patterns, radiation hazard zones, etc. with an antenna placed on a large structure, e.g. ship, aircraft, armored car.

- EMC: analysis of diverse EMC problems including shielding effectiveness of an enclosure, cable coupling analysis in complex environments for e.g. wiring in a car, radiation hazard analysis etc.

- Bio-electromagnetic: analysis of SAR extraction for homogeneous or non-homogeneous bodies.

- RF components: analysis of waveguide structures for e.g. filter, slotted antennas, directional couplers etc.

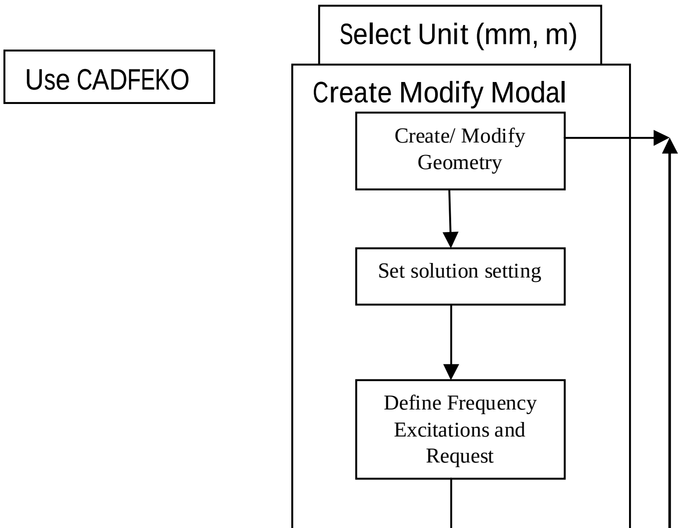
- 3D EM circuits: analysis of couplers, micro-strip filters, inductors, etc.

- Radomes: analysis of multiple dielectric layers in a large structure.

- Scattering problems: RCS analysis of small and large structures.

3.6.2 Typical workflow for CADFEKO

Before constructing a CADFEKO model it is important to understand the CADFEKO workflow as shown in figure. Thisworkflowis supported by the ribbon UI (user interface), where the user is encouraged to start working from the left to right on the ribbon when creating a model.Creation of geometry is the first step in constructing a CADFEKO model. After defining the geometrical design, all electrically and physically connected parts in the geometry must be union. Ports and excitations required for the model are defined later.Next step is the frequency or frequency range declaration. The model is then meshed where after the FEKO solver is run.Then geometry and results as obtained by the FEKO solver can then be post-processed by POSTFEKO. Fig. 3.6 shows CADFEKO workflow.



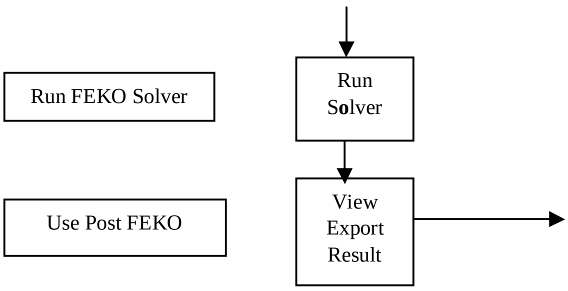


Fig. 3.6:CADFEKO workflow

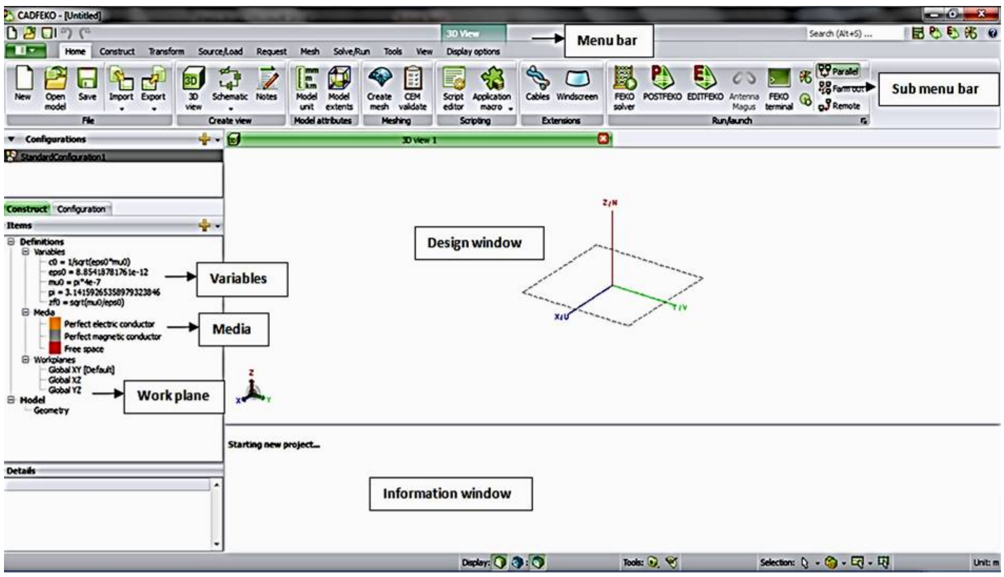


Fig. 3.7: Screenshot of EMSS CADFEKO with various interface units

Fig. 3.7 shows the screenshot of EMSS CADFEKO. The CADFEKO v7.0 window can be divided into following parts:

- Menu Bar: The bar at the top with all the menu options. Clicking on these options will open subsequent submenu options.

- Sub Menu Options: Just below the Menu bar, lies the sub menu pane. Here we can select all the options for creating, meshing and solving antenna designs.
- Variables pane: This pane contains definition of all the variables in a design, including the voltage, frequency and other design variables.
- Design Faces Pane: This pane displays the edges and faces of the antenna, which is designed in the design window. This pane is used to access properties of faces and edges of the antenna. It is just below the construction pane.
- Information Window: This pane gives the information about processing and error messages while designing and simulating the antenna.
- Design Window: This window is the workspace to create the required design. The design can be rotated in 3 dimensions with proper scaling features.

3.7 Design steps:

Following are the design steps for creating the DGS patch antenna on CADFEKO v 7.0.

1. Change the modal unit:

From the ‘Construct’ tab, select the model unit option and change the units to ‘Millimeters (mm)’.

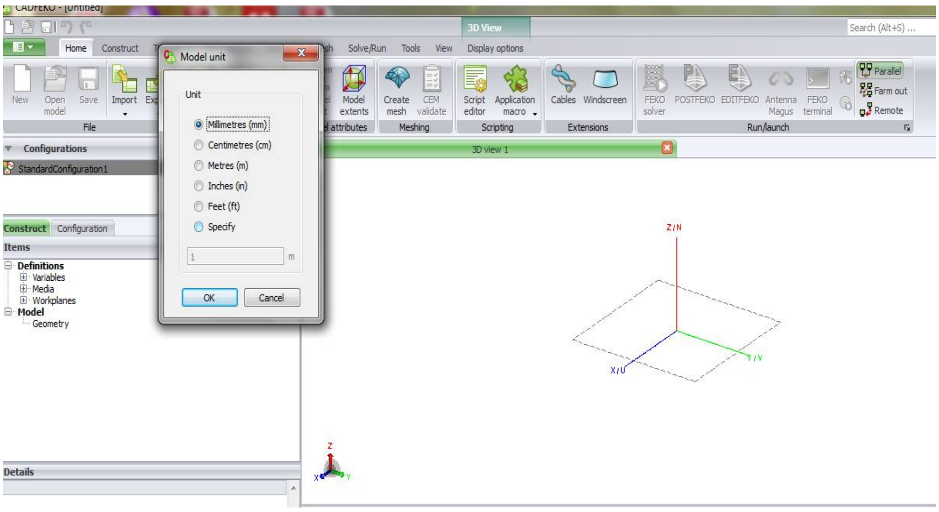


Fig. 3.8: Screenshot of EMSS FEKO with model unit options

2. Select material :

From the media library, select the required medium and add it to the model, like in this project Substrate FR4 is selected.

