A
Project Report
on

Design and Analysis of Microstrip Antenna for 5G Application

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the requirements for the Degree of
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Certificate

This is to certify that the project report entitled **"Design and Analysis of Microstrip Antenna for 5G Application"** is hereby approved as a creditable study carried out and presented by

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Abstract

As technology evolves, we require more bandwidth antennas for communication. To provide one of the major solutions to 5G technology, we designed a 5.3GHz microstrip patch antenna. We made the antenna from FR4, which is a double-sided copper-coated PCB. It has a dielectric constant of 4.4 and a substrate height of 1.6 mm. We started with antenna simulation in Advanced Design System (ADS). We obtained good results in terms of gain, directivity, frequency plot, radiation pattern, electric field plane, and magnetic field.

Acknowledgement

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Abbreviations

ADS	- Advanced Design System
DC	- Direct Current
GHz	- GigaHertz
IC	- Integrated Circuit
IDE	- Integrated Development Environment
IoT	- Internet of Things
MHz	- MegaHertz
MIC	- Microwave Integrated Circuits
MIMO	- Multiple Input Multiple Output
MPA	- Microstrip Patch Antenna
PCB	- Printed Circuit Board
RF	- Radio Frequency
SWR	- Standing Wave Ratio
VSWR	- Voltage Standing Wave Ratio
Wi-Fi	- Wireless Fidelity
WiMAX	- Worldwide Interoperability for Microwave Access

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Introduction

Chapter 1

1. Introduction

To communicate from one point to another point we need antenna which will serve as backbone of transmitter and receiver. As per the revolution of the communication technology in recent development we found that we can implement the 5G antenna. Currently we are using 4G in India with mobile antenna bandwidth operating at around 800-900 Mhz. To implement the for 5G we need to design antenna in such way that it will be supporting the required application. As the population is increasing continuously and requirement of quality network is also increasing. Still the 5G is trying to solve the problem by providing the solution to the problem discussed above. For the same we had come up here with basic antenna of 5.3 GHz and implemented it using the ADS software first. After successfully implementing the design work we went on to making the hardware. We designed and tested the antenna and made it a stepping stone for 5G work. Here we used basic microstrip patch antenna to build the antenna of frequency 5.3Ghz. Due to the lightweight, telecommunication systems can be structured to be mounted when required or necessary. Moreover, they are easily fabricated, due to low cost and are easy integrated into arrays or into microwave printed circuits.

In this project we implemented the antenna we printed. the pattern onto the pcb material. After printing it we connected it with connector and connected it to the machine to generate the output. The advantages that a microstrip patch antenna is that it is light weight, easy to implement, low profile antenna, low cost and very versatile.

1.1 Objective

Microstrip patch antennas are small antennas that are fabricated over a Printed Circuit Board and can be used in embedded systems and applications as such. In this thesis, our aim is to provide a solution for the various demanding parameters in the microstrip patch antenna for reduction in size apart from large bandwidth and higher data rates. The objective is to study the different antenna parameters and come up with a comparative study on why meta-material based antenna are better than the conventional antenna.

1.2 Motivation

5G technology will introduce advances throughout network architecture. 5G New Radio, the global standard for a more capable 5G wireless air interface, will cover spectrums not used in 4G. New antennas will incorporate technology known as massive MIMO (multiple input, multiple output), which enables multiple transmitters and receivers to transfer more data at the same time. But 5G technology is not limited to the new radio spectrum. It is designed to support a converged, heterogeneous network combining licensed and unlicensed wireless technologies. This will add bandwidth available for users .

5G technology will not only usher in a new era of improved network performance and speed but also new connected experiences for users.

In healthcare, 5G technology and Wi-Fi 6 connectivity will enable patients to be monitored via connected devices that constantly deliver data on key health indicators, such as heart rate and blood pressure. In the auto industry, 5G combined with ML-driven algorithms will provide information on traffic, accidents, and more; vehicles will be able to share information with other vehicles and entities on roadways, such as traffic lights. These are just two industry applications of 5G technology that can enable better, safer experiences for users.

1.3 Flowchart

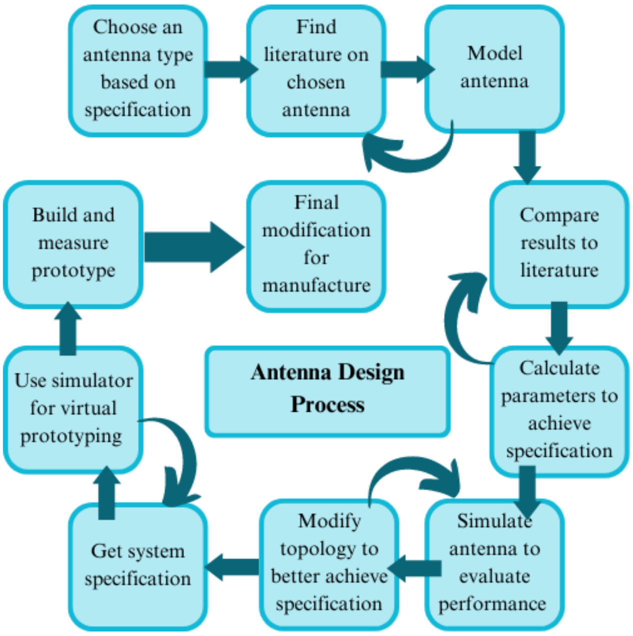


Figure 1.1 Flowchart of antenna design process

Figure 1.1 explains the design methodology used in this project for design of patch antenna. In the first stage, the requirement of the antenna for Wi-MAX is investigated. After literature review the type of antenna to be designed is decided for particular applications and depending on it we have decided the operating frequency and size of the antenna. Various softwares are available for the antenna simulation. After comparative study, ADS is chosen as the simulation software for antenna design. In the second stage, actual modeling and simulation of an antenna is done, by using the parameters decided in first stage. After simulation the results are evaluated.

In the third stage, we have done actual fabrication of an antenna according to the constructed model in simulation software and then actual testing and measurement of antenna parameters such as return loss, VSWR, radiation pattern etc. is carried out for the fabricated antenna.

1.4 Organization of Thesis

The organization of this thesis is as follows.

Chapter 1: In this chapter the basic theory of antenna, fundamental parameters such as radiation pattern, impedance, VSWR, gain etc. and types of antennas are presented.

Chapter 2: It presents background of microstrip patch antenna including the basic geometries, radiation mechanism, feeding method, types and characteristics of the MPA. The advantages and disadvantages of MPAs, impedance matching, waves on patch, the methods of analysis used for the MPA design, finally the calculations required to find the dimensions of the conventional MPA using transmission line model are presented in this chapter.

Chapter 3: In this chapter the design consideration and procedure of microstrip antenna design by using ADS is presented. Also, effect of change in feeding techniques is analyzed. Characteristics investigation of different parameters is discussed in briefly for proposed design.

Chapter 4: In this chapter the fabrication and testing of antenna is presented.

Chapter 5: This chapter contains conclusion and future work.

1.5 Literature Review

“Design of a Multiband Patch Antenna for 5G Communication Systems” by Atik Mahabub & et. al proposed an antenna which can effectively operate at 2.4 GHz as Wi-Fi, 7.8 GHz as WiMAX and 33.5 GHz for 5G communication purposes. The proposed antenna arrays have given directional radiation patterns, very small voltage standing wave ratio(VSWR), high gain and directivity. This antenna is made for multiband purpose which can be effective for not only Wi-Fi and WiMAX but also 5G applications. Though this antenna has various advantages, it can be improved. This antenna’s height and width can be deduced to make it light-weight, more frequency bands can be added to it to make it more effective and directivity can be improved so that it can cover more areas.

