DEBRE TABOR UNIVERSITY

GAFAT INSTITUTE OF TECHNOLOGY (GIT)

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Final Year Thesis

On

Design and Analysis of a 28 GHz Microstrip Patch Antenna for 5G Communication Systems

Submitted to

Department of Electrical and Computer Engineering of Debre Tabor University in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Electrical Engineering [communication Engineering]

Prepared by:	ID NO
1. Eredie Andarge	ENG®1266/11
2. Tekeste Birhan	ENG®1014/11
3. Yonas Chekole	ENG® 1171/11
4. Yonas Mekonnen	ENG®1174/11

Advisor: Mr.Muhabaw A.

June, 2015 E.C

DEBRE TABOR, ETHIOPIA

APPROVAL PAGE

This is to certify that the thesis entitled “Design and Analysis of a 28 GHz Microstrip Patch Antenna for 5G Communication Systems”that is submitted by this group members in partial fulfillment of the requirement for the award of the thesis in ELECTRICAL AND COMPUTER ENGINEERING (Communication Stream) of Debre Tabor University, is a record of the candidate own work carried out by him under my own supervision. The matter embodies in the thesis is original.

Signed by Examining Board:

Advisor Name:	Sign	Date
Mrs.Muhabaw A.	....	....
Chairperson name:		
Mrs.Muhabaw A.	....	....
Dept. Head name:		
Mrs. Abere T.	....	....
Student1 name:		
Eredie Andarge	....	....
Student 2 name:		
Tekeste Birhan	....	....
Student 3 name:		
Yonas Chekole	....	....
Student 4 name:		
Yonas Mekonnen	....	....

DECLARATION

WE, the undersigned, declare that the work which is being presented in the thesis entitle, “Design and Analysis of a 28GHz Microstrip Patch Antenna for 5G Communication Systems” The requirements of the bachelor degree of engineering in communication submitted to electronics and communication stream chair school of electrical and computer Engineering, Debre Tabor university, is an authentic record of our own work carried out under supervisor of Mrs.Muhabaw. A.

ACKNOWLEDGMENT

First and for most, we are extremely grateful to the Department of Electrical and computer Engineering, for giving us the opportunity to carry out this thesis, which is an integral part of the curriculum in Debretabor university Gafat institute of technology.

Secondly, we would like to express our earnest gratitude and regards to our thesis advisor Mr. Muhabaw. A. in the Department of Electrical and Computer Engineering, for being the corner stone of our thesis. It was his perpetual motivation and guidance during the period of doubts and uncertainties that has helped us to carry on with this thesis.

Finally, we extend our gratefulness to one and all who are directly or indirectly involved in the successful completion of this thesis work.

ABSTRACT

An antenna is a device ordinarily used for transmitting and receiving electromagnetic energy. Microstrip antenna is one of the newest developments in the area of electromagnetic antenna design. A new design of Microstrip patch antenna is proposed for wireless mobile communication applications. The exponential growth of user demand, the limitation of the 4G communication system and the emergence of the new technologies on the market have brought researchers to a throughout reflection on the 5G. Thus to meet the recent 5G technology, antennas are the most important components required to create a communication link. Microstrip antennas are the most suited for aerospace and mobile applications because of their low profile, light weight and low power handling capacity. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth, dual band and circular polarization to even ultra-wideband operation. In this paper, the design and analysis of Rectangular micro strip patch antenna for the 5G mobile communication system is presented. The shape of proposed antenna will provide the wide bandwidth which is required for the operation of 5G mobile communication systems. The effects of different antenna parameters like return loss, voltage standing wave ratio (VSWR), gain, directivity, efficiency, etc are also studied. The operating frequency of antenna is 28 GHz, the dielectric constant and thickness of the antenna is 4.4, 1mm respectively. The entire project is designed and simulated in a soft HFSS software.

The design micro strip patch antennas have achieved better operating bandwidth of 1600MHZ, considerable reduction in return loss which is –16.1196 dB and VSWR is 1.3706 which indicated approaches impedance matching, stable radiation patterns, unity gain, directivity 4.9304 dB,7.35501dB respectively and the antenna efficiency is 67.89% by using micro strip inset feed line technique.

Key Words: Micro strip patch antenna, Bandwidth, Beam-gain, Directivity, Fifth-Generation.

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLE

ABBREVIATION

BW	band width
dB	decibel
FR4	Flame Retardant
5G	fifth Generation
GPS	Global Positioning System
HFSS	High Frequency Structure Simulator
IEEE	Institute of Electrical and Electronics Engineers
MMIC	Monolithic Microwave Integrated Circuits
MSPA	micro strip patch antenna
RL	return loss
TEM	transverse electro magnetic
VSWR	voltage standing wave ratio

CHAPTER ONE

1. INTRODUCTION

Wireless communication technology have significantly changed how people live their daily lives during the last few decades. As a result, more and more users are connecting their devices to the current networks today, which is fueling an exponential rise in data traffic and rising demand for high-speed networks in the years to come. The fifth generation wireless network, which is now in the planning stages of deployment, is thought to provide the solution to the rising amount of wireless data traffic [1].In particular, the large unlicensed bandwidth in the millimeter-wave spectrum, will be utilized by the next 5G communication systems to significantly increase transmission capacity. It is also anticipated that it will be capable of supporting extremely high data rates, which will present a challenge for the network's requirements as well as antenna design to meet the anticipated data rate and capacity [2].

The development of wireless communication systems necessitates low-profile antenna types that can give astounding performance throughout a broad frequency band. In this aspect, the MSPA is a sensible option for wireless devices because of its affordable manufacturing costs, light weight, low volume, and low-profile design in contrast to other bulkier types of antennas. Regarding input impedance, polarization, resonant frequency, pattern, and ease of use, the MSPA is versatile and easy to use. High-performance vehicles, rockets, satellites, missiles, cars, hand-held mobile phones, and spacecraft can all have patch antennas mounted on their surfaces. Consequently, the MSPA is playing a significant role in the wireless communications business, which is experiencing the fastest growth. The depth of the substrate material, however, reduces the MSPA bandwidth and radiation efficiency by increasing spurious feed and surface wave radiation that travels laterally through the feeding line. As a result, feed radiation effects focus unwanted cross-polarized radiation in a certain direction. Additionally, the MSPA experiences losses from conductor, dielectric, and radiation, which causes the bandwidth to become smaller and the gain to decrease [3].

As a result of this performance constraint, MSPA has a limited bandwidth and poor directivity, gain, and radiation efficiency for 5G communication systems of the future. Different designs have been shown and documented in the scientific literature in an effort to improve the MSPA performance for 5G communication. Many broadband patch antenna designs are published in order to improve the bandwidth and radiation efficiency of these. Some of these design optimizations includes; the patch with multi-layer substrate integrated waveguide, and multi-patch designs, by incorporating multiple slots on the patch, by employing a defected ground plane, tuning dimension of the patch width, and employing a serial feed of the patch. Similarly, to reduce the feeding network structures and patch edge impedance mismatch, the use of quarter wavelength microstrip feed-line as inset-feed and lumped element to the patch edge were presented in [3] [4].

In general, the rectangular patch antenna given in uses the aforementioned methods at resonant frequency minimums return losses and has a broad dB impedance bandwidth. Alternatively, the antenna return loss reported in is inaccurate due to inadequate impedance matching at the interfaces is large for wireless communication. Besides, the antenna reported in has a good beam-gain but the design reported in achieved bandwidth is narrow for 5G applications. In another similar MSPA is presented and achieved a minimum VSWR and better radiation efficiency. Therefore, from the above summary of obtained simulation results in previous work, we can infer that the demonstrated work is tried to find better functionality in terms of one or two specific performance metrics. In this study, we are motivated to design and analyses a 28 GHz single element rectangular MSPA to see it’s feasibility for 5G systems, and also increase all the key performance metrics of the antenna. To ensure this, we have used inset-feed and quarter-wavelength impedance matching techniques, tuning dimensions of the antenna [4].

1.2. Statement of the Problem

One of the key advantages of modern communication systems is wireless technology, and a study of communication systems would be lacking without a grasp of the modeling, operation, and fabrication processes of antennas. Thus, we will research rectangular micro-strip patch antenna. Since many years ago, micro-strip patch antennas have been used in a variety of wireless communication applications, making them one of the most important issues in antenna theory and design. Rectangular micro strip patch antennas still have certain 3G, and 4G restrictions. The primary shortcomings of the third, fourth network generations micro strip patch antenna include low directivity, a small band width, low directivity and gain, high return loss etc. By designing and analysing a rectangular micro strip patch antenna for the 5G network with various feeding methods, the issues of the previous network generation will be resolved.

1.3. Objectives

1.3.1. General Objective

Design and Analysis of a 28 GHz Micro strip Patch Antenna for 5G Communication Systems.

1.3.2. Specific Objective

- To analysis a micro-strip patch antenna for 5G communication system.
- To design rectangular microstrip patch antenna.
- To measure the performance of micro-strip patch antenna in 5G.