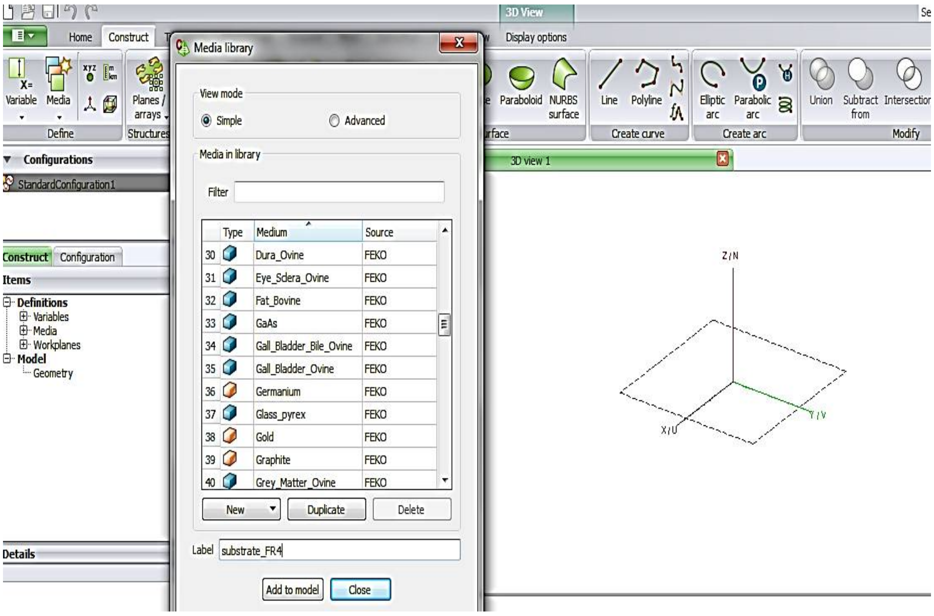


Fig.3.9:Screenshot of EMSS FEKO with Media Library

3. Create Design:

The antenna is then designed using various surface blocks available in the 'Construct' tab.

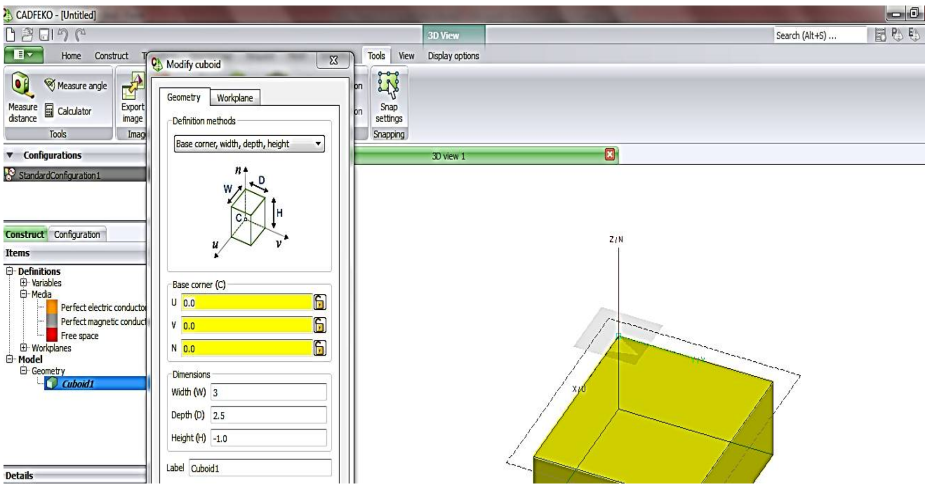


Fig. 3.10: (a) Screenshot of EMSS FEKO with surface creation options

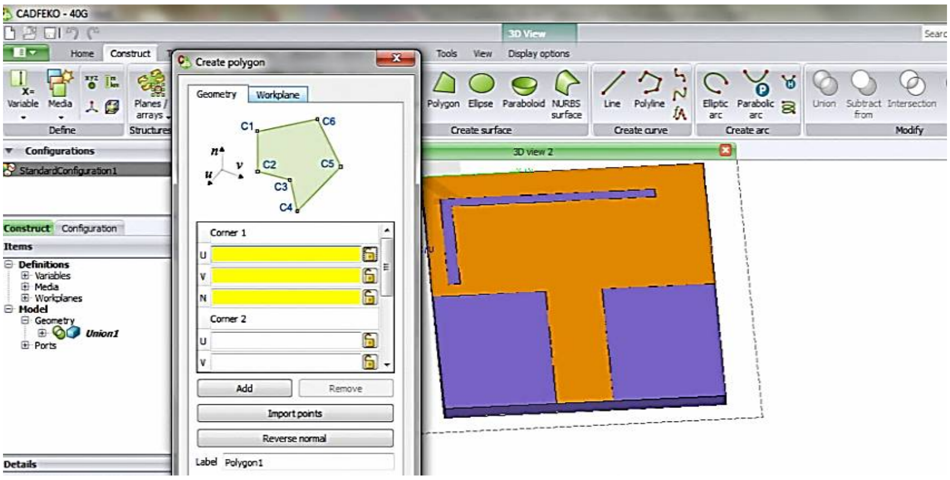


Fig. 3.10: (b) Screenshot of EMSS FEKO with surface creation options

4. **Assign Medium to Design:**

   From the side pane, all the surfaces of the antenna design are selected and a medium is assigned to them through their property window.

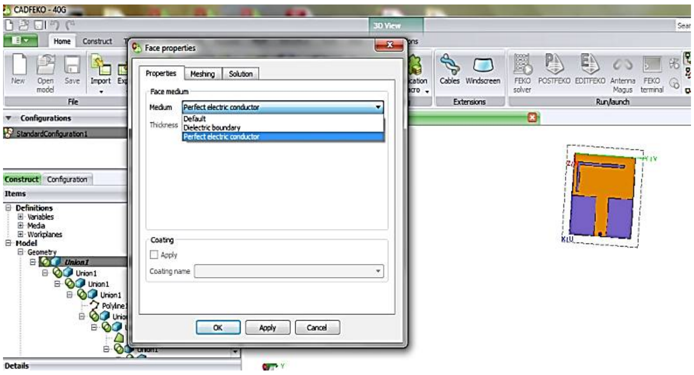


Fig. 3.11: Screenshot of EMSS FEKO showing face properties

5. **Union:**

   Selecting the whole structure, right click than apply union. Now the whole antenna structure is complete so to make the whole entity as one unit, union the whole structure.

6. **Inserts Ports:**

   By right clicking at wire element insert port. According to the design requirements numbers of ports are inserted at the preferred place.

7. **Select Frequency:**

   In the left pane, right click on the Frequency option under the Solution option and Assign frequency to the model.