“Dual polarized Antenna and Array with Filtering Response and Low Cross Polarization for 5G Millimeter Wave Applications” by Jia Wang Li & et. al proposed 5G antenna whose isolation better than 20 dB between two feeding ports. This isolation was achieved with the two ports in the same plane. The antenna is low profile with only 1.4 mm thickness including two dielectric layers and a bounding layer. The operating frequency band is from 26.5 GHz to 29.5 GHz, which can be applied to n257 5G mm wave band. In addition, a rotating sequence 2 × 2 antenna array is designed and measured. The same polarization is fed by a differential feeding network, which will further reduce the cross polarization of the array, the cross polarization is better than 20 dB.

“Dual Band 9-Shaped Graphene-Film Patch Antenna for 5G Applications” by Ankit Kaim and Dr. Shailesh Mishra presented a 9-shaped planar dual-band graphene antenna for 5G application.The 9- shaped graphene-film is used as radiation patch with microstrip fed line. This antenna satisfies the requirement of -10dB. reflection coefficients for the impedance bandwidth of LTE2500MHz and WiMAX3.5GHz bands. The simulated gain for lower and upper band is 1.85dB and 2.4dB respectively. The radiation efficiencies are 82% and 77% for lower and upper band respectively. The radiation efficiency is slightly less as compare to conventional copper material, which could be improved in graphene antenna at lower frequency region.

Chapter 2
Antenna Theory

Chapter 2

2. Antenna Theory

2.1 Definition of Antenna

An antenna is a device that provides a means for radiating or receiving radio waves. In other words, it provides a transition from guided waves on a transmission line to a "free space" wave. Thus information can be transferred between different locations without any intervening structure. Furthermore, antennas are required in situations where it is impossible, impractical or uneconomical to provide guiding structures between the transmitter and receiver.

Antennas are frequency dependent devices. Each antenna is designed for a certain frequency band. Beyond the operating band, the antenna rejects the signal. Therefore, we might look at the antenna as a band pass filter and a transducer. Antennas are essential parts in communication system.

Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the same frequency band of the radio system to which it is connected; otherwise the reception and the transmission will be impaired.

2.2 Antenna and its types

An antenna is a means of radiating and receiving the radio waves. It is a transition structure between the free space and the guiding device. So it can be said as a directional device that guides the device and can also probe for signals. In Figure 2.1 one can easily see the role of antenna in wireless communication

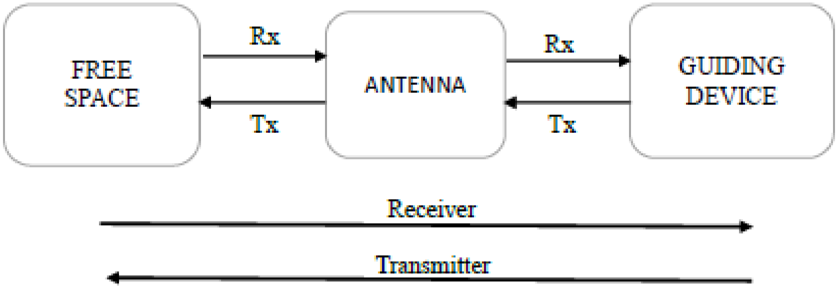


Figure 2.1 Basic block diagram depicting the role of antenna in transmission and reception

The equivalent circuit of an antenna is given in Figure 3 as one can see that there is an impedance (Zg) at the generator. The characteristic impedance of the transmission line (Zc) which does not depend on the length of the transmission line but depends upon the material used in the transmission line and the impedance matching. The impedance of the antenna (Za) is given by:

$$Za = (Rl + Rr) + j\,Xa$$

Where,

Rl is the conduction and dielectric loss

Rr is the radiation resistance

Xa is the radiation impedance

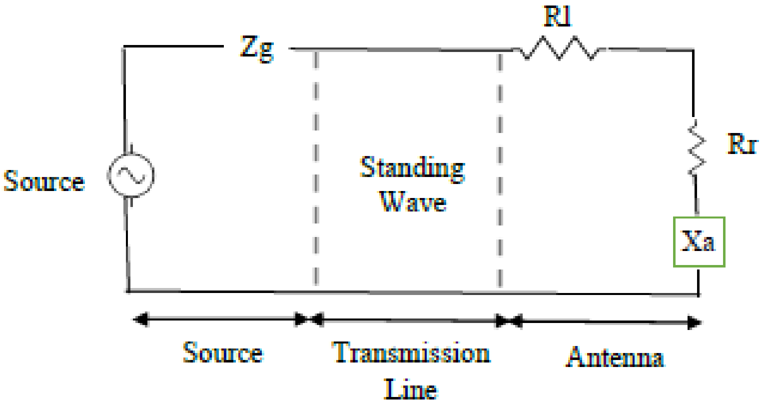


Figure 2.2 Equivalent Circuit Diagram of the antenna as a guiding device

There are several ways to classify the antennas. If we classify on basis of frequency band we can have narrowband, wideband and ultra-wideband antennas. The antennas can be considered to be classified on the basis of electromagnetic, physical or electrical structure. Directionality also defines the classification in antenna as they can be directional and non-directional in nature.

There can be different types of antenna. The following chart in Figure 4 depicts the different types of antenna and their combinations or derivatives. The main antenna and their types are mentioned herewith.

- **Conducting Wire:** They are mainly constituted of a single wire. These are further arranged in form of dipoles, loops and helices'.
- **Apertures:** They consist of a radiating aperture for higher directivity. These are further subdivided to waveguides and horns.

- **Patch (Microstrip):** These are the majorly used in embedded applications. They can be of various shapes like rectangular, circular etc.
- **Array of elements:** they consist of a group of smaller antennas excited at a fixed phase difference to generate high directivity.
- **Reflector**
- **Lens**

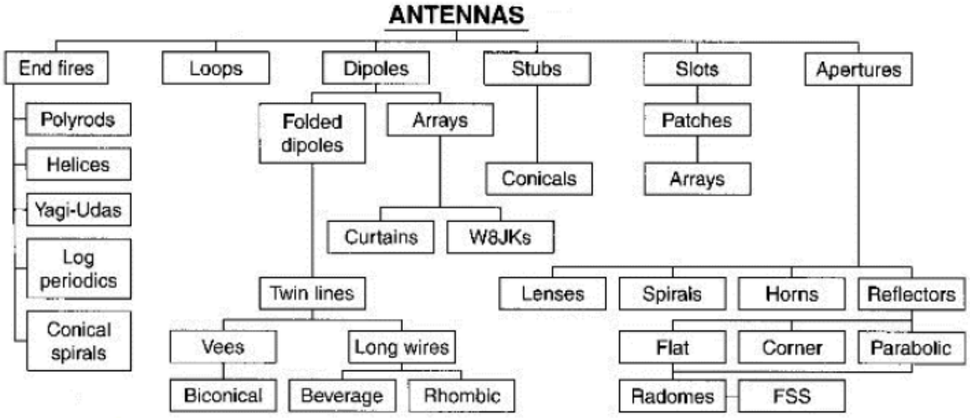


Figure 2.3 Classification of antenna on basis of physical structure

2.3 Microstrip Antenna

A microstrip patch antenna consists of a dielectric substrate sandwiched by a radiating patch on one side and the ground plane on the other side as shown in Figure 5. The radiating patch is made of a good conductor material such as annealed copper or gold. It can take any shape in the two dimensional plane and thus unlimited configurations are possible. The shapes can be anything ranging from triangular, circular, semi-circular and rectangular. The feed-lines and the radiating patch are usually photo-etched on the dielectric substrate. The dielectric substrate can be thick or thin, and must be chosen with permittivity between 2.2 to 12. The patch thickness should be much less than the operating wavelength of the antenna.