1.4. Scope of the Project

The scope of this thesis is to design and analyze a 28 GHz micro strip patch antenna for 5G communication systems. Specifically, includes an assessment of the antenna's radiation patterns, impedance, efficiency, bandwidth, and directivity. Additionally, the thesis will explore various design parameters such as substrate material selection, feed line location and size. The Simulated results will be compared to measured data for verification purposes. Finally, based on the obtained objectives an optimal model will be proposed which can be used by current and future 5G communication systems.

1.5. Significance of the project

Due to tremendous growth of the importance of microstrip patch increases daily and many studies are done. But the major disadvantages are narrow bandwidth, so it is very important to increase the bandwidth; the one method that available to increase bandwidth is use of different slot shapes

- ✓ The 28 GHz antenna enabling them to fit into small and compact devices making them even more versatile than before.
- ✓ The ability for an antenna to deliver lower latency, higher capacity, and increased bandwidth and facilitate data rate in 5G communications.
- ✓ It gives the how to mathematically model the micro strip patch antenna for 5G communication.
- ✓ It also gives some knowledge about the designing of micro strip patch antennas using HFSS software.
- ✓ As the micro strip patch antenna are part of the components required in the design of telecommunication systems manufacturer may fabricate the simulated design.
- ✓ It creates some awareness about the micro strip patch antenna designing methods

1.6. Methodology

The main goal of this thesis is by studying the HFSS software to improve the performance of micro strip patch antenna. So we can achieve this goal by following the formal methodologies:

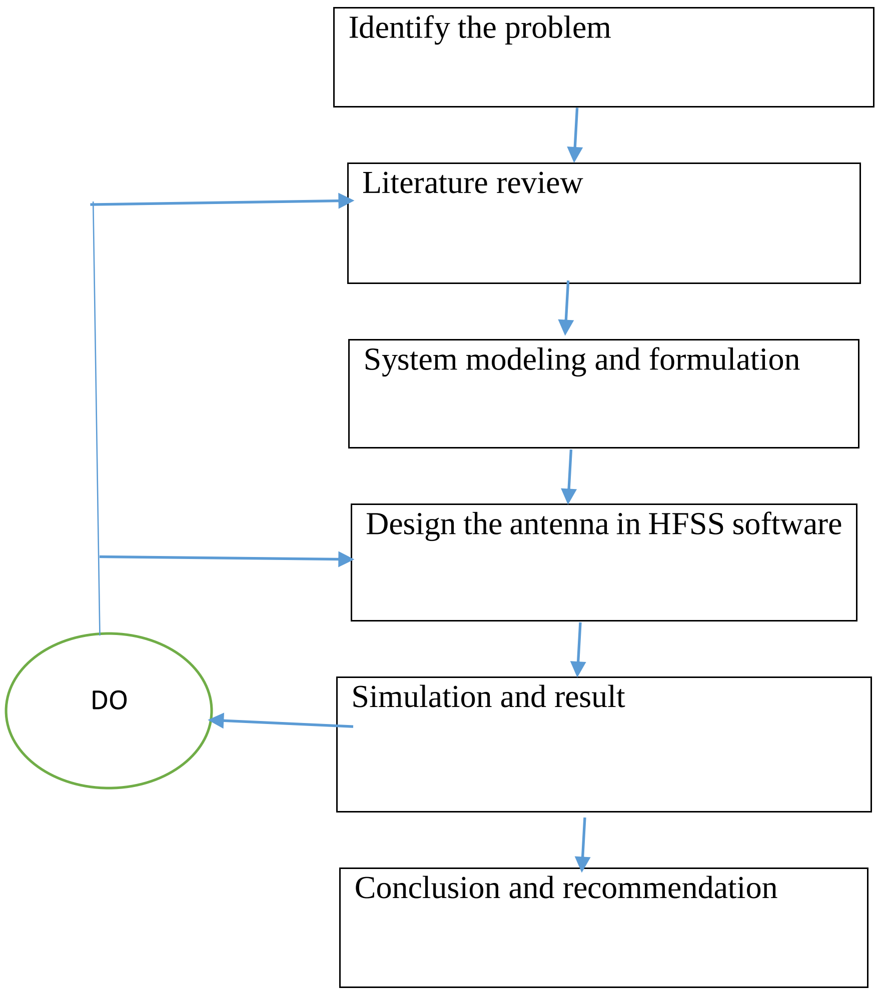

Figure 1.1: Flow chart Of Methodology

1.7. Outline of the Thesis

This thesis consists of five chapters.

Chapter one: - describes the introductory concepts, problem of statement, objectives, and methodology used related to the thesis.

Chapter two: - describes the Literature Review

Chapter three:- describes the main part of this thesis; in this section definition of micro strip patch antenna, feeding techniques and methods of analysis of micro strip patch antenna is described.

Chapter four: - deals with the micro strip patch antenna design, and simulation results and discussions.

Chapter five: - we introduce the result and discussion, and describes conclusions and future scope.

CHAPTER TWO

2. LITERATURE REVIEW

X. Gu, A (2008),multilayer organic package with 64 dual-polarized antennas for 28GHz 5G communication, In Proceedings of the IEEE International Microwave Symposium, 2018.This paper presents the design and simulation of a micro strip patch antenna operating at 28 GHz for 5G communication. The antenna operates at the Local Multipoint Distribution Service band having a center frequency at 27.91 GHz with a maximum reflection coefficient of –12.59 dB, a very wide bandwidth of 582 MHz and a high gain of 6.69 dB. The transmission line of the antenna used is an inset feed. The substrate used is Rogers RT Duroid 5880 which has a dielectric constant of 2.2 and a height of 0.254 mm but the limitation of this research it use small height so there no as much as isolate ground and patch . The antenna dimensions were calculated and simulated results have been displayed and analyzed using HFSS [5].

Rajat Arora1 , Ajay Kumar2 , Saleem Khan3 , Sandeep Arya (2018), Finite Element Modeling and Design of Rectangular Patch Antenna with Different Feeding Techniques,2013.From Modeling and Design of Rectangular Patch Antenna with Different Feeding Techniques In this paper, two different designs have been modeled and analyzed and both designs are based on the rectangular patches. The feeding point of one design is inside the patch while the other design contains feeding point outside the patch is T shaped. The computational analysis showed some interesting results for radiation pattern and far field domain. For these designs, the characteristic impedance taken is 50 Ω and the operating frequency domain is 1.4 to 1.7 GHz its limitation is consider the small frequency range so the size of the antenna is maximum. The micro strip patch antennas are encapsulated in the inert spherical atmosphere of 20 mm thickness containing air inside it [6].

M.Dheeraj and D. (2012), Shankar, Micro strip Patch Antenna at 28GHz for 5G Applications, Journal of Science Technology Engineering & Management Advanced Research and Innovation,2018.An organic-based multi-layered phased-array antenna package for a 28GHz 5G radio access applications is hereby introduced. The package incorporates 64 dual-polarized antenna elements and features an air cavity common to all antennas. Direct antenna probing measurements of the package show over 3GHz bandwidth and 3dBi gain at 28GHz. A phased array transceiver module has been developed with the package and four SiGe BiCMOS ICs are attached using flip-chip assembly. Module-level measurements in TX mode show 54dBm EIRP and near-ideal 35dB gain increase for 64-element power combining its limitations focused on the array antenna so that it is very complex structure (computer, phase shifter, data bus to each radiator), high costs (still). 64-element radiation pattern measurements are reported with a steering range of > ±40 degrees without tapering in off-boresight direction [7].

Darboe, D. B.Onyango, and F. Manene (2018), A28GHz Rectangular Microstrip Patch Antenna for 5G Applications, IJERT (International Journal of Engineering Research and Technology), 2019. In this paper, a 28GHz micro strip patch antenna (MSPA) design and performance analysis for fifth-generation (5G) communication systems is presented. The antenna is designed using FR4 substrate material with thickness of 0.244 mm, and and analyzed using HFSS (High frequency structure simulator) simulator. The simulated results show that, the beam-gain of 7.587 dBi, directivity of 7.509 dBi, the radiation efficiency of 97.33 %, and bandwidth of 1.046 GHz, compared to other similar designs suffers from losses are gained from the antenna significantly better bandwidth, beam-gain, return loss, and radiation efficiency. Therefore, the proposed antenna gives a highly competitive performance as related to other works, and also, it is a potential candidate antenna type for 5G wireless communication systems but it have their limitation because it use small thickness [14].

Siddik, M. Hossain, and D. Haque (2017), Design and Radiation Characterization of Rectangular Microstrip, American Journal of Engineering Research, 2019. This paper presents the effect of dielectric constant and height of the substrate on radiation efficiency, directivity and gain, fringing field and radiation pattern, which are calculated and investigated with different parameters of the patch antenna for the millimeter-wave of 900 MHz and 1800 MHz frequencies. The fringing field created on patch antenna depends on the relative dielectric constant of the substrate. The desired radiation efficiency, directivity, beam width and gain can be achieved by selecting proper design parameters and substrate material of the patch antenna. For the height of 1.5 mm of polypropylene tape substrate, the estimated result of radiation efficiency is consistence with the previous report. Moreover, it is investigated that the electric field radiation pattern area is reduced with the increasing of dielectric constant of the substrate [11].