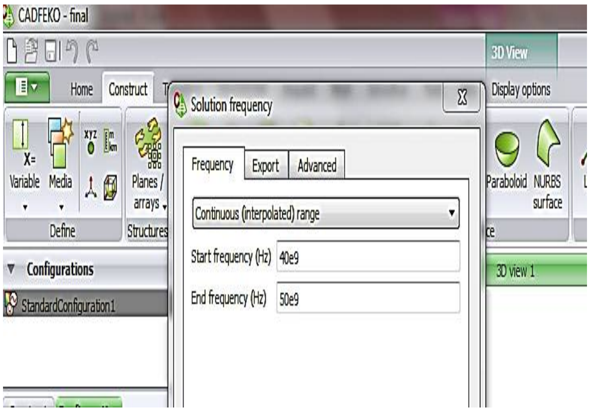


Fig. 3.12: Screenshot of EMSS FEKO with solution Frequency window

8. Create Far Field Request:

Under the Request tab, select the 'Far fields' option, then in the corresponding window, click on the '3D pattern' button.

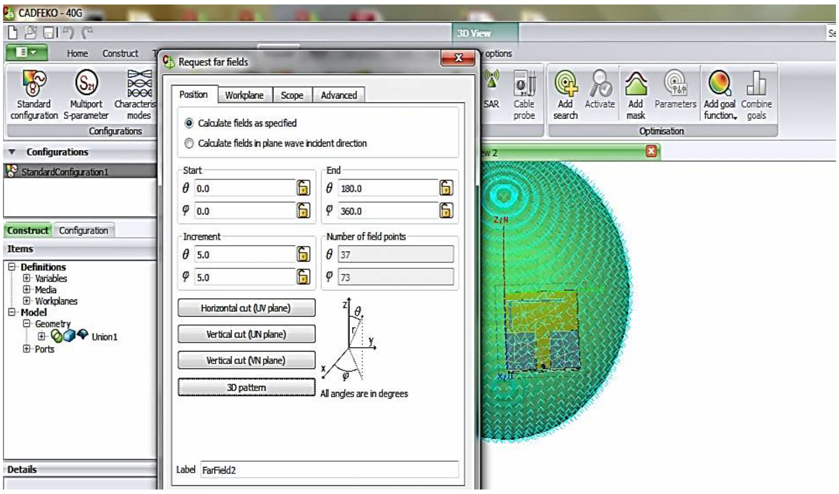


Fig. 3.13: Screenshot of EMSS FEKO with far field request window

9. Create Mesh:

Under the 'Mesh' tab, select the 'Create mesh' option. Specify the Mesh size and Insert wire segment radius than click on the 'Mesh' button.

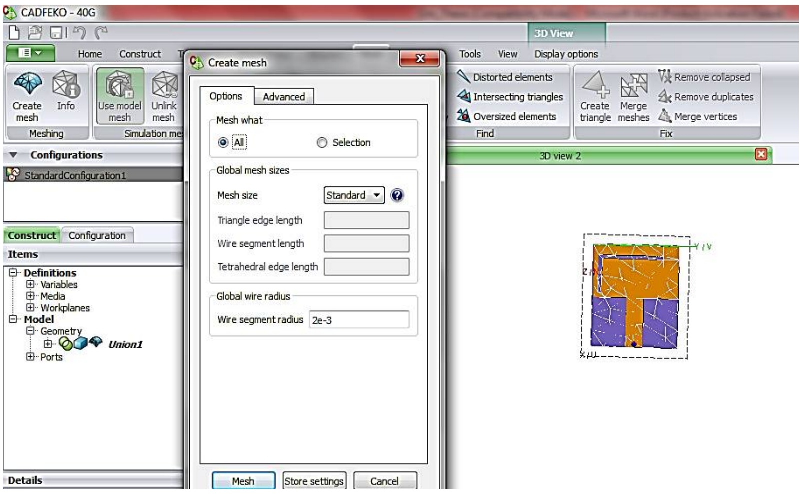


Fig. 3.14: Screenshot of EMSS FEKO with meshing options selection window

10. CEM Validate:

Under the Solve/Run tab, click on the 'CEM validate' button. It will validate the model for the final simulation.

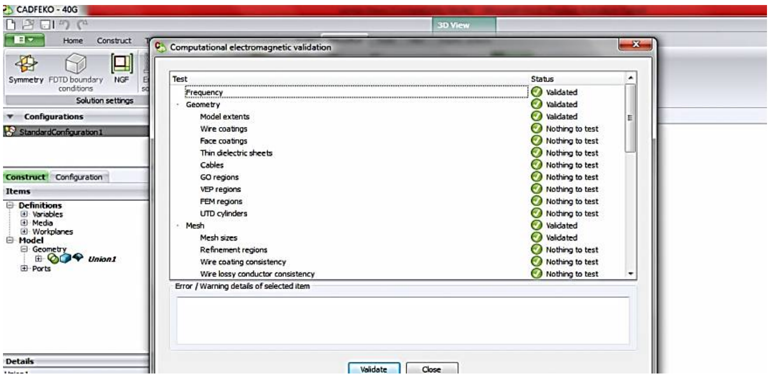


Fig. 3.15: Screenshot of EMSS FEKO while validating the design

11. Solve:

Click on FEKO solver button under 'Solve/Run' tab.

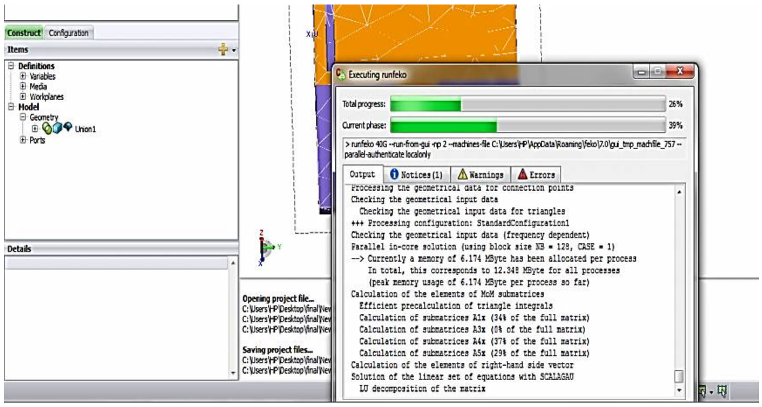


Fig. 3.16: Screenshot of EMSS FEKO with FEKO Solver

The antenna design is solved by CADFEKO using Method of Moments (MOM) numerical method. The module which solves the antenna design is called FEKO solver. After the FEKO solver has completed its processing. POSTFEKO is used to view the results.

CHAPTER 4

RESULTS & DISCUSSION

The proposed MMW antenna is designed by EMSS FEKO v 7.0 software. In this section, simulated return loss results of the designed T-shaped antenna with DGS are presented. As discussed, parametric analysis of the geometrical dimensions of designed T-shaped patch antenna has been performed to achieve the desired impedance bandwidth.A Defected Ground structure patch antenna is designed with 3 x 2.5mm^2 and rectangular ground plane. FR4 substrate is used for designing antenna; having permittivity 2.2 and thickness 0.1 mm.simulated result of the designed antenna has been shown in the figure.

Chapter 15 4.1 Simulation results of DGS Antenna

4.1.1 Return Loss or S_{11}

Using wave port configuration, S11 parameters are obtained as antenna return loss.Value of -10dB is taken as the base value which is considered excellent in case of mobile communication. The antenna operates at proposed band for 5G wireless standard.