The radiation in microstrip patch antennas is due to the fringing fields between the edge of the patch and the ground plane. A thick substrate with a very low dielectric constant is suitable for good antenna performance since it provides a larger bandwidth, better efficiency and better radiation. But in such a scenario, the antenna size increases. Thus to reduce the size, substrate with high dielectric constants must be used which have narrow bandwidth and are less efficient. Hence a proper trade-off must be done at the designing stage to realize an improved performance of an antenna at a particular operating frequency and constrained physical dimensions. The figure below shows a standard rectangular microstrip patch antenna.

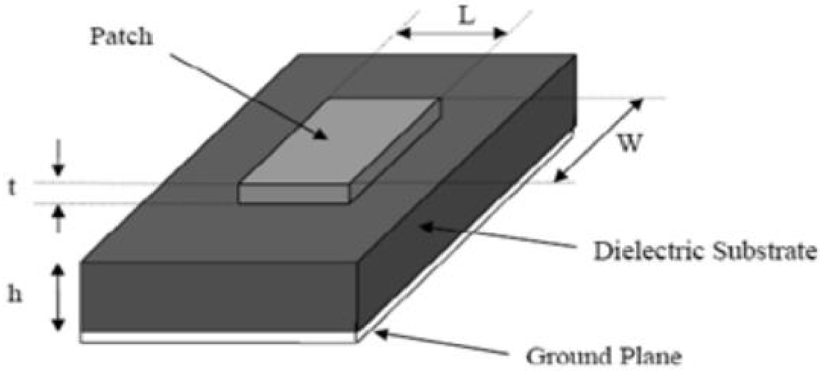


Figure 2.4 Rectangular Microstrip Patch Antenna

2.4 Categories of Waves on Microstrip

The method involving the transmission and radiation in a Microstrip can be understood considering a point current source (Hertz dipole) located on top of the grounded dielectric substrate. This source radiates electromagnetic waves depending on the direction where the waves are transmitted; they consist of two distinct categories with different behavior.

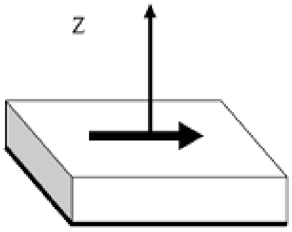


Figure 2.5 Hertz dipole on a substrate

2.4.1 Surface Waves

This involves the waves are transmitted slightly downward, having elevation angle ϴ between $\pi 2$ and $\pi - \arcsin\ (1/\sqrt{Er})$ meet the ground plate, which in turn reflects them, towards the dielectric-to-air boundary, which in turn reflects them (total reflection condition). The magnitude of the field amplitude increases for some particular incidence angles leading to an excitation of a discrete set of surface wave modes. This occurs to the rapid decay of the dielectric above the surface due to the field mostly trapped within it. The wave is a non-uniform plane wave.

The direction of largest attenuation (the vector α) pointing upwards; the wave propagates horizontally across β with little absorption in good dielectric. The surface waves take up some part of the signals energy, which does not reach the intended user. This leads to a reduction in the impedance, contributing to the decrease in the efficiency of the antenna.

Also, surface waves introduce spurious coupling between different circuit or antenna elements. This effect drastically reduces the performance of the Microstrip filters because the parasitic interaction reduces the isolation in the stop bands.

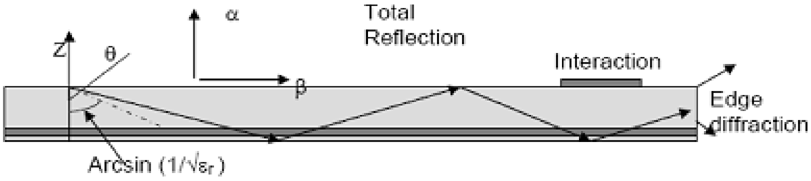


Figure 2.6 Surface Wave

2.4.2 Leaky Waves

The waves are directed sharply downwards, with angles ϴ between π – arcsin ($1/\sqrt{Er}$), which in turn is also reflected by a ground plane but only partially by the dielectric-to-air boundary. This leads to a leak from the substrate into the air, hence the name leaky waves.

The leaky wave are non-uniform plane where the attenuation direction α points downwards, leading to an increase in amplitude as the waves moves from the dielectric substrate because the wave radiates from a point where the amplitude of the signal is higher (figure 2.7). Leaky-wave antennas can be divided into two important categories, uniform and periodic, depending on the type of guiding structure.(Onofrio Losito and Vincenzo Dimiccoli, 1997) A uniform structure has a cross section that is uniform (constant) along the length of the structure, usually in the form of a waveguide that has been partially opened to allow radiation to occur.

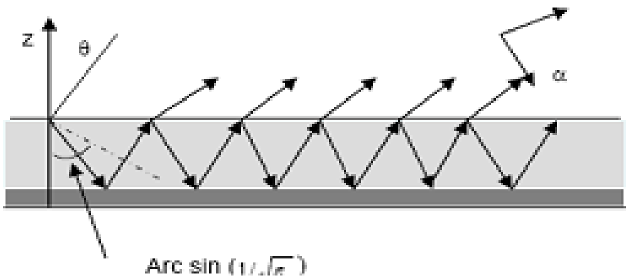


Figure 2.7 Leaky waves

2.4.3 Directional Antenna

Directional antennas are antennas used to radiate power in a focused and specific direction. These antennas are fixed in a specific location and directed towards the receiver (or transmitter). The ability of an antenna of focus in one direction more than other directions is the measure of the quality of the antenna and is often expressed in terms of Power Gain, front to back ratio and other factors of the antenna.

2.5 Important Parameters of Antenna

Antennas are made to efficiently radiate or receive the electromagnetic signals. There are various parameters which describe performance of the antenna. Some of the parameters are.

2.5.1 Radiation Pattern

When a signal is fed into an antenna, the antenna will emit radiation distributed in space in a certain way. A graphical representation of the relative distribution of the radiated power in space is called a radiation pattern.

An antenna radiation pattern or antenna pattern is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization.” The radiation property of most concern is the two-or three dimensional spatial distribution of radiated energy as a function of the observer’s position along a path or surface of constant radius. A convenient set of coordinates is shown in Figure 2.8.

For a linearly polarized antenna, its performance is often described in terms of its principle E-plane and H-plane patterns. The E-plane is defined as the plane containing the electric field vector and the direction of maximum radiation whilst the H-plane is defined as the plane containing the magnetic field vector and the direction of maximum radiation.

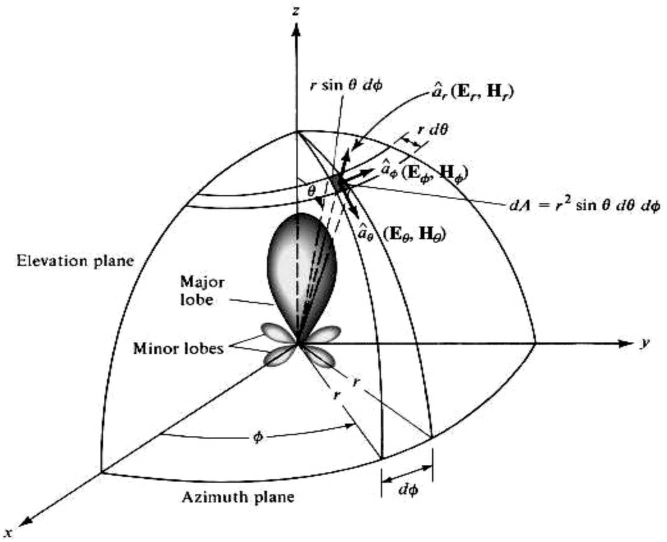


Figure 2.8 3-D view of radiation pattern

There are three common radiation patterns that are used to describe an antenna's radiation property:

(a) Isotropic - A hypothetical lossless antenna having equal radiation in all directions. It is only applicable for an ideal antenna and is often taken as a reference for expressing the directive properties of actual antennas.