CHAPTER THREE

3. SYSTEM DESIGN AND MATHEMATICAL MODELING OF MICRO-STRIP PATCH ANTENNA

An antenna is a device that is designed to transmit or receive electromagnetic waves. It converts electrical currents into radio waves for transmission, or vice versa for reception. Antennas are used in wireless communication systems such as smartphones, radios, televisions, and wireless routers to communicate with other devices via radio frequency signals. Antennas come in several shapes and sizes, and their design depends on their intended use and the frequency of electromagnetic waves they are designed to transmit or receive. There are different types of antennas; Wire Antennas, Aperture Antennas, Micro strip Antennas, Array Antennas, Reflector Antennas, Lens Antennas [5].

Micro strip Antennas; these antennas consist of a metallic patch on a grounded substrate. However, the rectangular and circular patches are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. The micro strip antennas are low profile, comfortable to planar and non-planar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance air craft, spacecraft satellites, missiles, cars, and even handheld mobile telephones.

In our thesis, we preferred microstrip antenna: The Microstrip antenna has proved to be an excellent radiator for many applications because of its several advantages as compared to conventional microwave antennas. This result its many applications over the broad frequency range from around 100 MHz to 100 GHz. Size of microstrip antenna comes in both advantages and disadvantages but there are some applications where the size of microstrip antenna is outsized for any use. The size of a microstrip antenna is inversely proportional to its frequency. At frequencies lower than microwave, microstrip patches don't make sense because of the sizes required. The narrow bandwidth is one of the main drawbacks of these types of antennas. A straight forward method of improving the bandwidth is increasing the substrate thickness. However, surface wave power increases and radiation power decreases with the increasing substrate thickness, which leads to poor radiation efficiency. Therefore various other techniques are presented to provide wide-impedance bandwidths of microstrip antennas. Some of the techniques in principle are suitable feeding techniques and impedance matching networks, insertion of slot, slit and notches on the microstrip antennas. Feeding technique has a large number of adjustable parameters like length, width and shape. Other ways to overcome these limitations are decreasing dielectric constant of the substrate, increasing thickness of the substrate and width of the patch. Another problem to be solved is the low gain for conventional microstrip antenna element [6].

Applications of Microstrip Antenna Numerous commercial requirements are fulfilled by the use of microstrip or printed patch antenna. Out of many shapes, rectangular shaped patch antennas are the most widely used antennas. Microstrip patch antenna fulfils most requirements for mobile and satellite communication system and many kinds of microstrip antennas is designed for this purpose. Air-craft, spacecraft, satellite, and missile are others dominant applications, where the use of microstrip antenna is most suitable due to its size, weight, cost, performance, ease of installation, and low-profile nature. Also, there are other government and commercial applications in the area of mobile radio and wireless communications where the requirement of this antenna is suitable [5].

3.2. Structure of Microstrip Antenna

Most commonly used microstrip antenna is the rectangular and circular patches. These patches can be used for the simplest and the most demanding applications. Any new numerical or analytical technique is standardized by first applying to these geometries. Undoubtedly the simplest microstrip antenna configuration is rectangular microstrip patch antenna. Hence this article deals with rectangular microstrip antenna. In its simplest form a microstrip antenna is a dielectric substrate panel sandwiched in between two conductors. The lower conductor is called ground plane and upper conductor is known as patch [7]. The patch is selected to be very thin. Patches are normally made of material such as gold or copper and design in to any shapes. These conducting metals are the main choice because of their low resistivity, resistance to oxidation, and ease in soldering and adhere well to substrate. The feed line and radiating patch is etched on the dielectric substrate. The radiating patch can be design in various shapes according to the desired characteristics but circular, square and rectangular shapes are common due to ease of fabrication and analysis. Their radiation characteristics are similar, despite the difference in the geometrical shape, because they behave like a dipole. If the thickness of the dielectric substrate is large the surface waves and spurious feed radiation increases, this will reduce the bandwidth of the antenna The feed radiation also leads to undesired cross polarized radiation [6] [7].

A circular microstrip antenna is a type of directional antenna that radiates radio waves in all directions perpendicular to its surface. It consists of a circular metal patch placed on top of a ground plane and separated by a dielectric layer. The patch is usually fed using a coaxial cable or microstrip line, and its circular shape helps to achieve properties such as omnidirectional radiation pattern and wide bandwidth. This type of antenna is commonly used in communication systems for satellite, cellular, and wireless applications. One disadvantage of a circular microstrip antenna compared to a rectangular microstrip antenna is that it has a lower bandwidth. This means that the circular microstrip antenna can operate at fewer frequencies compared to the rectangular microstrip antenna. Additionally, circular microstrip antennas may have higher losses due to radiation pattern distortion caused by edge diffraction effects.

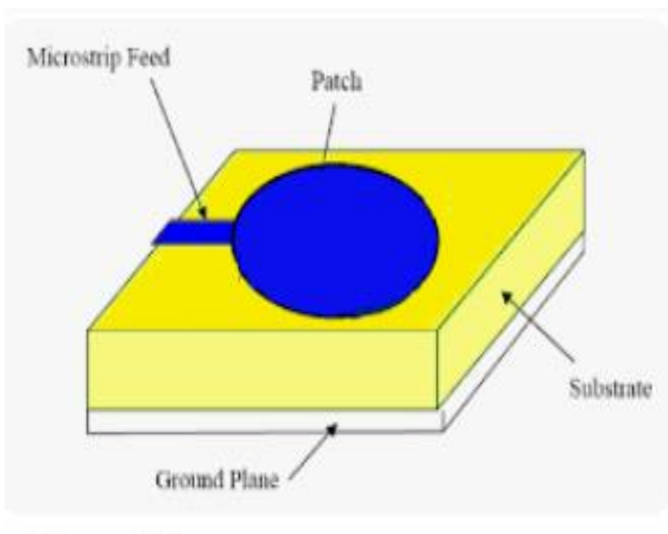

Figure 3.1: Microstrip Circular patch antenna

A rectangular microstrip patch antenna is a type of antenna that is widely used in modern electronic devices such as mobile phones, GPS units and satellite communication systems. It consists of a thin conductive patch of metal, usually copper or aluminum, mounted on a dielectric substrate, which is typically made of materials like fiberglass or ceramic. it several advantages over other types of antennas, including high gain, low profile, and ease of fabrication. The antenna operates by exciting electromagnetic waves in the surrounding air, which propagate outward and can be received by other devices.it is popular because they are lightweight, inexpensive, and can be easily integrated into printed circuit boards. They are used in a wide range of applications, including wireless communication, radar systems, and remote sensing [7].

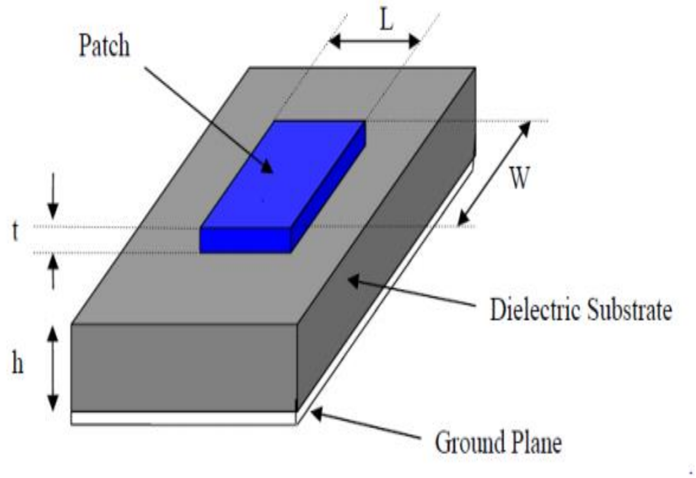

Figure 3.2: Microstrip rectangular patch antenna

The micro strip antenna height is related to substrate thickness or height (SH). The SH material is typically within the range of 0.003 λ0 ≤ SH ≤ 0.05 λ0. Where, λ0 denotes frees pace wavelength. For a rectangular patch, the length L of the patch is usually 0.3333 λo<L <0.5λ o where λo is the free-space wavelength. The patch is selected to be very thin such that t <<λo (where tis the patch thickness). The micro strip antenna height is related to substrate thickness or height (SH). The SH material is typically within the range of 0.003 λ0 ≤ SH ≤ 0.05 λ0. Where, λ0 denotes frees pace wavelength.

3.3. Feed Techniques

Micro strip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a micro strip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the micro strip line and the radiating patch. The four most popular feed techniques used are the micro strip line, inset line both are contacting schemes, aperture coupling and proximity coupling both are non-contacting schemes.so that they use the contacting feeding techniques [6] [8].

3.3.1. Micro strip Line Feed

A microstrip line feed is a common type of feeding mechanism used in antenna design. It involves using a thin strip of metal conductor placed on a dielectric substrate, which is then attached to the antenna element. This type of feed has advantages over other feeding techniques because it can be integrated with other components on the same substrate, and it can provide higher efficiency and lower loss than other methods. The feed typically consists of a transmission line that connects the antenna element to the source or receiver. The design of the microstrip feed can affect the performance and characteristics of the antenna, and must be carefully considered and optimized to achieve the desired results.