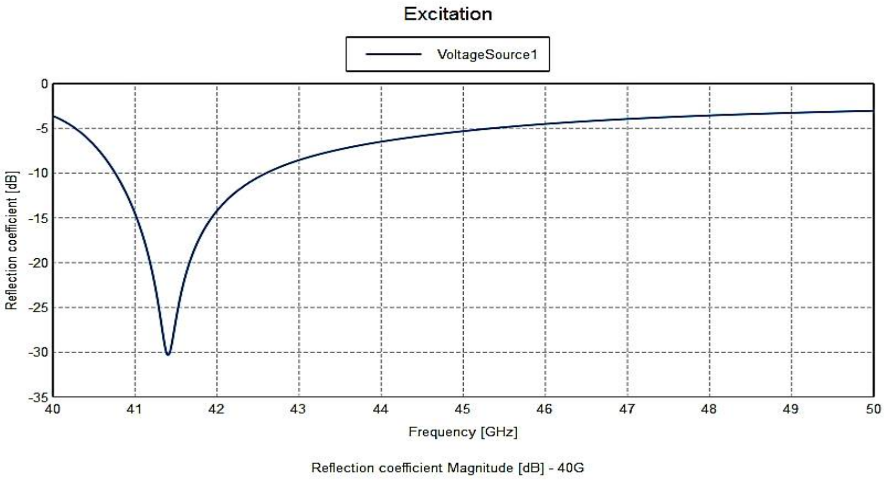


Fig. 4.1: Plot between Reflection coefficient & frequency for DGS patch antenna

Above results gives the information about the variation of reflection parameters with respect to frequency. As we clearly shown in the above figure that at the 41 – 42.5GHz frequency we got Reflection coefficient is approximately equal to -30dB. It represents the antenna has a wide Impedance bandwidth that ranges from 40.78GHz to 42.57GHz and Bandwidth is the 4% of the center frequency.

4.1.2 Voltage Standing Wave Ratio (VSWR)

VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by Γ, then the VSWR is defined by the following formula:

$$\text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|} \qquad ..18$$

The reflection coefficient is also known as S_{11} or return loss.Since VSWR is given by-

$$VSWR = \frac{10^{\frac{RL(dB)}{20}} + 1}{10^{\frac{RL(dB)}{20}} - 1}$$

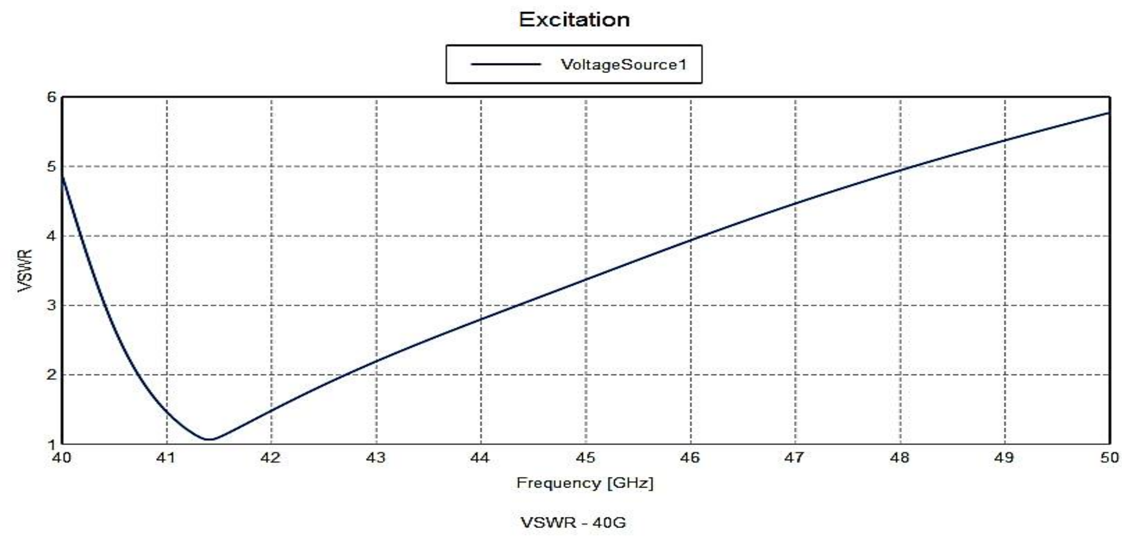


Fig. 4.2: Plot between VSWR & frequency for DGS patch antenna

The acceptable level of VSWR for most of the wireless applications should not be more than 2.5 dB and it should be 1 dB ideally.The VSWR is lies Between 1 – 2 shows in Fig. 4.2. This is the VSWR and Frequency plot of proposed partial ground T-shaped antenna with L slot and DGS.

4.1.3Radiation patterns:

Gain can be defined as the ratio of radiation intensity of practical antenna with respect to radiation intensity of idea antenna. It is stated in dB and dBi.

The 3D gain plot determines the antenna efficiency. The designed patch antenna achieved moderate gain of 3 dBi which is considered good in terms of a compact antenna design.Fig 4.3 shows the 3D omnidirectional pattern of the DGS antenna .In 3D pattern we obtained gain is 3dBi in range of frequency is 41-42.5GHz.

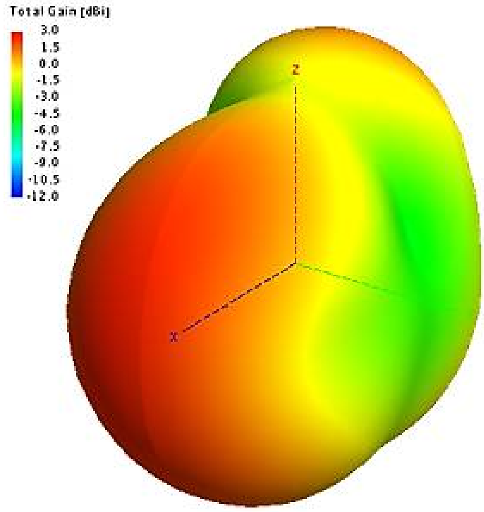


Fig. 4.3: 3D radiation pattern of DGS patch antenna

Fig 4.4 shows the 3D Omnidirectional pattern of the DGS antenna .In 3D pattern we obtained Theta gain is 5dBi in range of frequency is 41-42.5GHz.

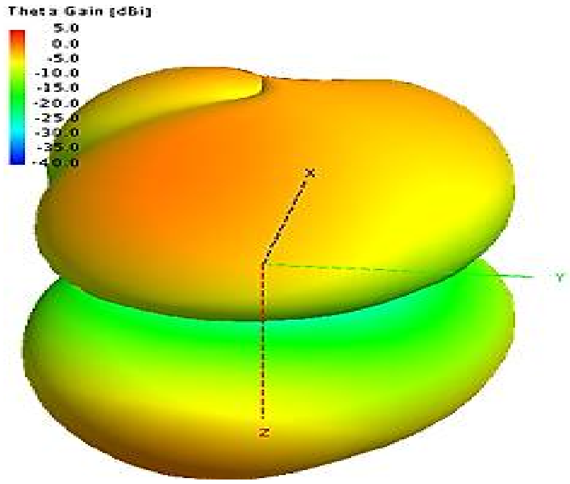


Fig. 4.4: 3D radiation pattern of DGS patch antenna(Gain in Theta)

Fig 4.5 shows the 3D Omnidirectional pattern of the DGS antenna .In 3D pattern we obtained Phi gain is 4dBi in range of frequency is 41-42.5GHz.