(b) Directional - An antenna having the property of radiating or receiving electromagnetic waves more effectively in some directions than in others. This is usually applicable to an antenna where its maximum directivity is significantly greater than that of a half- wave dipole.

(c) Omni-directional - An antenna having an essentially non-directional pattern in a given plane and a directional pattern in any orthogonal plane.

2.5.2 Voltage Standing Wave Ratio (VSWR)

VSWR stands for Voltage Standing Wave Ratio and is also referred to as Standing Wave Ratio (SWR). It is the ratio of maximum voltage to minimum voltage in standing wave pattern. It varies from +1 to infinite. The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to. VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by , then the VSWR is defined as

$$VSWR = \frac{1+|r|}{1-|r|}$$

VSWR is always a real and positive number for antennas. Smaller the VSWR better the antenna matched to the transmission line and more power is delivered to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal.

Often antennas must satisfy a bandwidth requirement that is given in terms of VSWR. For instance, an antenna might claim to operate from 100-200 MHz with VSWR<3. This implies that the VSWR is less than 3.0 over the specified frequency range. This VSWR specifications also implies that the reflection coefficient is less than 0.5 (i.e., <0.5) over the quoted frequency range.

2.5.3 Physical Meaning of VSWR

VSWR is determined from the voltage measured along a transmission line leading to an antenna. VSWR is the ratio of the peak amplitude of a standing wave to the minimum amplitude of a standing wave, as seen in the following Figure 2.9:

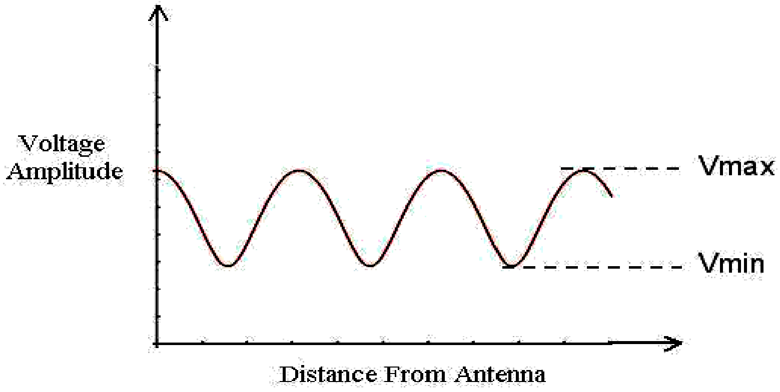


Figure 2.9 Voltage measured along a Transmission Line

When an antenna is not matched to the receiver power is reflected (so the reflection coefficient, r is not zero). This causes a "reflected voltage wave", which creates standing waves along the transmission line. The results are the peaks and valleys as seen in Figure 2.9. If the VSWR = 1.0, there would be no reflected power and the voltage would have a constant magnitude along the transmission line.

2.5.4 Antenna Gain

Gain of an antenna (in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π."

The definition of gain requires the concept of an isotropic radiator; that is, one that radiates the same power in all directions. An isotropic antenna, however, is just a concept, because all practical antennas must have some directional properties. Nevertheless, the isotropic antenna is very important as a reference. It has a gain of unity ($g = 1$ or $G = 0$ dB) in all directions, since all of the power delivered to it is radiated equally well in all directions. Although the isotopes are a fundamental reference for antenna gain, another commonly used reference is the dipole. In this case the gain of an ideal (lossless) half wavelength dipole is used. Its gain is 1.64 ($G = 2.15$ dB) relative to an isotropic radiator. The gain of an antenna is usually expressed in decibels (dB). When the gain is referenced to the isotropic radiator, the units are expressed as dBi; but when referenced to the half-wave dipole, the units are expressed as dB.

2.5.5 Bandwidth

The bandwidth of an antenna is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." The bandwidth can be considered to be the range of frequencies, on either side of a centre frequency, where the antenna characteristics (such as input impedance, pattern, beam width, polarization, side lobe level, gain, beam direction, radiation efficiency) are within an acceptable value of those at the centre frequency. For broadband antennas, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation. For example, a 10:1 bandwidth indicates that the upper frequency is 10 times greater than the lower. For narrowband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the centre frequency of the bandwidth. For example, a 5% bandwidth indicates that the frequency difference of acceptable operation is 5% of the centre frequency of the bandwidth.

Because the characteristics of an antenna do not necessarily vary in the same manner or are even critically affected by the frequency, there is no unique characterization of the bandwidth. The specifications are set in each case to meet the needs of the particular application Usually there is a distinction made between pattern and input impedance variations. Accordingly, pattern bandwidth and impedance bandwidth are used to emphasize this distinction. Associated with pattern bandwidth are gain, side lobe level, beam width, polarization, and beam direction while input impedance and radiation efficiency are related to impedance bandwidth.

2.5.6 Directivity

Directivity of an antenna is defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied".

The directivity of a non isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source.

The directive gain of an antenna is a measure of the concentration of the radiated power in a particular direction. It may be regarded as the ability of the antenna to direct radiated power in a given direction. It is usually a ratio of radiation intensity in a given direction to the average radiation intensity.

Antenna gain is defined as antenna directivity times a factor representing the radiation efficiency i.e.

$$G = \eta \times D$$

where,

G- Antenna Gain

η - Factor representing the radiation efficiency

D- Directivity

Directivity is the same as gain, but with one difference. It does not include the effects of power lost (inefficiency) in the antenna. If an antenna is lossless (100 % efficient), then the gain and directivity (in a given direction) would be the same.

2.5.7 Return loss

It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. In other words, it is the difference, in dB, between forward and reflected power measured at any given point in an RF system and, like SWR, does not vary with the power level at which it is measured. In other words, the amount of power which is reflected back to the source from an incorrectly terminated line is an important property called "Return Loss" and measurement of return loss can reveal line faults due to mismatching.

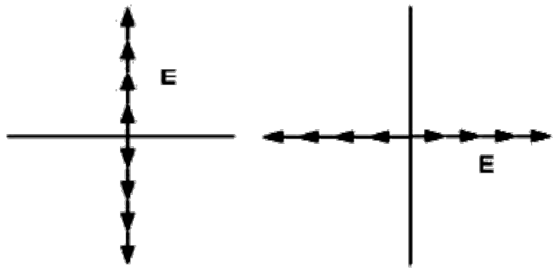
Return loss is a measure of the reflected energy from a transmitted signal. Larger the value of return loss less is the energy that is reflected. The relationship between SWR and return loss is the following: While some energy will always be reflected back into the system, a high return loss will yield unacceptable antenna performance. For good impedance matching resonant frequency must lie below -10 dB.

VSWR	Return Loss (dB)	Trans. Loss (dB)	Volt Refl Coefficient	Power Trans (%)	Power Refl (%)
1.00	-	.000	.00	100.0	.0
1.05	32.3	.003	.02	99.9	.1
1.10	26.4	.010	.05	99.8	.2
1.15	23.1	.021	.07	99.5	.5
1.20	20.8	.036	.09	99.2	.8
1.25	19.1	.054	.11	98.8	1.2
1.30	17.7	.075	.13	98.3	1.7
1.35	16.3	.093	.15	97.9	2.1
1.40	15.8	.122	.17	97.2	2.8
1.50	14.0	.117	.20	96.0	4.0

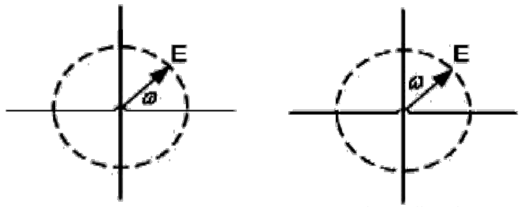
Table 2.1 Comparison of VSWR, Return loss and Transmission loss Voltage Reflection Coefficient Power Transmission Power reflection

2.5.8 Polarization

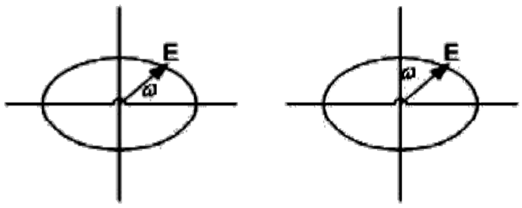
Antenna polarization indicates the orientation of radiated wave of the antenna in far-field region as shown in Figure 2.10. An antenna will generate an el electromagnetic wave that varies in time as it travels through space. If a wave traveling "outward" varies "up and down" in time with the electric field always in one plane, that wave (or antenna) is said to be linearly polarized (vertically polarized since the variation is up and down rather than side to side). If that wave rotates or "spins" in time as it travels through space, the wave (or antenna) is said to be elliptically polarized. As a special case, if that wave spins out in a circular path, the wave (or antenna) is circularly polarized. This implies that certain antennas are sensitive to particular types of electromagnetic waves. The practical implication of this concept is that antennas with the same polarization provide the best transmission/reception path.