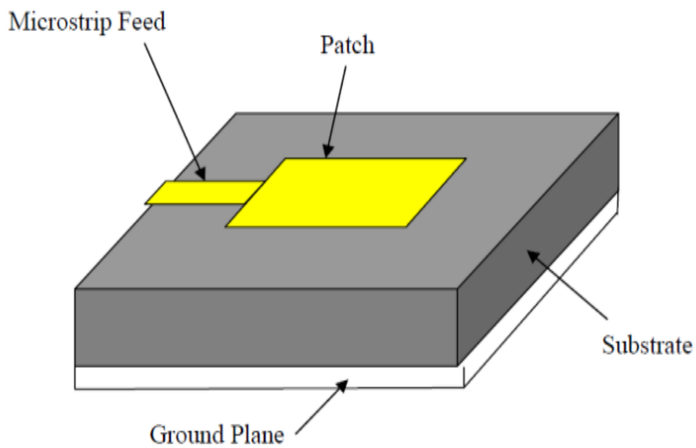

Figure 3.3: Rectangular patch with micro strip feed line

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation [8].

3.4. Inset line Feed

An inset line feed is a feeding technique used in micro strip antenna design to excite the antenna element. In this technique, a transmission line (usually a micro strip line) is inserted into the ground plane underneath the antenna patch. The distance between the edge of the patch and the inset line is a crucial parameter that determines the input impedance of the antenna. In the inset line feed configuration, the RF signal is launched into the antenna patch from the micro strip line through an aperture or gap in the ground plane. The length of the inset line is chosen such that it provides the necessary delay to match the impedance of the feed line with that of the antenna. This technique offers several advantages over other feeding techniques, including wide bandwidth, good impedance matching, and low radiation losses. Additionally, it allows for the optimization of other antenna parameters, such as gain and directivity, by tuning the physical dimensions of the feed line and the aperture. However, due to its complex design, the inset line feed is often not suitable for simple or compact antenna designs [6] [8].

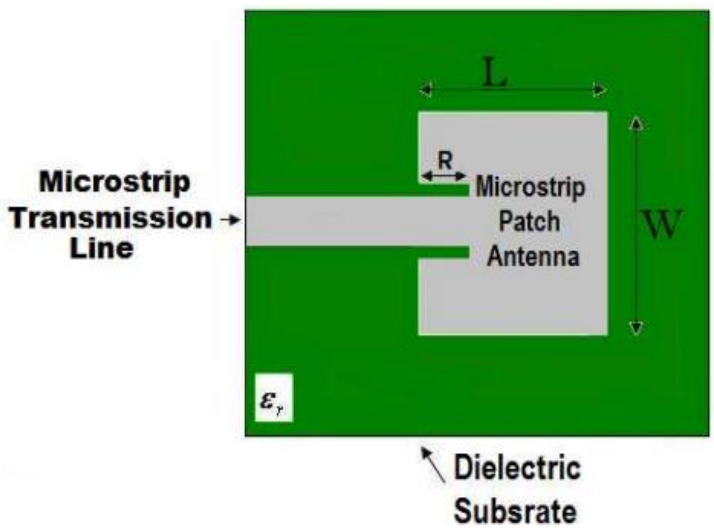

Figure 3.4: Rectangular Micro strip patch antenna with an Inset Line feeding

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda o$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems.

3.5. Methods of Analysis

The most popular models for the analysis of Micro strip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. In this project transmission line model is used as method of analysis.

3.5.1. Transmission Line Model

This model represents the micro strip antenna by two slots of width W and height h, separated by a transmission line of length L. The micro strip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air [9].

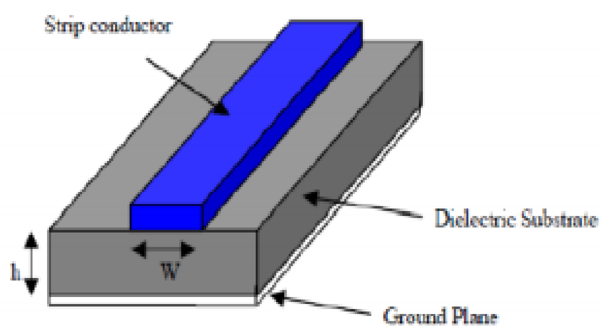

Figure 3.5: micro strip line

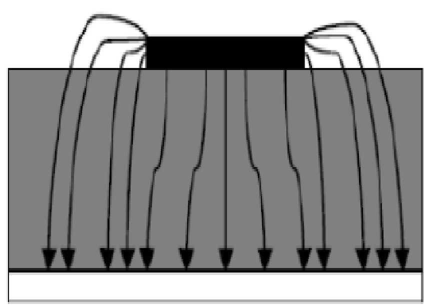

Figure 3.6: Electric field line

As shown figure above, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electromagnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. 22 Hence, an effective dielectric constant (εreff) must be obtained in order to account for the fringing and the wave propagation in the line. The value of εreff is slightly less than εr because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air.

The expression for εreff is given by

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{h}{w}\right]^{\frac{-1}{2}} \quad \ldots\ldots 3.1$$

Where εreff = Effective dielectric constant

εr = Dielectric constant of substrate h = Height of dielectric substrate

W = Width of the patch for a rectangular micro strip patch antenna of length

L , width W resting on a substrate of height h , the co-ordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the Z direction is in the figure bellow:

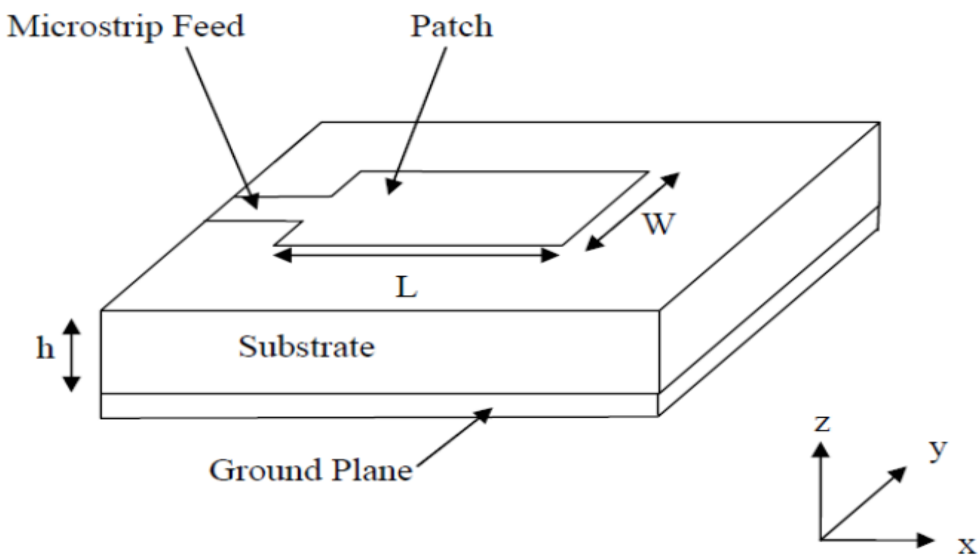

Figure 3.7: Micro strip Patch Antenna

In order to operate in the fundamental TM10 mode, the length of the patch must be slightly less than λ/ 2 where λ is the wavelength in the dielectric medium and is equal to 23 where λo is the free space wavelength. The TM10mode implies that the field varies one λ / 2 cycles along the length, and there is no variation along the width of the patch. In the Figure 3.8 shown below, the micro strip patch antenna is represented by two slots, separated by a transmission line of 27 length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edge scan be resolved into normal and tangential components with respect to the ground plane [9].

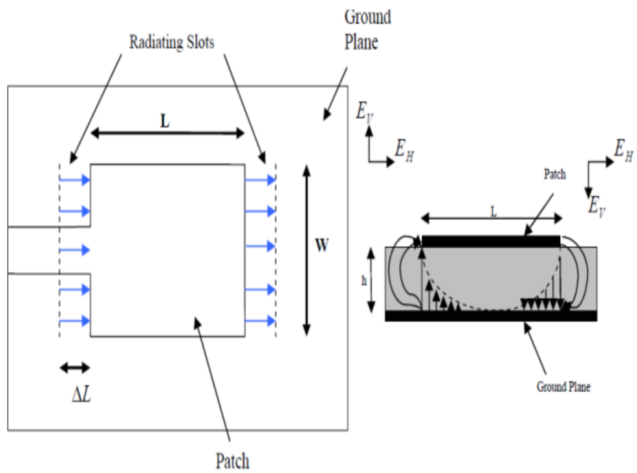

Figure 3.8: Top View of Antenna and Side View of Antenna

It is seen from Figure above that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is λ / 2 long and hence they cancel each other in the broadside direction. The tangential components (seen in Fig 3.8), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence the edges along the width can be represented as two radiating slots, which are λ / 2 apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the micro strip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL,

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{h}{w}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{h}{w}+0.8\right)} \quad \ldots\ldots 3.2$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\Delta L \quad \ldots\ldots 3.3$$

For a given resonance frequency f o, the effective length is given by:

$$L_{eff} = \frac{c}{2f_{\circ}\sqrt{\varepsilon_{reff}}} \quad \ldots\ldots 3.4$$

For a rectangular Micro strip patch antenna, the resonance frequency for any TM m n mode is given by: $f_{\circ} = \frac{c}{2\sqrt{\varepsilon_{reff}}}\,[(\frac{m}{L})^2+(\frac{n}{w})^2$ ……3.5

Where: m and n are modes along L and W respectively.