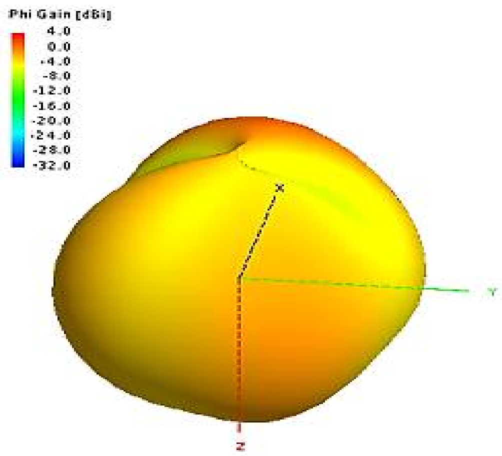


Fig. 4.5: 3D radiation pattern of DGS patch antenna(Gain in Phi)

4.1.4 Current Distribution:

Fig 4.6 shows the current distribution of the DGS antenna. The current flow through from bottom of the antenna where we create port for line feeding.

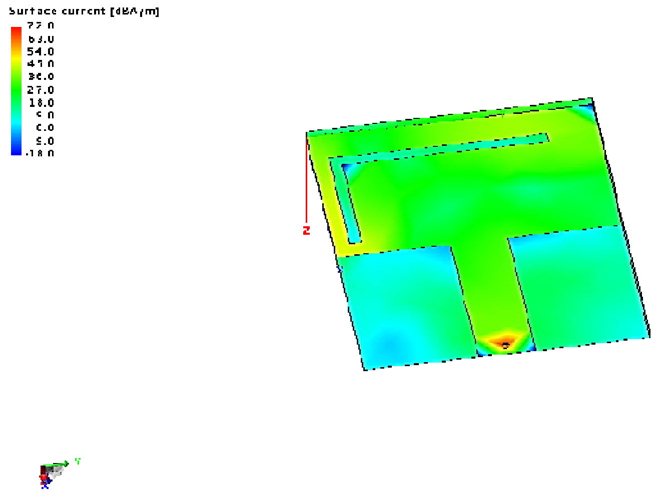


Fig. 4.6: Current distribution of DGS antenna

4.1.5 Antenna Efficiency:

Fig 4.7 shows the graph between Power Efficiency and Frequency. The efficiency for DGS antenna in range of 41-42.5GHz is above 85-89%.

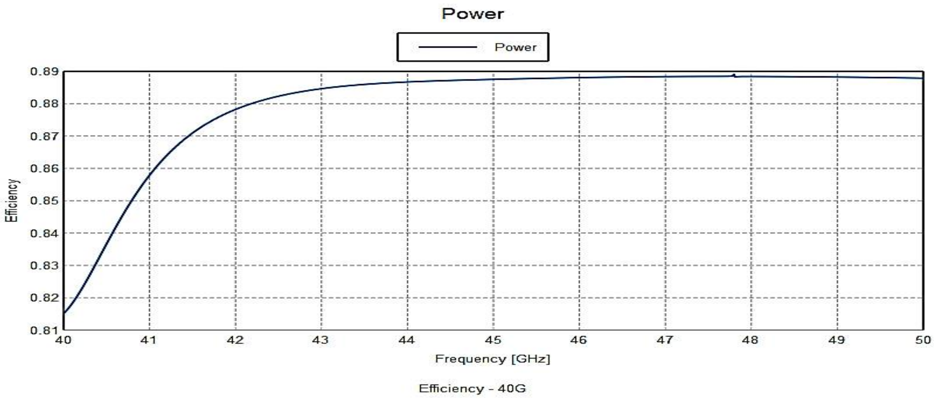


Fig. 4.7 Plot between Power Efficiency and frequency of DGS patch antenna

4.1.6 Antenna Impedance:

Antenna impedance is a way of measuring the level of resistance to an electrical transmission in an antenna. A large number of factors have an impact on an antenna's capability to transmit a transmission signal such as the environment that the antenna is in and the design and structure of the antenna. Understanding antenna impedance is important when designing components that connect an antenna to a receiver or transmission device.

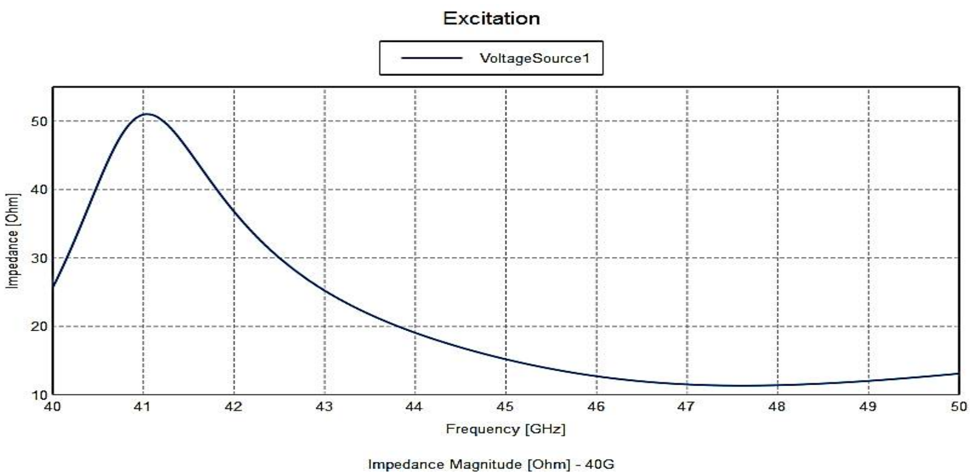


Fig. 4.8 Plot between Frequency and Impendence of antenna

4.2 Comparative Studies:

In this section we are discuss about comparisons of thesis work to other reference base papers.

Table 4.1 shows simulation results of the Designed DGS antenna

Table 4.1: Simulation results of the Designed DGS antenna

Parameter	Simulated Result

Frequency range	41 to 42.5GHz
Return loss	>-10db
Gain	3dBi
Impedance	50 Ω
VSWR	Less than 2
Radiation pattern	Omni-directional
Size	3 X2.5 mm^2
Efficiency	85-88%
Impedance Bandwidth	1.79GHz

Table 4.2 Results from Base Paper1(Jilani, 2016):-

Table 4.2 Results from Base Paper 1

Parameter	**Simulated Result**
Frequency range	25.1-37.5 GHz
Return loss	>-10db
Gain	5dBi
Impedance	50 Ω
VSWR	Less than 2
Radiation pattern	Omni-directional
Size	8 X 3.1 mm^2
Efficiency	80%

From this Reference paper we got the size of the antenna is compact and the efficiency is greater. In the Reference paper the size of the antenna is 8 x 3.1mm^2on frequency range 25.1GHz to 37.5GHz but in my designed work got the size of the antenna is 3 x 2.5mm^2 on frequency range 41GHz to 42.5GHz.

Table 4.3 Result from Base Paper 2(Kumar, 2016):-

Table 4.3 Result from Base Paper 2

Parameter	**Simulated Result**
Frequency range	30.5 to 32GHz and 40.5 to 42 GHz
Return loss	>-10db
Impedance	50 Ω
VSWR	Less than 2
Radiation pattern	Omni-directional
Size	10 X 10 mm^2
Bandwidth	1.5GHz

Comparisons from base papers and other research paper i have obtain best result. The size of the antenna is also reduced and the more bandwidth is obtained and the VSWR is lies between 1 and 2 it means the antenna is 90%radiated and in such case the reflection power is low.