(a) Vertical linear polarization (b) Horizontal linear polarization



(c) Left hand circular polarization (d) Right hand circular polarization



(e) Left hand elliptical polarization (f) Right hand elliptical polarization

Figure 2.10 Some wave polarization states where the wave is approaching

Note that the polarization of an antenna doesn't always imply anything about the size or shape of the antenna. Antennas that are circular in their construction do not have to be circularly polarized. Many circular patches are linearly polarized and many rectangular patches are circularly polarized.

2.5.9 Input impedance

There are three different kinds of impedance relevant to antennas. One is the terminal impedance of the antenna, another is the characteristic impedance of a transmission line and the third is wave impedance. Terminal impedance is defined as the ratio of voltage to current at the connections of the antenna (the point where the transmission line is connected). The complex form of Ohm's law defines impedance as the ratio of voltage across a device to the current flowing through it. The most efficient coupling of energy between an antenna and its transmission line occurs when the characteristic impedance of the transmission line and the terminal impedance of the antenna are the same and have no reactive component. When this is the case, the antenna is considered to be matched to the line. Matching usually requires that the antenna be designed so that it has a terminal impedance of about 50 ohms or 75 ohms to match the common values of available coaxial cable.

Chapter 3

Microstrip Antenna

Chapter 3

3. Microstrip Antenna

3.1 Introduction

The Microstrip Patch Antenna consist of a single-layer design which includes four parts (Patch, ground plane, substrate, and the feeding part). These antennas are integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. Patch antennas are classified as single – element resonant antennas. Once the frequency is obtained, everything (such as radiation pattern input impedance, etc.) remains constant. The patch is a very slim ($t<<\lambda_0$, where λ_0 = the wavelength of free space), radiating metal strip (or array of strips) located on one side of a thin no conducting substrate, the ground plane is the same metal located on the other side of the substrate.

The patch is usually made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

The substrate layer thickness is 0.01–0.05 of free-space wavelength ($\lambda 0$). This is used primarily to provide proper spacing and mechanical support between the patch and its ground plane. It is also often used with high dielectric-constant material to load the patch and reduce its size.

The advantages of the Microstrip antennas includes:

i. They are compatible for embedded antennas in handheld wireless devices such as cellular

phones, pagers etc.

ii. Low profile planar configuration which can be easily made conformal to host surface.

iii. Can be easily integrated with microwave integrated circuits (MICs).

iv. Capable of dual and triple frequency operations.

v. Low fabrication cost, hence can be manufactured in large quantities.

vi. Mechanically robust when mounted on rigid surfaces

Microstrip antenna some disadvantages

i. Low efficiency.
ii. Narrow bandwidth of less than 5%
iii. Low RF power due to the small separation between the radiation patch and the ground plane (not suitable for high-power applications)

Microstrip patch antennas consist of a very high antenna quality factor (Q). It shows the losses associated with the antenna where a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave.

3.2 Types of Patch Antenna

There are numerous shapes of Microstrip patch antennas; they have been designed to match specific characteristics.

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure 3.1. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\lambda_0$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda_0$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda 0 \leq h \leq 0.05\lambda_0$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

Microstrip patch antennas radiate mainly due to the fringing fields between the patch edge and the ground plane. The selecting of a substrate is very important, considerations are made depending on the temperature, humanity, and other environmental ranges of operating. The Thickness of the substrate h has a big effect on the resonant frequency fr and bandwidth BW of the antenna. The bandwidth of the Microstrip antenna will increase with an increase in substrate thickness h but with limits, otherwise the antenna will stop resonating.

The most common types of patches are shown below:

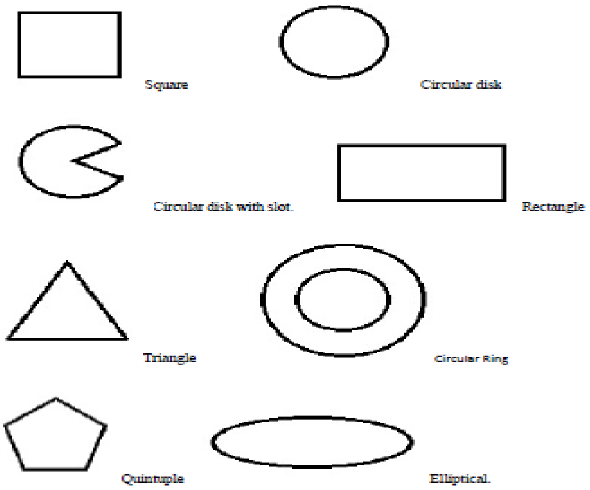


Figure 3.1 Common Type of Microstrip Antenna

3.3 Remedy

Microstrip patch antennas have a very high antenna quality factor (Q). It represents the losses associated with the antenna where a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics.

Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

Though as an element, these antennas radiate only in one half planes but, when used as an array, the array factor comes into play. By carefully designing an array, it is possible to quantify the impact of coupling between the elements and give greater isolation between array elements.

The excitation of surface waves can be minimized by using a new technique which employs "High Impedance Ground Plane" called a Photonic band gap substrate. Other problems, such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

3.4 Types of microstrip antennas

There are different types of microstrip antennas which are classified based on their physical parameters. The different types of antennas have many different shapes and dimensions. The basic categories of these Microstrip antennas can be classified in to four, which are:

Microstrip patch antennas
Microstrip dipoles
Printed slot antennas
Microstrip travelling wave antenna

3.4.1 Microstrip Patch Antennas

A Microstrip patch antenna is a thin square patch on one side of a dielectric substrate and the other side having a plane to the ground. The simplest microstrip patch antenna configuration would be the rectangular patch antenna shown in Figure 3.2.

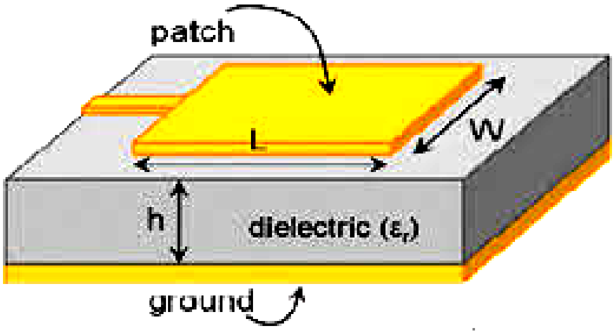


Figure 3.2 Microstrip patch antenna

The patch in the antenna is made of a conducting material Cu (Copper) or Au (Gold) and this can be in any shape. The basic antenna element is a strip conductor of length L and width W on a dielectric substrate with constant ϵr; thickness or height of the patch being *h* with a height and thickness t is supported by a ground plane. The rectangular patch antenna is designed so as it can operate at the resonance frequency. The length that is for the patch does depend on the height, width of the patch and the dielectric substrate.