For efficient radiation, the width W is given by:

$$W = \frac{c}{2f_{\circ}\sqrt{\frac{\varepsilon_r+1}{2}}} \quad \ldots\ldots 3.6$$

3.6. System Design Methods and Procedures

The design of Rectangular micro strip patch antenna was developed using essential mathematical equations and High Frequency Structure Simulator software. In this section the system architecture is briefly described [10] [11]. We have followed some procedures to design and simulate the micro strip patch antenna. The general system architecture that we followed to design the antenna is shown in the Figure 3.10 below.

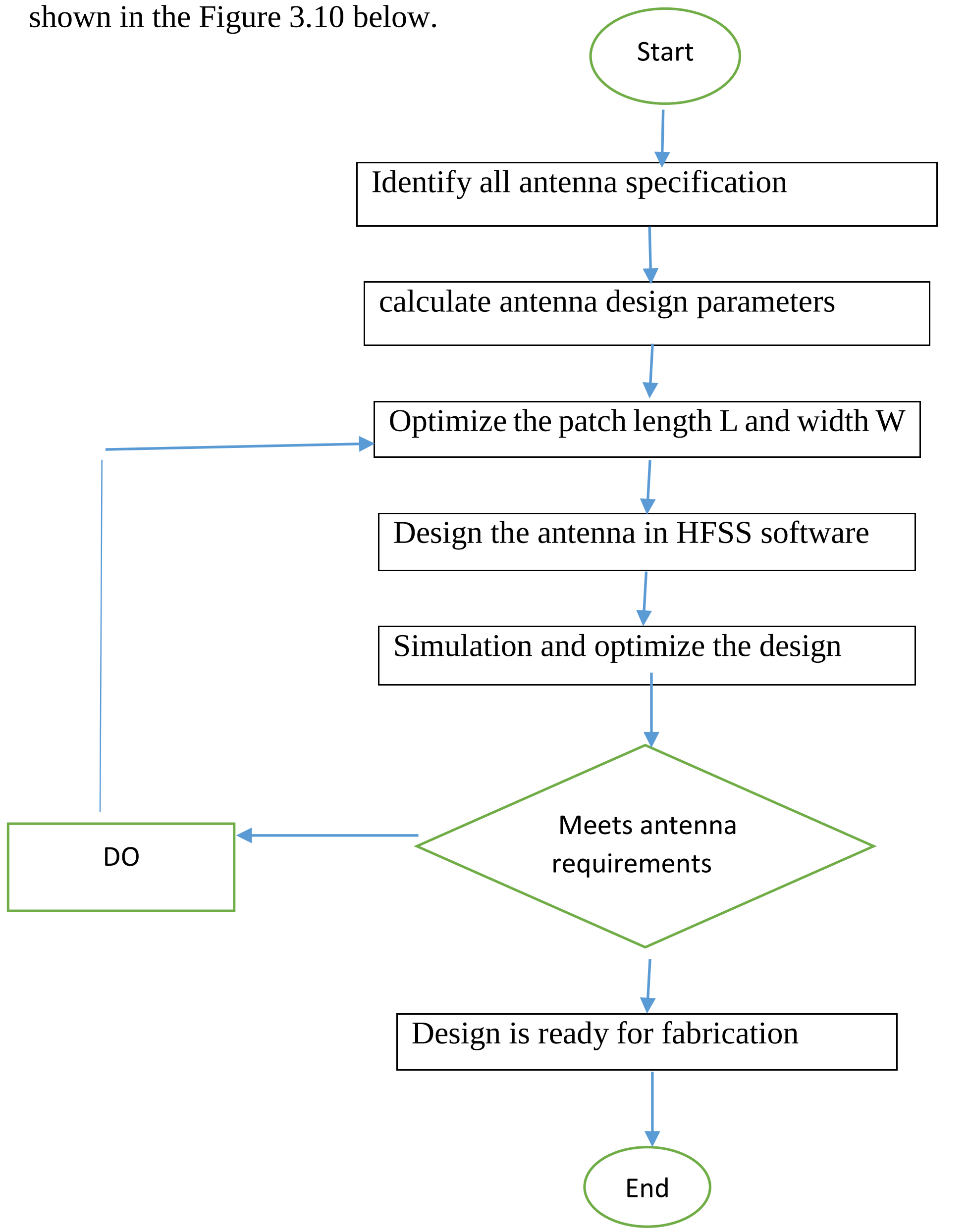

Figure 3.10: General flowchart of the design process

3.7. Design Specifications and material selection

The performance characteristics of the antennas are mainly structures, and the material properties from which they are made. In this study, the rectangular patch shape selected because it is easy to angular patch shape selected because it is easy to design and analyze and it has wide bandwidth by reason of its broader shape as compared to other types so that they are select the material copper:

Copper ground, Grounding in microstrip antenna design provides several advantages such as: It helps to reduce the radiation from the back of the patch, thereby improving the front-to-back ratio of the antenna. Improves the radiation efficiency of the antenna by reducing the power loss due to surface waves. It helps to reduce the cross-polarization and increase the axial ratio of the antenna. Creates a stable reference plane for the antenna, which reduces the impact of environmental factors such as temperature and humidity on the performance of the antenna. It helps to reduce the size and weight of the antenna by eliminating the need for a bulky and heavy ground plane, which is required in other types of antennas.

Copper patch are commonly used in microstrip antenna designs as they can improve the antenna's radiation efficiency and bandwidth. They can also be used to adjust the impedance of the antenna where needed. Additionally, copper patches can help reduce cross-polarization levels and provide better gain performance.

Copper feed in the feed in design of an antenna, the feed is directly attached to the antenna structure, which allows the signal to be directly fed into the antenna without the use of any other medium. This design offers several advantages, such as a broader range of operating frequencies, higher efficiency, and improved directivity. It also simplifies the design and reduces the overall dimensions of the antenna structure. Additionally, it allows for easy integration with other components, such as filters and amplifiers, which can improve performance in applications like wireless communication systems.

Substrate FR4 material has a relatively low dielectric constant, which makes it an excellent choice for antenna designs. The lower the dielectric constant of the substrate material, the lower the loss and the more efficient the radiation. Also, FR4 is an inexpensive and widely available material that can be easily machined to meet custom design requirements. Therefore, using an FR4 substrate in antenna design helps to improve the overall performance and efficiency of the antenna while keeping the cost low.

Radiation boxes in air (vacuum) are used to improve the performance of antennas by reducing the effect of surrounding objects on the radiation pattern. The use of vacuum or air helps to prevent the loss of energy due to the presence of other materials or gases that tend to absorb the signal and can cause interference. This enables the antenna to work more efficiently and effectively, producing a clearer and stronger signal. Additionally, using vacuum in the design of an antenna can reduce the overall size and weight of the antenna, making it easier to install and less expensive to manufacture.

A port is a point on the antenna where electromagnetic waves can be coupled in or out. Ports are typically defined by the location of a feed point, or by the use of a waveguide or other transmission line. There are two main types of ports in antenna design: Wave ports: Wave ports are used to couple electromagnetic waves into or out of an antenna using a waveguide or other transmission line. Wave ports are typically used for antennas that are designed to operate over a wide range of frequencies. Lumped ports: Lumped ports are used to couple electromagnetic waves into or out of an antenna using a lumped element, such as a resistor or capacitor. Lumped ports are typically used for antennas that are designed to operate over a narrow range of frequencies.

The three essential parameters for the design of a rectangular Micro strip Patch Antenna is: Frequency of operation (fo): The resonant frequency of the antenna must be selected appropriately. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for this design is 28 GHz. The high order 5G networks use the frequency range from 24-40 GHz. Dielectric constant of the substrate (ε_r): The dielectric material selected for this design is FR4 epoxy which has a dielectric constant of 4.4. A substrate with a low dielectric constant has been selected since it improves the bandwidth of the antenna. Height of dielectric substrate (h): For the micro strip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1mm [11] [12].