CHAPTER 5

SUMMARY

In this thesis, a DGS patch antennais designed, that works on Millimeterfrequency bands. These bands are specified for 5G Mobile applications and the frequency of operation in these bands is 41 to 42.5GHz.

The DGS, used in the antenna design, is much improved compared to earlier ones in terms of its compactnesswithout compromising in performance. This would find practical applications in microwave integrated circuits, especially where a single substrate is used for implementing printed antennas along with active devices and circuits.

Now to achieve high isolation, again design is modified by inserting a slotAccording to the standard;high speed data rate is possible for mobile application with Millimeter wave technology. So along with the high data rate, it is providing reliability at the places like offices, hotels, college campuses etc. with high quality service.

5.1 Conclusion:

A very compact Defected Ground Structure Antenna is presented in this paper Proposed design covers the frequency range of 41 to 42.5GHz i.e. 5G Band.This Report presents an efficient antenna design at MMW frequencies. The compact Patch antenna is designed using a technique that is defected ground structure. Defected ground structures (DGS) have been added in the ground Plane. The top geometry of the suggested antenna consists of a T-shaped radiating patch with L Slot. The bottom part comprises of a partial ground with v Slot acting as resonating “defects”. Parametric analysis has also been performed to achieve theoptimal performance of the antenna. The proposed antenna has demonstrated a high impedance bandwidth of 41-42.5GHz and a gain of 3dBi. Moreover, the numerically calculated efficiency is above 85-88% in operating range. The distinguishing performance attributes of designed antenna suggest its applications in future 5G wireless networks and cellular applications.

Literature Cited

Aris M. A., Ali M. T., Abd R. N. H., Ramli N. "Frequency Reconfigurable Aperture-Coupled Micro strip Patch Antenna Using Defected Ground Structure" 2015 IEEE International RF and Microwave Conference (RFM 2015), Riverside Majestic Hotel, Kuching, Sarawak on December, 14 - 16, 2015.

Arora A.,Khemchandani A., Rawat Y.,Singhai S. and Chaitanya G. 2015. Comparative study of different Feeding Techniques for Rectangular Micro-strip Patch Antenna .IEEE International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering 3:1-6.

Ashwini K. Arya, M. V. Kartikeyan, A .Patnaik, "Gain Enhancement of Micro strip antenna using Dumbbell shaped Defected Ground Structure: International Journal of Research Engineering & Technology July 2013 Vol.2,Issues 4,pp.184-188.

AyatollahiM., RaoQ. and WangD. 2012. A Compact, High Isolation and Wide Bandwidth Antenna Array for Long Term Evolution Wireless Devices. In: IEEE transactions on antennas and propagation, vol. 60. october 10, 2012

Bala, S. 2010. Multiple-Input Multiple-Output Antennas for Ultra Wideband Communications. M.Tech Thesis, submitted to Grenoble Institute of Technology, France.

Balanis C. A., "Antenna Theory and Analysis," Second Edition, John Wiley & Sons, 1997.

Balanis C. A., Antenna Theory: Analysis and Design. New York: Wiley, 1982.

Balanis, C. A . 2009. Antenna Theory: Analysis and Design. Wiley Publications.

BayatmakuN., LotfiP., AzarmaneshM. and SoltaniS. 2011. Design of simple multi-band patch antenna for mobile communication applications using new E-shape fractal.In: IEEE Antennas Wireless Propag. Lett., vol. 99, p. 1, 2011.

Bisht S., Saini S , Prakash V. and Nautiyal B.2014. Study The Various Feeding Techniques of Microstrip Antenna Using Design and Simulation Using CST Microwave Studio. IJEATE International Journal of Emerging Technology and Advanced Engineering, Vol.4, Issues 9,pp.318-324.

Biswas S.,Guha D. and Kumar C. 2013. Control of Higher Harmonics and Their Radiations in Micro-strip Antennas Using Compact Defected Ground Structures. IEEE Transactions on Antennas and Propagation 61:3349 – 3353.

C. A. Balanis, *Antenna Theory*, 3rd ed. Hoboken, NJ: John Wiley & Sons, 2005.

C. A. Balanis, Antenna Theory: Analysis and Design(New York: Wiley, 1997)

Chan Hwang See, Raed A. Abd-Alhameed, Zuhairiah Z. Abidin, Neil J. McEwan, and Peter S. Excell, 2012. Wideband Printed MIMO/Diversity Monopole Antenna for WiFi/WiMAX Applications. In: IEEE transactions on antennas and propagation, vol. 60, no. 4, April 06, 2012. pp.: 2028-2035

Chung Y.,Siek Jean S., Kim S.,Ahn D. , Choi J.K. and Itoh T. 2003. Multifunctional Micro-strip Transmission Lines Integrated with Defected Ground Structure for RF Front-End Application. IEEE Transactions on Microwave Theory and Techniques 52: 1425 – 1432.

CISCO, 2009. Antenna Patterns and their meanings. White paper.

Denidni A. T. , Hotton M. 1998. Broadband micro-strip patch antenna for wireless applications. In: proceeding of IEEE Symposium on Antenna Technology and Applied Electromagnetics during Aug 9-12 1998, pp: 221 – 224.

Er-rebyiy R., Tajmouati A. , Latrach M. , Errkik A. and El Abdellaoui L. 2017. A New Design of a Miniature Micro-strip Patch Antenna Using Defected Ground Structure DGS. In: proceeding of IEEE International Conference On Wireless Technologies, Embedded and Intelligent Systems (WITS) during April 19 20 2017, pp:1-4.

Foschini G. J., Gans M. J. On Limits of Wireless Communications in a Fading Environment when using Multiple Antennas. Wireless Personal Communications 1998. pp.: 311-335.

G. A. Deschamps, BMicro-strip microwave antennas,[presented at the 3rd USAF Symp. on Antennas, 1953.

Garg R., Bhartia P., Bahl I., and Ittipiboon A., Microstrip Antenna Design Handbook, 2nd ed.

Haraz O. M., Elboushi A., Alshebeili A.S. and Sebak A.R. 2014. Dense Dielectric Patch Array Antenna With Improved Radiation Characteristics Using EBG Ground Structure and Dielectric Superstrate for Future 5G Cellular Networks. IEEE Access 2 : 909 - 913

Chapter 16 Haraz O.,Ali M.M.M., Alshebeili S. and Sebak A.R. 2015. Design of a 28/38 GHz Dual-Band Printed Slot Antenna for the Future 5G Mobile Communication Networks. In: proceeding of IEEE Antennas and Propagation & USNC/URSI National Radio Science Meeting during July 19-15 2015.pp:1532 – 1533.

Haraz O.,Ali M.M.M., and Alshebeili S. 2016. Broadband printed slot antenna for the fifth generation (5G) mobile and wireless communications. In: proceeding of IEEE 17th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM) during July 10-13 2016.pp:1 – 2.

Jajere A.M. 2017. Millimeter Wave Patch Antenna Design Antenna for Future 5g Applications. International Journal of Engineering Research & Technology (IJERT) 6:289–291

Jilani S.F. and Alomainy A. 2016. Millimeter-wave T-shaped antenna with defected ground structures for 5G wireless networks. In: proceeding of IEEE Loughborough conference on Antennas and Propagation during Nov 14-15 2016,pp:1-3.