3.4.2 Microstrip or Printed Dipole Antennas

The Microstrip or Printed Dipole Antennas differ from the Microstrip Patch antennas in their geometric shape. The length of this printed dipole antenna is less than 0.05λ. Bandwidth, radiation resistance and the cross polar radiation differs widely when compared to the patch antennas.

These Microstrip dipole antennas are very attractive when it is seen on the cases of the size and linear polarization. The feed mechanism is very important here in these types of antennas and should be taken care of. These types of antennas can be operated at high frequencies as the substrate is electrically thick which leads to the desired band width.

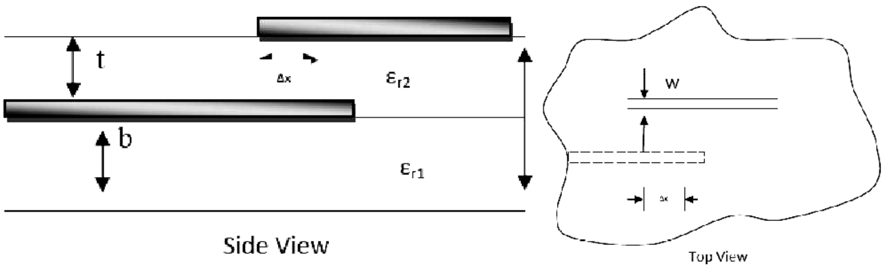


Figure 3.3 Configuration of a Microstrip and printed dipoles, proximity-coupled strip dipole

The Figure 3.4 above shows the printed dipole antenna, which are said to be very attractive on their size and linear polarization. The Figure 15 below is the folded dipole combined with another related dipole give way to the symmetrical structure. And this particular construction can be used or is considered to be the rectangular patch with an H shaped slot

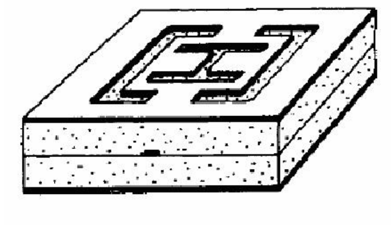


Figure 3.4 Symmetrical folded printed dipoles

3.4.3 Printed Slot Antennas

The printed slot antennas are those which have the slot in the ground plane of a grounded substrate, these slot antennas are bi-directional radiators; it means that they radiate both sides of the slot. There is no specific shape for the slot here, it can have any shape. Most of the Microstrip patch shapes are in the form of printed slots. This can be used for the unidirectional radiation as well by placing a reflector on the other side of the slot. Just like the microstrip patch antennas these slot antennas can be fed by a microstrip line.

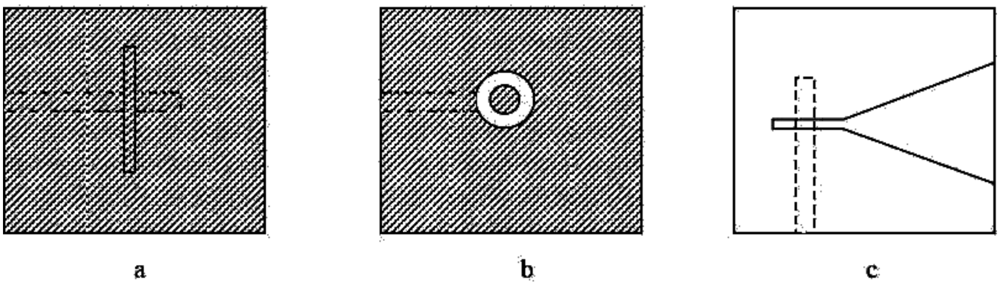


Figure 3.5 a) Rectangular slot with Microstrip feed (b) Annular slot with Microstrip feed (c) Tapered slot

3.4.4 Microstrip travelling wave antennas

These Microstrip travelling wave antennas are designed having a long microstrip line with enough width to support the TE. These antennas are designed so that the main beam lying in any direction from broadside to end fire. The other end of the microwave is ended in a matched resistive load in order to avoid the standing waves of the antenna. The use of these antennas like rampart line antenna, chain antenna, square loop antenna are in circular polarization.

Table 3.1 gives comparison of the characteristics of the microstrip patch antennas, microstrip slot antennas and printed dipole antennas.

Characteristics	Microstrip Patch Antenna	Microstrip Slot Antenna	Printed Slit Antenna
Profile	Thin	Thin	Thin
Fabrication	Very easy	easy	Easy
Polarization	Both Linear and Circular	Both Linear and Circular	Linear
Dual-Frequency Operation	Possible	Possible	Possible
Shape Flexibity	Any Shape	Mostly rectangular and circular shape	Rectangular and Triangular
Spurious radiation	Exist	Exist	Exist
Bandwidth	2-50%	5-30%	30%

Table 3.1 Characteristics of Microstrip Patch Antennas Feeding techniques

Feeding techniques are important in designing the antenna to make antenna structure so that it can operate at full power of transmission. Designing the feeding techniques for high frequency, need more difficult process. This is because the input loss of feeding increases depending on frequency and finally give huge effect on overall design. There are a few techniques that can be used.

1. Microstrip Line feeding
2. Coaxial Probe feeding
3. Aperture Coupled feeding
4. Proximity Coupled feeding

3.4.5 Microstrip Line feeding

It has more substrate thickness i.e. directly proportional to the surface wave. Radiation bandwidth limit is 2-5%. It is easy to fabricate and model. Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.

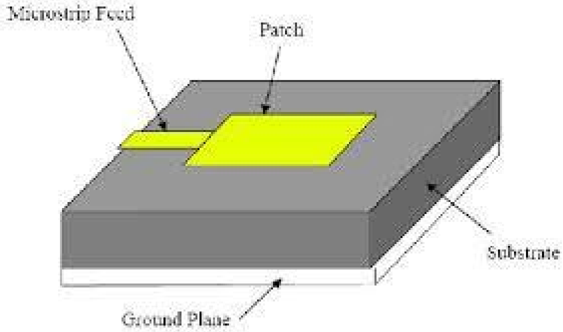


Figure 3.6 Microstrip Patch Antenna

Advantages:

Since the feed line and radiating elements are in same surface of substrate. Hence this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. Impedance matching techniques are also simpler in comparison to other methods.

Disadvantages:

As the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, this hampers bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

3.4.6 Coaxial Probe Feeding

It has low spurious radiation and narrow bandwidth. Coaxial feeding is feeding method in which that the inner conductor of the coaxial is attached to the radiation patch of the antenna while the outer conductor is connected to the ground plane difficult to model.

Advantages

1) Easy to fabricate

2) Easy to match

3) Has low spurious radiation

Disadvantages

1) Has narrow bandwidth

2) It is difficult to model specially for thick substrate

3) It is easy to fabricate but it possesses inherent asymmetries which generate higher order modes which produce cross-polarization radiation.

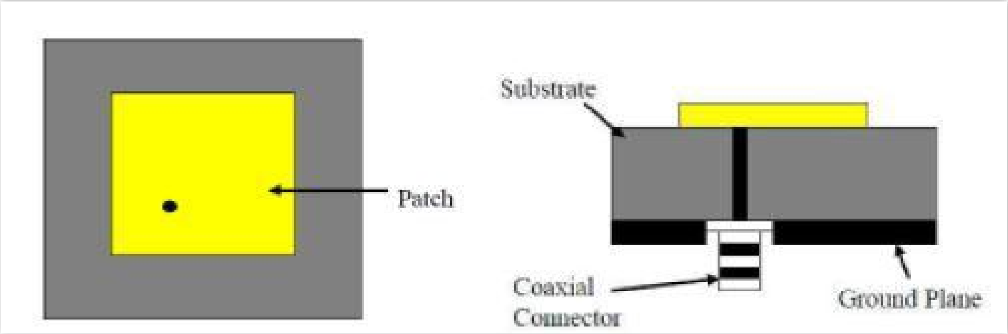


Figure 3.7 Coaxial Probe feeding

3.4.7 Aperture Coupled Feeding

This technique involves the use of the aperture mechanism, where the radiating patch and the Microstrip feed line are separated by the ground plane.