3.7.1. Design Procedure Using Transmission Line Model

Step 1: Calculation of the Width (W): The width of the Micro strip patch antenna is given as

$$W = \frac{c}{2f_\circ\sqrt{\frac{\varepsilon_r+1}{2}}} \quad \ldots\ldots 3.9$$

Substituting $c = 3*10^8\,\frac{m}{s}$, $f_\circ = 28*10^9$HZ, $\varepsilon_r = 4.4$

W = 3.26025mm=3.3mm

Step 2: Calculation of Effective dielectric constant (ε_{reff}):

The effective dielectric constant is:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{h}{w}\right]^{\frac{-1}{2}} \quad \ldots\ldots 3.10$$

Substituting ε_r = 4.4, h = 1mm, W=3.3mm ε_{reff}=3.93393

Step 3: Calculation of the Effective length (L_{eff}):

The effective length is:

$$l_{reff} = \frac{c}{2f_{\circ}\sqrt{\varepsilon_{reff}}} \quad \ldots\ldots 3.11$$

Substituting ε_{reff} = 3.93393, c = $3*10^8$ m/s, f∘=28* 10^9HZ, L_{eff} = 2.701mm

Step 4: Calculation of the length extension (ΔL):

The length extension is:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{h}{w}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{h}{w}+0.8\right)} \quad \ldots\ldots 3.12$$

Substituting h=1mm, W=3.3mm, ε_{reff}=3.93393 ΔL=0.1114mm

Step 5: Calculation of actual length of patch (L):

The actual length is obtained by: L_{eff}=L+2ΔL……………..……………………..........3.13

$L=L_{eff}-2\Delta L$ …………………………………………..……………………3.14

L=2.701mm-2*0.1114mm L=2.4782mm=2.5mm

Step 6: Calculation of the ground plane dimensions (L^g, W^g):

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery [13] [14]. Hence, for this design, the ground plane dimensions would be given as:

Lg min=6h +L=6*1mm+2.5mm=8.5mm …………………………………………………3.15

Wg min=6h+W=6*1mm+3.3mm=9.3mm……………………………….………………3.16

Step 7: Calculation of feed width

$$\frac{wf}{h} = \{\frac{8e^{A}}{e^{2A-2}} \quad \ldots\ldots 3.17$$

$$= \frac{2}{\pi}\{B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}[\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}]\}\frac{wo}{h} \geq 2 \quad \ldots\ldots 3.18$$

Where

$$A=\frac{Zo}{60}\sqrt{\frac{\varepsilon_r+1}{2}}+\frac{\varepsilon_r+1}{\varepsilon_r-1}(0.23+\frac{0.11}{\varepsilon_r}$$

$$B=\frac{377\pi}{2Zo\sqrt{\varepsilon_r}}$$

Wf=0.5

Step 8: the length of feed

$$l_f=\frac{\lambda}{4*\sqrt{\varepsilon_r}} \quad \text{.........} 3.19$$

$$l_f=3mm$$

To achieve 50Ω characteristic impedance, the required feed width to height ratio is computed as

Step 9: Determination of Inset feed depth (y0):

An inset-fed type feed is to be used in this design. The feed depth is given by y_0. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method is used to locate the feed point.

$$Y_0=\left(\frac{L}{\pi}\right)\cos^{-1}\sqrt{\frac{Z_0}{Z_L}} \quad \text{.........} 3.20$$

Assuming that ZL= 121.6749Ω, $Z_\circ$ is the characteristic impedance of 50 Ω we get $y_\circ$= 0.9 mm

Table 3.1: Design parameters of the antenna structure

Design Parameters	Symbol	Optimized values(mm)
Width of the patch	PW	3.3
Length of the patch	PL	2.478
Length of microstrip feeder	LMF	2.1543
Width of microstrip feeder	WMF	0.478584
Inset gap	GP	0.23915
Length of inset feed	Y_o	0.9054
Width of the substrate	SW	9.3
Length of the substrate	SL	8.5
Width of a ground	GW	9.3
plane Length of a ground	GL	8.5

3.8. HFSS Design Model

This procedure involves the design of the Rectangular micro strip patch antenna in the HFSS software. The antenna design consists of a single layer of substrate thickness, dielectric constant and frequency at 28GHz.

Figure 3.13: Ground shape of antenna

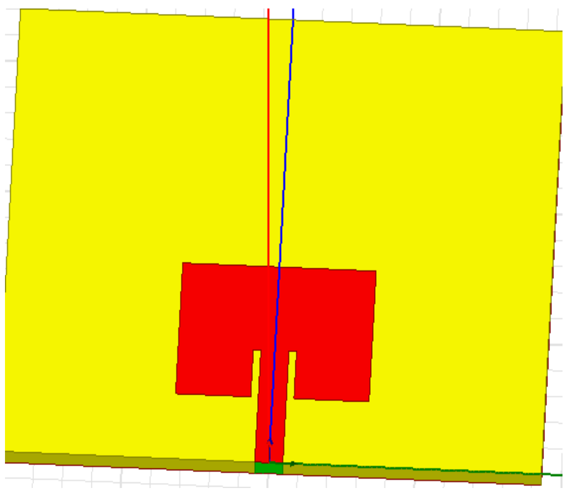

Figure3.14: substrate shape of yellow color

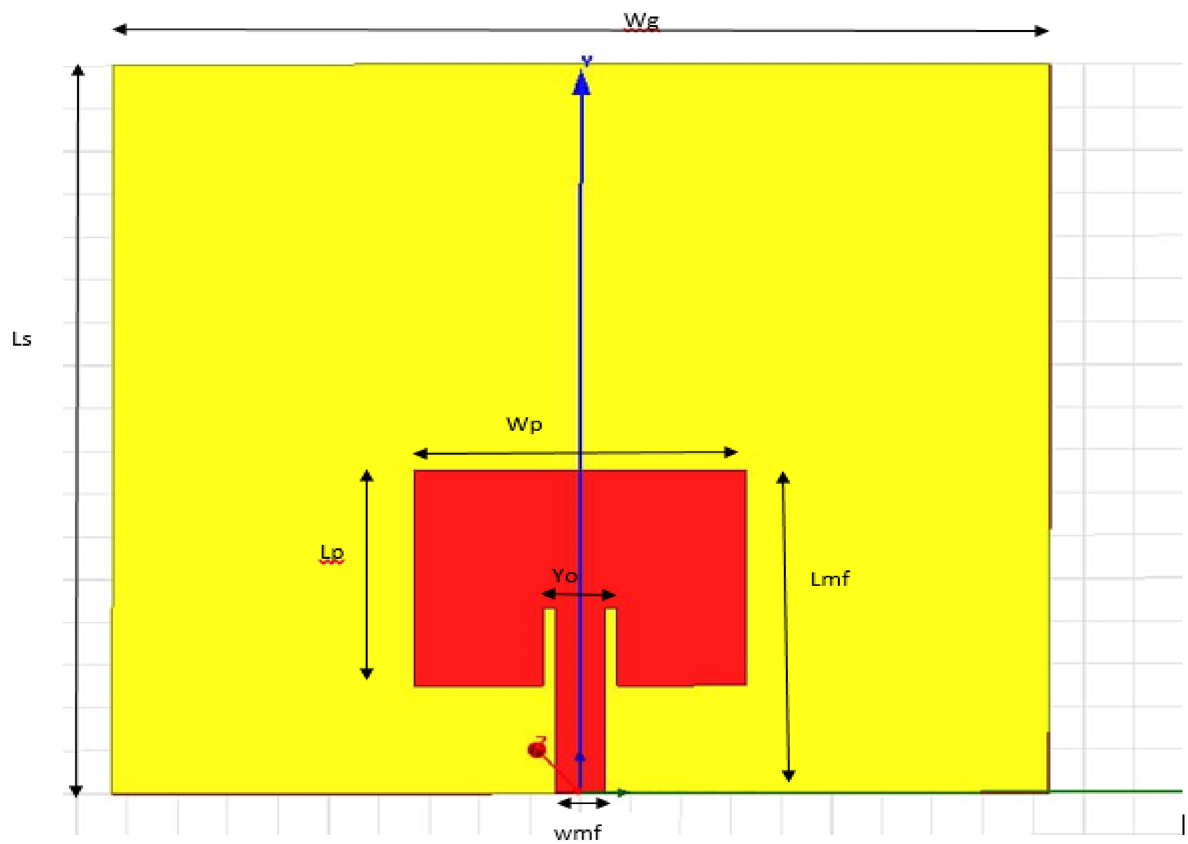

Figure 3.15: inset of feed shape with symbols represent of red color on the substrate

CHAPTER FOUR

4. SIMULATION RESULT AND DISCUSSION

4.2. Simulation Results

In this chapter, the results obtained from the HFSS simulations are demonstrated, from these results RL, VSWR, the radiation pattern plot that means the gain and directivity are discussed.

4.2.1. Return Loss

The Figure 4.1 below shows that the return loss of -16.1196dB was obtained at the resonant frequency of the designed antenna. The higher the return loss, the lower the reflection coefficient to zero, the better the power handling capacity of the antenna with less energy loss.