Jui-Han Lu and Jia-Ling Guo, 2014. Small-Size Octaband Monopole Antenna in an LTE/WWAN Mobile Phone. In: IEEE antennas and wireless propagation letters vol. 13, March 13, 2014. pp: 548 - 551

Khan F. and Z. Pi, “An introduction to millimeter wave mobile broadband systems,” IEEE Commun. Mag., vol. 49, pp. 101-107, 2011.

Khandelwal M.K. , Dwari S. and Kanaujia B.K. 2013. Design and analysis of micro-strip DGS patch antenna with enhanced bandwidth for Ku Band applications. In: proceeding of IEEE International Conference on Microwave and Photonics (ICMAP) during Dec 13-15 2013. pp:1 – 4.

Kumar A. and Kapoor P. 2016. Design and Performance Evaluation of a Dual-Band Antenna for the 5G Mobile Communication. In: proceeding of IEEE International Conference On Recent Trends In Electronics Information Communication Technology on during May 20-21 2016,pp:2034-2036.

Lee, J., Kim, K., Ryu, H. and Woo, J. 2012. A Compact Ultrawideband MIMO Antenna with WLAN Band-Rejected Operation for Mobile Devices. In: *IEEE Antennas And Wireless Propagation Letters*11, August 21, 2012pp: 990 – 994.

Licul S., Noronha J.A.N., DavisW.A., Sweeney D.G., Anderson C.R., Bielawa, T.M. A parametric study of time-domain characteristics of possible UWB antenna architectures. In: Proceedings of IEEE 58th Vehicular Technology Conf., Vol. 5, Oct. 2003. pp:3110-3114

Licul S., Noronha J.A.N., DavisW.A., Sweeney D.G., Anderson C.R., Bielawa, T.M. A parametric study of time-domain characteristics of possible UWB antenna architectures. In: Proceedings of IEEE 58th Vehicular Technology Conf., Vol. 5, Oct. 2003. pp:3110-3114

M. A. Aris, M. T. Ali, N. H. Abd Rahman, N. Ramli “Frequency Reconfigurable Aperture-Coupled Micro-strip Patch Antenna Using Defected Ground Structure” In: proceeding of IEEE Conference on International RF and Microwave (RFM Riverside Majestic Hotel, Kuching, Sarawak during December 14 – 16 2015.pp:200-204.

Marotkar A., Zade P. And Kapur V. 2015. To Study the Effect of DGS on Antenna Parameters. IEEE International Journal of Industrial Electronics and Electrical Engineering 3:17-20

Marotkar D.,Zade P. and Kapur V. “To Study the Effect of DGS on Antenna Parameters” iraj conference 2015.

Marotkar D.S., Zade P.2016. Bandwidth enhancement of micro strip patch antenna using defected ground structure. In: proceeding of IEEE International Conference on Electrical, Electronics and Optimizations Techniques (ICEEOT) during March 3-5 2016.pp:1712-1716.

Mittal A. and Khullar R.2014. Micro strip Planar Array Antenna with DGS. IJSRD - International Journal for Scientific Research & Development 2 : 516-519.

Ojaroudiparchin N., Shen M.,and Pedersen G.F. 2015. A 28 GHz FR-4 Compatible Phased Array Antenna for 5G Mobile Phone Applications. In: proceeding of IEEE International Symposium on Antennas and Propagation (ISAP) during Nov. 9-12 2015, pp:1-4.

Oktafiani F. and Wijayanto N. Yusuf 2016. Analysis of printed patch antenna array for 37 GHz point-to-point wireless links. In: proceeding of IEEE 22nd Asia-Pacific Conference on Communications (APCC) during Aug.25-27 2016,pp: 379 – 382.

Patel K. R., Kulkarni R. “Ultra-Wideband (UWB) Wireless System “(IJAIEM) Special Issue for International Technological Conference-2014.

R. Dhanalakshmi, A. Sivasankar,2014. Isolation Enhancement of MIMO Antenna for Wireless Routers in LTE band Applications. In: International Journal of Science and Research Volume 3, Issued May 5, 2014. pp: 759-763

R.Dakir, J. Zbitou, A. Tribak, M.Latrach “Design of a New Compact Printed Monopole Antenna by using Tuning Stub “ in Revue Méditerranéenne des Télécommunication Vol. 4, N° 2, October 2014 Mediterranean Telecommunication Journal.

Rappaport T.S., et al., “Millimeter wave mobile communications for 5G cellular: It will work!,” IEEE Access, vol. 1, pp. 335-349, 2013.

Rappaport T.S., J.N. Murdock, and F. Gutierrez, “State of the art in 60- GHz integrated circuits and systems for wireless communications,” Proc. of IEEE, vol. 99, pp. 1390-1436, 2011.

Rappaport, Theodore S., et al. "Millimeter wave mobile communications for 5G cellular: It will work!" IEEE access 1 (2013): 335-349.

Reza Karimian, Homayoon Oraizi , Saeed Fakhte, and Mohammad Farahani. 2013. Novel Shaped Quad-Band Printed Slot Antenna for WLAN and WiMAX MIMO Systems. In: IEEE antennas and wireless propagation letters, vol. 12, 2013.

Rezaul Azim and Mohammad Tariqul Islam: chapter 7 “Printed wide slot Ultra-Wideband Antenna”INTECH 2013.

Ruchi, 2011. Slot Based Microstrip Antennas for Dual Band WLAN Applications. M.tech Thesis, submitted to Thapar university, India.

Sang-Hyeong Kim, Zhe-Jun Jin, Yoon-Byung Chae, and Tae-Yeoul Yun.2013. Small Internal Antenna Using Multiband, Wideband, and High-Isolation MIMO Techniques. In: ETRI journal, volume 35(1), Feb.1, 2013.

Shubair R.M.,AIShamsi A.M.,Khalaf K. and Kiourti A., "Novel miniature wearable microstrip antennas for ISM-band biomedical telemetry," in Antennas Propagation Conference (!APC), 2015 Loughborough, pp. 1-4.

Soni, Mousami , and Mahesh Goud. "Designing And Analysis Of 2x1 MIMO Antenna Using Full Ground And Slotted Ground For Wireless Application." International Journal Of Engineering Sciences & Research Technology 6.8 (2017) 5 Aug. 2017.pp: 89-98.

Subbulakshmi P. and Rajkumar R. 2013. Design and characterization of corporate feed rectangular micro-strip patch array antenna. In: proceeding of IEEE International Conference on Emerging Trends in Computing, Communication and Nanotechnology (ICE-CCN) during March25-26 2013,pp: 547 – 552.

Suvalka R.,Agrahari S. and Rathi A. 2016. Design Planar Micro-strip Antenna for Wireless and Lower UWB Applications Using DGS.In: proceeding of IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2016) during December 23-25, 2016,pp:1-4.

Tariqul I M, Shakib M N, Misran N, and Sun T S (2009), "Broadband microstrip patch antenna." European Journal of Scientific Research 27, No. 2: pp.174-180.

Telatar I.E.1999.Capacity of multi-antenna Gaussian channels. European Trans. Telecommunications, volume 10 (6), Jan 1999. pp: 585-595

Tzu-Chun Tang and Ken-Huang Lin, 2014. “MIMO antenna design for WLAN applications”, IEEE transactions on antennas and propagation, jan. 6, 2014. pp: 492-493

Y. S. Wu and F. J. Rosenbaum 1973. Mode chart for microstrip ring resonators. In: IEEE Trans. Microw. Theory Tech.vol. MTT-21, during Jul. 1973. pp.487–489.