The ground plane consists of an aperture usually centered under the patch, in the shape of a circle or rectangular, and separates two substrates: the upper substrate $\varepsilon r1$ with the patch on it, and the lower substrate $\varepsilon r2$ with the Microstrip feed line under it, spurious radiation is minimized.

This involves the use of a high dielectric material as the bottom substrate and a thick, low dielectric constant material is used as the top substrate to optimize radiation from the patch. This type of coupling gives wider bandwidth.

Advantages:

It is difficult to fabricate due to multiple layers, which leads to an increase in the antenna thickness.

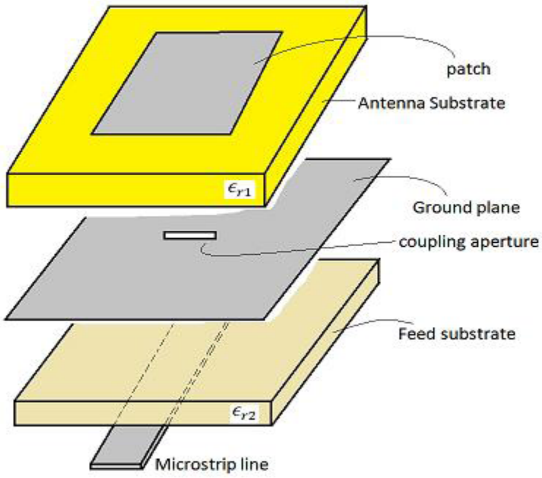


Figure 3.8 Aperture coupling feed Technique

3.4.8 Proximity Coupling

This type of feed technique is known as the electromagnetic coupling scheme. This involves the use of two substrate $\varepsilon r1$and $\varepsilon r2$ consisting of the patch at the top, and the ground plane in the bottom. A Microstrip line is connected to the power source and lying between the two substrates.

The principle involves the capacitive behavior between the patch and the feed strip line. Analysis and design of such an antenna is complicated than the other ones discussed in the previous sections because it takes into account the effect of the coupling capacitor between the strip feed line and the patch as well as the equivalent

R-L-C resonant circuit representing the patch and the calculating of two substrates ($\varepsilon r1$ and $\varepsilon r2$).

Advantage:

1) It has largest band width.
2) It is easy to mode
3) It has low spurious radiation and is difficult to fabricate.

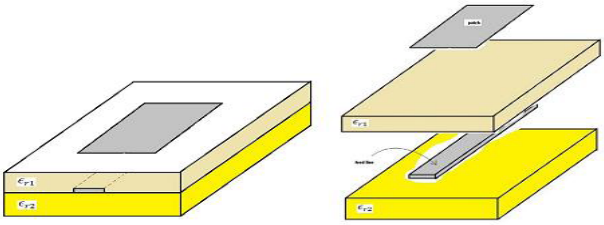


Figure 3.9 Proximity Coupling feed Technique

Feed Type Property	Microstrip line feed	Coaxial Feed	Aperture coupling feed	Proximity Coupling feed
Spurious feed radiation	More	More	Less	Minimum
Polarization purity	Poor	Poor	Excellent	Poor
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	2-5%	13%

Table 3.2 Comparison amongst Various Feeding Methods

3.5 Substrate material

The relative permittivity, ε_r of dielectric substrate is in the range 2 to 10, but variety of material can be used depend on the application. Air or low density foam offers the lower lost and higher radiation efficiency, but higher permittivity substrates results in smaller element and broader radiation pattern. Therefore, a good performance antenna has to be thicker substrate with lower dielectric constant but, affects larger in antenna size. In order to design a compact microstrip antenna, higher dielectric constant must be used results in lower efficiency. Table 3.4 shows relative permittivity values of some materials. There are some important parameters of dielectric substrate in order to design the microstrip transmission line or any others antennas, which are:

Dielectric constant
Dielectric Cost
Loss tangent
The thickness of the copper

.

Material	ε_r
RT 5870	2.32
RT 5880	2.2
RT 6006	6.15
RT 6010	10.2
FR-4	4.4
Roger-3002	3
Roger-3006	6.15

Table 3.4 Relative Permittivity values

3.6 FR4 substrate

FR-4 (or **FR4**) is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing).FR-4 glass epoxy is a popular and versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. These attributes, along with good fabrication characteristics, lend utility to this grade for a wide variety of electrical and mechanical applications.

NEMA is the regulating authority for FR-4 and other insulating laminate grades.

Grade designations for glass epoxy laminates are: G10, G11, FR4 and FR5. Of these, FR4 is the grade most widely in use today. G-10, the predecessor to FR-4, lacks FR-4's self-extinguishing flammability characteristics. FR-4 epoxy resin systems typically employ bromine, a halogen, to facilitate flame-resistant properties in FR-4 glass epoxy laminates. Some applications where thermal destruction of the material is a desirable trait will still use G-10 *non flame resistant*. FR-4 materials are being used in numerous PCB applications. They are well proven, relatively low cost and their performance is well understood.

FR-4 is the primary insulating backbone upon which the vast majority of rigid printed circuit boards are produced. A thin layer of copper foil is laminated to one or both sides of an FR-4 glass epoxy panel. These are commonly referred to as "copper clad laminates."FR-4 copper-clad sheets are fabricated with circuitry etched into copper layers to produce printed circuit boards. More sophisticated and complex FR-4 printed circuit boards are produced in multiple layers, aka "multilayer circuitry".FR-4 is also used in the construction of relays, switches, standoffs, bus bars, washers, arc shields, transformers and screw terminal strips.

3.7 Method of Analysis

There are many methods of Microstrip antenna analysis; the preferred models for the analysis of Microstrip patch antennas are the transmission line model and the cavity model.

The transmission line model involves where we assume that the patch is a transmission line or part of a transmission line. The transmission line model is very simple to study but it is less accurate.

The cavity model is accurate and provides good physical insight but is complex in nature, it involves the assumption that the patch is a dielectric-loaded cavity.

3.7.1 Transmission Line Model:

The transmission line method is an easy way of studying the Microstrip antenna. This involves the representation of the Microstrip antenna using two slots of width W and height h, separated by a low-impedance transmission line of length L. The Microstrip is a non-homogeneous line of two dielectrics, typically the substrate and air.

The study of the Microstrip line involves a wider transmission line ($w/h >> 1$ and $\varepsilon r > 1$) using the figure (3.10) below to build a good picture of the study of the antenna.

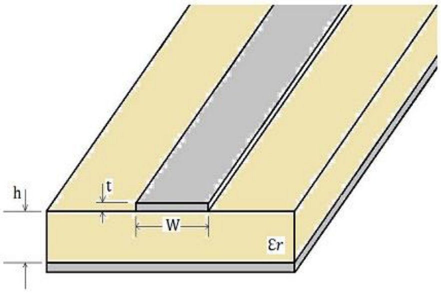


Figure 3.10 Microstrip Line

The approximation occurs initially to assume the thickness of the conductor t that forms the line has no effect on our calculations, because it is very thin comparing with the substrate h, (h >> t); therefore empirical formulas are used depending only on the line dimensions: The width W, the length L, the height h, and the dielectric constant εr of the substrate.