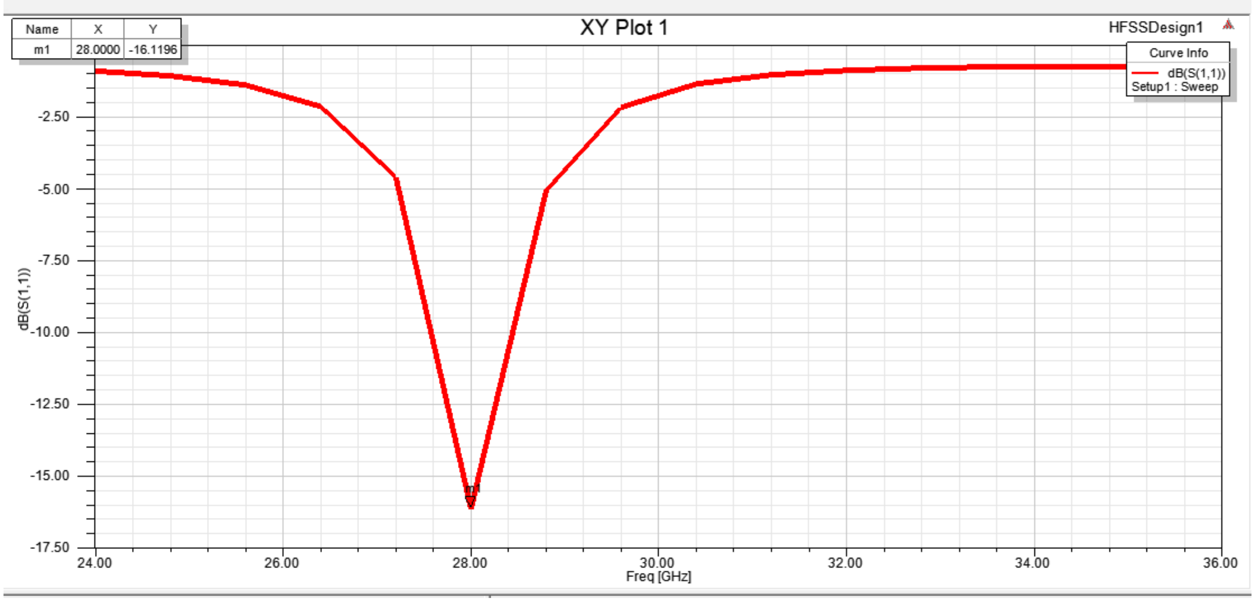

Figure 4.1: Return loss versus frequency plot operating at 28GHz

4.2.2. Voltage Standing Wave Ratio

The Figure 4.2 below shows VSWR against the frequency. For perfect matching of a line feed to the designed antenna the VSWR≤1.5. For this design, the desired VSWR = 1.3706 indicating that the antenna is well matched over the resonant frequency. This also shows that it consist of its lowest at 28 GHz in accordance to the resonant frequency of the antenna.

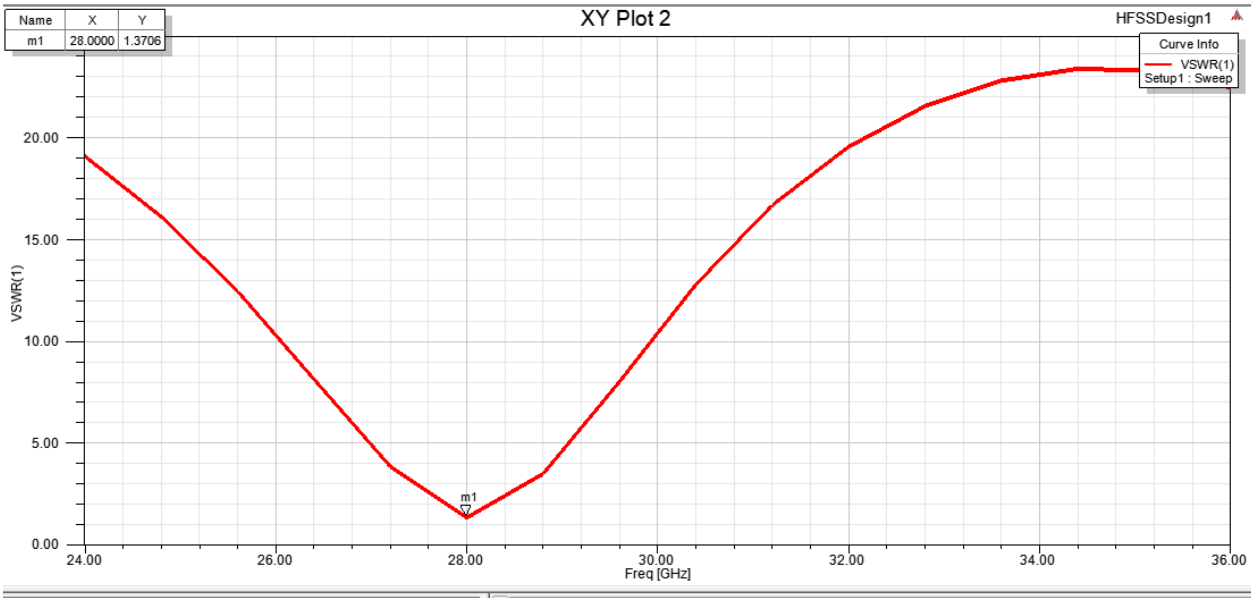

Figure 4.2: VSWR versus frequency plot

4.2.3. Radiation Pattern of the Antenna

The most vital part is the radiation pattern of any antenna. The radiation pattern illustrated the direction and gain of the designed antenna. The result shown in Figure 4.3 denotes the polar plot, radiation pattern of the designed antenna at the resonant frequency of 28 GHz. The antenna gain at zero degrees is more than 3.5 dBi.

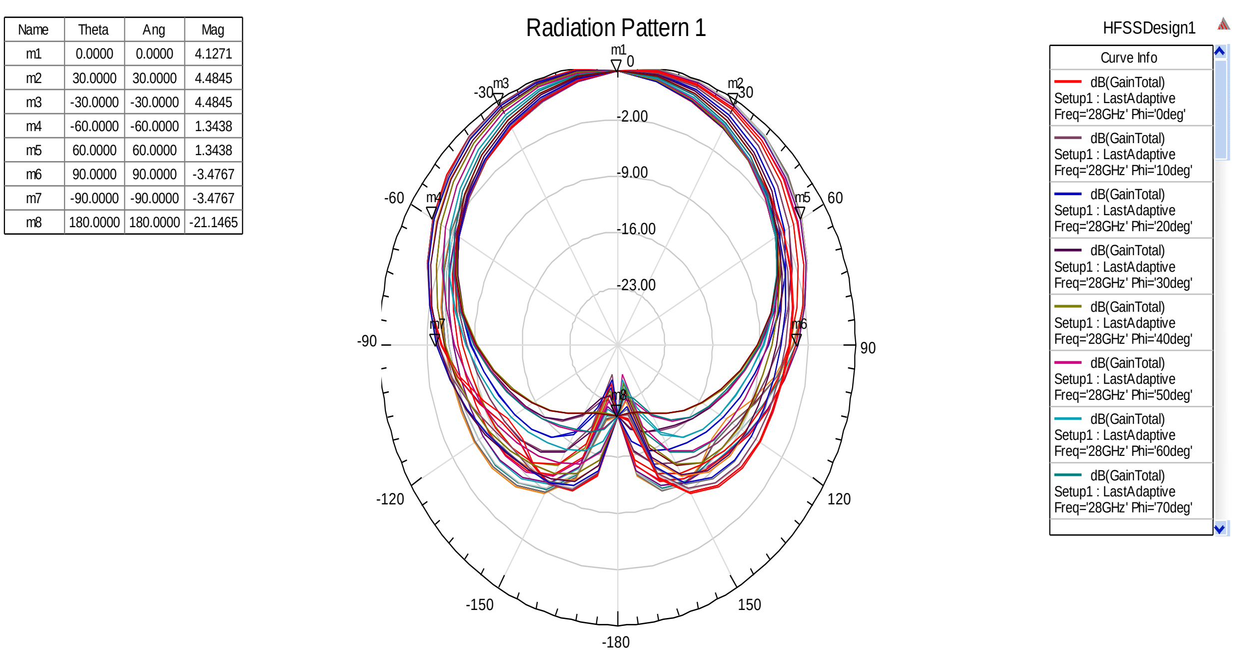

Figure 4.3: radiation pattern of antenna

At 30^{o} the antenna has the gain of 4.4845dBi. Moreover, by observing the radiation pattern, it is clearly visible that at 0^{o} direction from the main lobe the gain is around 4.1271dBi.In case of negative angles, such as for -30^{o}, the gain is around 4.4845 dBi.

4.2.4. Gain of the results

The gain of the results at the frequency of 28 GHz value 4.9304 dB.