Yablonovitch E.1987 “Inhibited spontaneous emission in solid-state physics and electronics,” Physical Review Letters, vol. 58, no. 20, pp. 2059- 2062.

Yamada, W., Kita, N., Mori, D., and Takao, T. 2005. Novel Wide-Band Antennas for 2.4/5 GHz Dual-Band MIMO-OFDM WLAN Systems. In: International Symposium on IEEE Antennas and Propagation Society (3A).pp: 553 - 556

Yazdandoost K.Y. & Kohno, R. 2014 Ultra Wideband antenna. IEEE Communication Magazine, volume 42 (6) 2014. pp: 30-38.

Zhanmeng, L., Chunlan, L., Luqu, Y., Jianxin, J. and Jie, Y. 2012. A Novel Compact Dual-Band MIMO Antenna for WLAN Application", In: proceedings of international conference on microwave and millimeter wave technology *(ICMMT)*3. pp:1–4.

ABSTRACT in ENGLISH

The goal of design the 5G Micro-strip Patch Antennas with Defected Ground Structure on ground slots. Slots or defects integrated on the ground plane of microwave planar circuits are referred to as Defected Ground Structure. DGS is adopted as an emerging technique for improving the various parameters of microwave circuits. Partial Defected Ground Structure is used to improve the VSWR, Bandwidth, Return Loss, Compactness, and Efficiency of an antenna. Defected ground structure (DGS) helps to absorb the waves which propagate through the ground plane. This report presents an L Slot antenna at millimeter-wave (MMW) frequency ranges to offer a number of advantages including simple structure, high operating bandwidth, and high gain. This paper addresses the millimeter wave antenna design aspect of the future 5G wireless systems This paper presents an L-slot on patch antenna at millimeter wave (MMW) frequency ranges of 5G Band at 41GHz to 42.5GHz. Defected Ground Structure is used to improve the Return Loss, VSWR, Bandwidth, Compactness, and Efficiency of the antenna. Defected ground structure (DGS) helps to absorb the waves which propagate through the ground plane. These waves are known as surface waves. This technique focuses on the compactness of antenna for Mobile Applications. Moreover, simulation evaluation of gain of the antenna is 3 dBi, Phi Gain of the antenna is 5dBi and Theta gain of the antenna is 4dBi, and efficiency is higher than 85% in the complete range of operation.

ABSTRACT in HINDI

ग्राउंडस्लॉटपरदोषग्रस्तग्राउंडस्ट्रक्चरकेसाथ 5 जीमाइक्रो-स्ट्रिपपैचएंटेनाडिजाइनकरनेकालक्ष्य।माइक्रोवेवप्लानरसर्किटकेग्राउंडप्लेनपरएकीकृतस्लॉटयादोषकोदोषग्रस्तग्राउंडस्ट्रक्चरकेरूपमेंजानाजाताहै।माइक्रोवेवसर्किटकेविभिन्नमानकोंमेंसुधारकेलिएडीजीएसकोउभरतीहुईतकनीककेरूपमेंअपनायाजाताहै।आंशिकदोषग्रस्तग्राउंडस्ट्रक्चरकाउपयोगवीएसडब्ल्यूआर, बैंडविड्थ, रिटर्नलॉस, कॉम्पैक्टनेसऔरएंटीनाकीक्षमतामेंसुधारकेलिएकियाजाताहै।दोषग्रस्तग्राउंडस्ट्रक्चर (डीजीएस) जमीनकेविमानकेमाध्यमसेफैलतीलहरोंकोअवशोषितकरनेमेंमददकरताहै।यहरिपोर्टमिलीमीटर-तरंग (एमएमडब्लू) आवृत्तिश्रेणियोंपरएकएलस्लॉटएंटीनाप्रस्तुतकरतीहैजिसमेंसरलसंरचना, उच्चपरिचालनबैंडविड्थऔरउच्चलाभसहितकईफायदेउपलब्धहैं।यहपेपरभविष्यमें 5 जीवायरलेससिस्टमकेमिलीमीटरलहरएंटीनाडिज़ाइनपहलूकोसंबोधितकरताहैयहपत्र 5 जीबैंडकीमिलीमीटरलहर (एमएमडब्लू) आवृत्तिरेंजपर 41 गीगाहर्ट्ज़से 42.5GHz परपैचएंटीनापरएल-स्लॉटप्रस्तुतकरताहै।क्षतिग्रस्तग्राउंडस्ट्रक्चरकाउपयोगरिटर्नलॉस, वीएसडब्ल्यूआर, बैंडविड्थ, कॉम्पैक्टनेसऔरएंटीनाकीक्षमतामेंसुधारकेलिएकियाजाताहै।दोषग्रस्तग्राउंडस्ट्रक्चर (डीजीएस) जमीनकेविमानकेमाध्यमसेफैलतीलहरोंकोअवशोषितकरनेमेंमददकरताहै।इनतरंगोंकोसतहतरंगोंकेरूपमेंजानाजाताहै।यहतकनीकमोबाइलअनुप्रयोगोंकेलिएएंटीनाकीकॉम्पैक्टनेसपरकेंद्रितहै।इसकेअलावा, एंटीनाकेलाभकाअनुकरणमूल्यांकन 3 डीबीआईहै, एंटीनाकाफाईलाभ 5 डीबीआईहैऔरएंटीनाकाथेटालाभ 4 डीबीआईहै, औरऑपरेशनकीपूरीश्रृंखलामेंदक्षता 85% सेअधिकहै।

APPENDIX A: Abbreviations

CMOS	Complementary Metal Oxide Semiconductor
CCK	Complimentary Code Keying
CPW	Coplanar Waveguide
CST	Computer Simulation Technology
CEM	Computational Electromagnetics
D	Dimension
dB	Decibels
DD	Dense Dielectric
DGS	Defected Ground Structure
DSS	Direct Sequence Spread Spectrum
EHF	Extremely High Frequency
EM	Electromagnetic
EMF	Electromotive Force
EMC	Electromagnetic Controller
FHSS	Frequency Hopping Spread Spectrum
FICA	Folded Inverted Conformal Antenna
G	Generation
GHz	Giga Hertz
GPS	Global Positioning System
GP	Ground Plane
HFSS	High Frequency Structure Simulator
IE3D	Integral Equation 3 Dimension
IEEE	Institute of Electrical and Electronics Engineers

ISM	Scientific And Medical
IJSRD	International Journal For Scientific Research & Development
L	Length
LAN	Local Area Network
LTE	Long-Term Evolution
LMDS	Local Multipoint Distribution System
MIMO	Multiple Input Multiple Output
MHz	Mega Hertz
MMW	Millimeter Wave
MPA	Micro Strip Patch Antenna
MW	Microwave
MMIC	Microwave Monolithic Integrated Circuits
OFDM	Orthogonal Frequency Division Multiplexing
PBCC	Packet Binary Convolution Coding
PDAS	Personal Digital Assistance
PLF	Polarization Loss Factor
PIFA	Planer Inverted F Antenna
RCS	Rich Communication Services
RFID	Radio Frequency Identification
RMPA	Rectangular Micro Strip Patch Antenna
SMA	Sub Miniature version A Connector
SWR	Standing Wave Ratio
SAR	Specific Absorption Rate

TV	Television
UNII	Unlicensed National information Infrastructure
UWB	Ultra Wideband
VSWR	Voltage Standing Wave Ratio
W	Width
WAN	Wireless Area Network
WI-FI	Wireless Fidelity
Wi MAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Networking