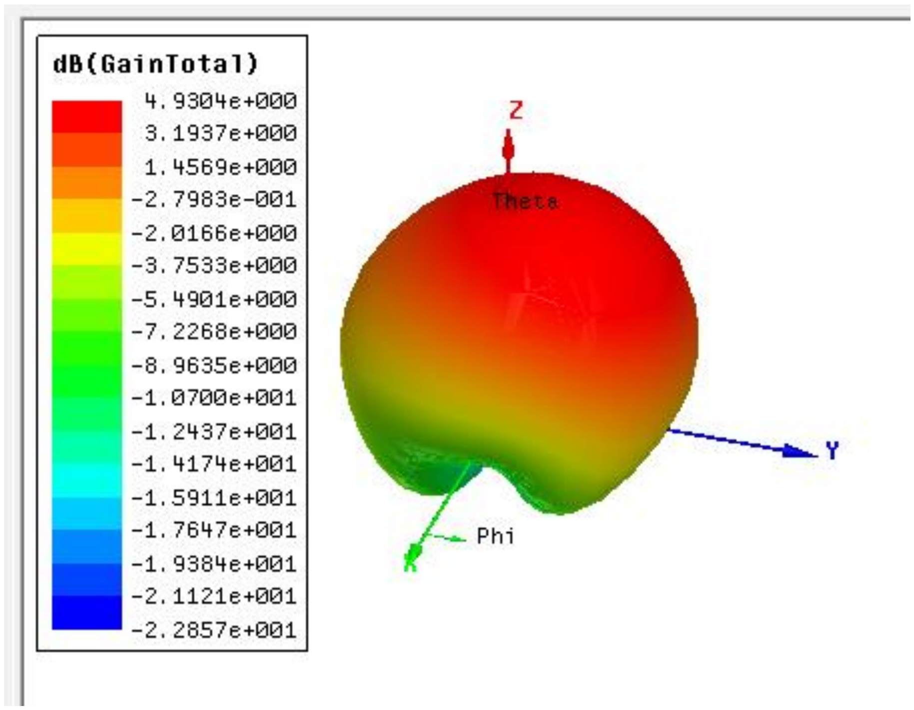

Figure 4.4: gain of inset feed antenna

4.2.5. Directivity

The directivity of results at the frequency of 28 GHz value 7.35501dB.

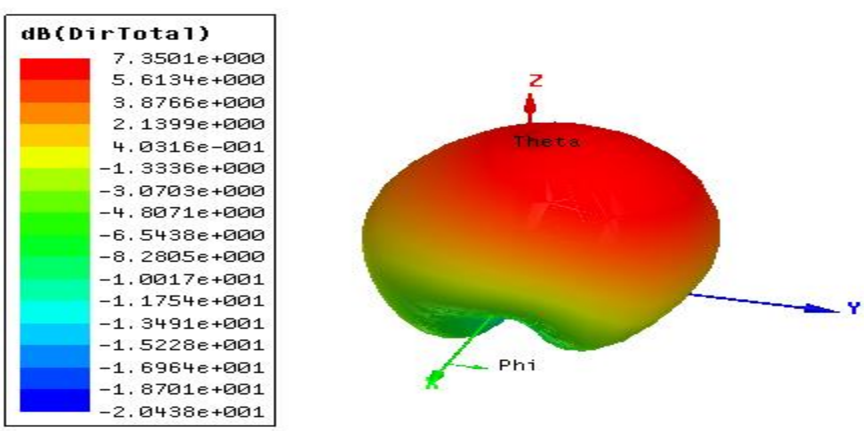

Figure 4.5: directivity of inset feeding antenna

4.2.6. Bandwidth (BW)

BW = m1-m2=28.8-27.2=1.6GHz=1600MHz

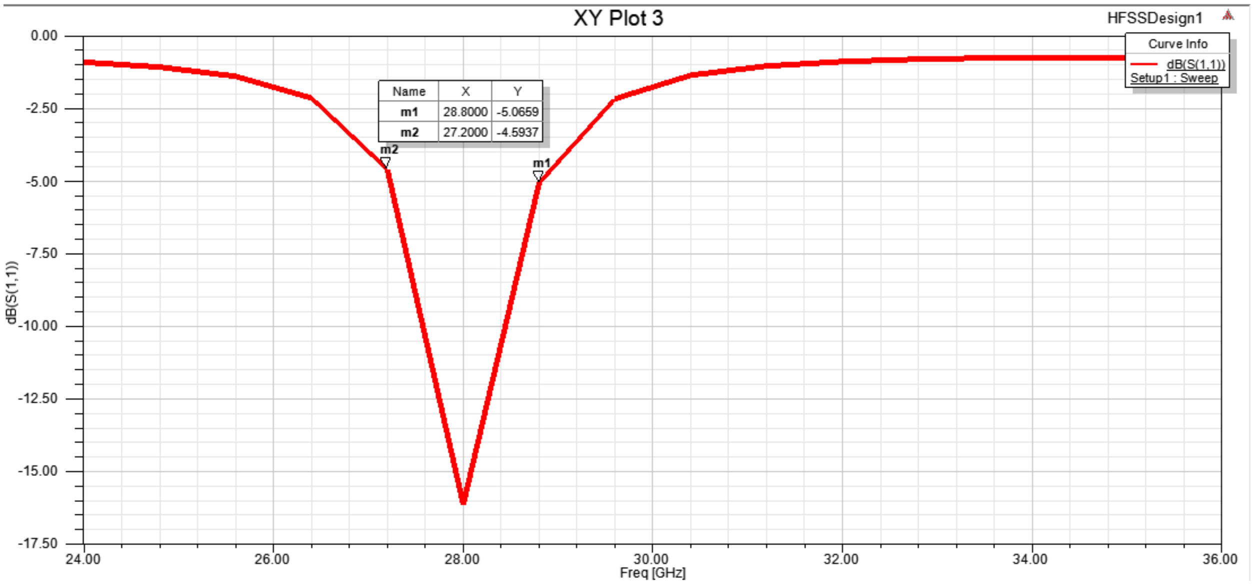

Figure 4.5: Bandwidth of inset feeding antenna

4.3. Discussions

Generally from the above results we discussions we obtained these parameters: such as the RL, VSWR, BW, gain, directivity, and radiation efficiency of the design micro strip patch antennas for handheld cell phones at the operating frequency of 28GHZ:

- RL = -16.1196dB
- VSWR = 1.3706
- BW = 1600MHZ
- Gain = 4.9304 dB
- Directivity = 7.35501dB
- Antenna efficiency percentage= $\frac{\text{gain}}{\text{directivity}}$ *100%= $\frac{4.9304\ \text{dB}}{7.35501\text{dB}}$ = 67.89%

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATION

5.2. Conclusion

It has been designed rectangular micro strip patch antennas operating at 28 GHZ for 5G communication systems and the characteristics of proposed antennas have been investigated through different parametric studies using HFSS. The design micro strip patch antennas have achieved better operating bandwidth of 1600MHZ, considerable reduction in return loss which is –16.1196 dB and VSWR is 1.3706 which indicated approaches impedance matching, stable radiation patterns, unity gain, directivity 4.9304 dB,7.35501dB respectively and the antenna efficiency is 67.89% by using micro strip inset feed line technique and transmission line model as method of analysis for lower substrate dielectric materials of FR4 epoxy and the inset feed line is 2.1543mm generally inset of feed is preferred b/c of ;Better impedance matching: Inset feed structures can be designed to maximize the impedance matching between the antenna and the transmission line, resulting in higher efficiencies and improved performance, Improved radiation performance: It's structures help to reduce surface currents on the antenna, which can improve radiation efficiency and reduce unwanted radiation patterns..

5.3. Future scope And Recommendation

According to scope of our project we model and simulate a micro strip patch antenna for 5G mobile communication at resonant frequency 28 GHz. But because of the time we cannot beyond to our scopes, but in the future we believe that this system can be fully operational by having enough time and fully information.

Finally, we would recommend for future work to be made in future we are going to study further in antenna and extend this concept to improve micro strip patch operating at multiband frequency for many applications for instance mobile communications.

REFERENCES

[1] Dahlman, G. Mildh, S. Parkvall, J. Peisa, J. Sachs, Y. Selen, and J.Skold,, "5G wireless access: Requirements and realization," 2014.

[2] Stefano Vitturi; Claudio Zunino; Thilo Sauter, "Industrial Communication Systems and Their Future Challenges: Next-Generation Ethernet, IIoT, and 5G," 2019.

[3] MA Matin, AI Sayeed, A design rule for inset-fed rectangular microstrip patch antenna, 2010.

[4] C. Bergsrud, C. Freidig, M. Anderson, M. Clausing, T. Dito, and S.Noghanian, Inset Fed and Edge-Fed Patch Antennas, 2012.

[5] John Wiley & Sons, Inc, Modern antenna handbook, 2008.

[6] S. Johari, M. A. Jalil, S. I. Ibrahim, M. N. Mohammad, and Norhafiza, "28 GHz Microstrip Patch Antennas for Future 5G".

[7] G Singh, J Singh, "Comparative analysis of microstrip patch antenna with different feeding techniques," 2012.

[8] D. Mishra, "Overview of microstrip antenna," 2016.

[9] Rajat Arora1 , Ajay Kumar , Saleem Khan , Sandeep Arya, "Finite Element Modeling and Design of Rectangular Patch Antenna with Different Feeding Techniques," 2013.

[10] M.Dheeraj and D. Shankar, "Microstrip Patch Antenna at28GHz for 5G Applications," 2018.

[11] J. Zhang, M. Guizani, and Y, Zhang, "5G Millimeter-Wave Antenna Array: Design and Challenges," 2017.

[12] V. Adepu, "A 28GHz FR-4 Compatible Phased Array Antenna for 5G," 2017.

[13] A. Siddik, M. Hossain, and D. Haque, "Design and Radiation Characterization of Rectangular Microstrip," 2019.

[14] O.Darboe,D. B.Onyango, and F. Manene, "A28GHz Rectangular Microstrip Patch Antenna for 5G Applications," 2019.