The impedance of the Microstrip is determined using:

$$z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}\left(1.393+\frac{w}{h}+\frac{3}{2}\ln\left(\frac{w}{h}+1.444\right)\right)}}$$

The width of the Microstrip line is derived using the equation below:

$$W = \frac{1}{2F_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

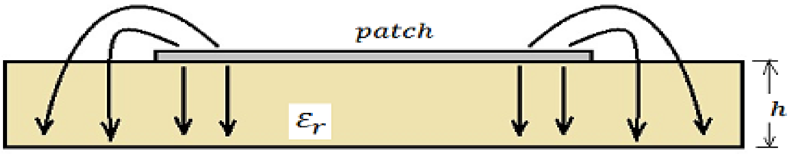


Figure 3.11 Electric field lines

From Figure 22, it is seen that 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-electric-magnetic (TEM) mode of transmission, since there is different phase velocities in air and the substrate. Therefore, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant ($\varepsilon reff$) must be obtained in order to account for the fringing and the wave propagation in the line, leading to the value of $\varepsilon reff$ 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 Effective dielectric constant($\varepsilon reff$) is given by Balanis as:

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

Where

$\varepsilon reff$= Effective dielectric constant.

εr = Dielectric constant of substrate.

h = Height of the dielectric substrate.

w = Width of the patch.

The Microstrip patch antenna in figure (3.9 and 3.10) is longer than its physical dimensions because of the effect of fringing. The effective length is therefore different from the physical length by ΔL. The fringing fields along the width is modelled as the radiating slots.

The extension of the length of patch is determined using the equation by Hammerstad as:

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

This extension of length ΔL expresses it as a function of the ratio Wh and εre .

To calculate the effective length of the patch $Leff$:

$$Leff = L + 2\Delta L$$

For a given resonance frequency $f0$, the effective length given as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

For effective radiation, the width W is given by Bahl and Bhartia as:

$$w = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

3.7.2 Cavity method:

The cavity model used in analyzing the Microstrip antennas is based on the assumption that the region between the Microstrip patch and ground plane has a resonance cavity bounded by ceiling and floor of electric conductors and magnetic walls along the edge of the conductor.

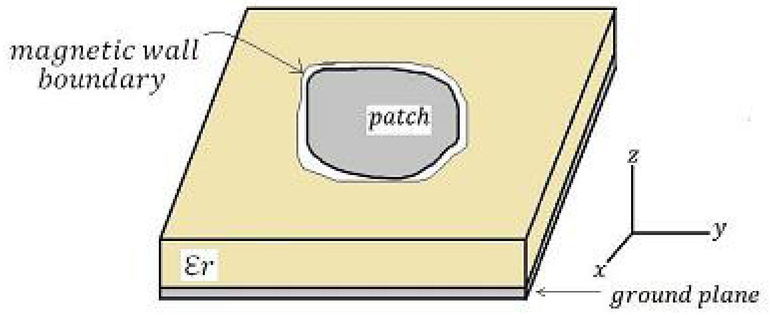


Figure 3.12 Magnetic wall model of a Microstrip antenna

Although the transmission line model discussed in the previous section is easier to use, it consist of some inherent disadvantages especially when used in rectangular patches, it ignores field variations along the radiating edges. These disadvantages can be overcome by using the cavity model.

The assumption of the cavity method is based on the following observations for thin substrates (h<< λ):

- The region enclosed by the cavity consist of only three field components: E component in the z axis (Ez) and two components of ⁏ along the x and y axis (,).
- Since the h (height of the substrate) is very thin (h << λ), the fields in the interior region do not vary much with z-coordinates for all frequencies i.e. normal to patch.
- The electric current in the Microstrip patch has no component normal to the edge of the patch at any point.

This model is good for the study of Microstrip resonators with the edge extending slightly to account for the fringing field.

This is used to study the mechanism of the cavity. This involves the process where the Microstrip patch is provided power when connected to a microwave source, charge distribution is created and seen on the upper and lower planes (surface of the patch and the bottom of the ground plane) of the antenna. The charge distribution is controlled by two mechanism; an attractive and repulsive mechanism.

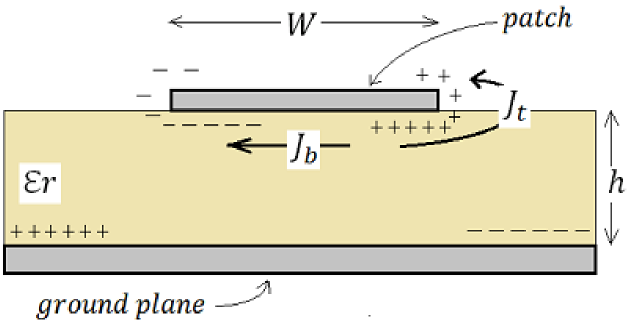


Figure 3.13 Charge distribution and current density creation on the Microstrip patch

The attractive mechanism consist of a force between the opposite charges on the patch and on the ground plane, it creates a current density inside the dielectric Jb at the bottom of the patch, which helps in keeping the charge concentration intact at the bottom of the patch.

The repulsive mechanism is between the like charges on the bottom surface of the patch, which tend to push the charges from the bottom of the patch around the edge of the patch to the top of the patch, this will create the current density JT. As a result of this charge movement, currents flow at the top and bottom surface of the patch.

3.8 Applications of microstrip patch antenna

Several versions of microstrip patch were developed depending on designer, all with different capabilities and specific performance. The various applications of microstrip patch antenna are,

- Satellite communication, direct broadcast services
- Mobile communication, handsets and base stations
- Biomedical radiators
- Global Positioning System Application
- Doppler and other radars Missiles and telemetry Commercial aircraft
- Remote sensing and environmental instrumentations Satellite navigation receiver
- Integrated antennas
- Feed elements in complex antennas etc.

Chapter 4

Microstrip Patch Antenna Design and Analysis

Chapter 5

4. Microstrip Patch Antenna: Design and Analysis

4.1 Introduction

This chapter presents the procedure for designing multiband microstrip antenna. Equations pertaining to rectangular antenna design are also presented in this chapter. The frequency of operation is taken as 5.3 GHz. The design of the antenna has been undertaken in four major steps. In the first two phases the rectangular microstrip antenna is designed and simulated using ADS software to verify the design parameters. The best result obtained from the second step is used such that multiband patch geometry could be incorporated into the design. The final phase involved the characteristics investigation of designed multiband rectangular microstrip antenna.

4.2 General design steps for Rectangular Microstrip Antenna

The basic design procedure for rectangular microstrip antenna is illustrated in the following flowchart,

Step 1 Choose the desired resonant frequencies

↓

Step 2 Choose appropriate substrate height and dielectric constant

↓

Step 3 Decide the size of patch and ground

↓

Step 4 Choose proper feed point location

↓

Step 5 Simulate the design using ADS software

↓

Step 6 Measure the best results of designed antenna

4.3 Design Method

The simplified formulation discussed in the previous sections above involves the procedure for designing a rectangular Microstrip antenna.

This procedure involves the specification of the substrate that will be used, the resonant frequency and the thickness of the substrate. Once these parameters are derived the width and the length of the patch is determined using the relationship. The design of the rectangular patch antenna, these essential are required:

i) Frequency of operation (fo) : This is also known as the Resonant Frequency; it is essential to select an appropriate resonant frequency of the antenna. Communication systems make use of frequency ranging from 1800 – 5600 MHz, therefore the antenna must be designed to operate in this frequency range. The frequency selected for our design is for 5G applications. Therefore, the resonant frequency employed for this work is 5.3 GHz.

ii) Dielectric constant of the substrate (ε_r) : This is referred to as the Effective Permittivity of the substrate. The dielectric material used for my design is FR4 epoxy Polycarbonate consisting of a dielectric constant of 4.4.

iii) Height of the Dielectric Substrate (h) : The height of the dielectric substrate for this design is selected as 1.5mm as it is the standard height of the FR4 epoxy substrate.

4.4 Antenna Design Template

The design of a rectangular patch antenna was developed using essential equations required to perform this process

Step 1: Calculation of the width (W):

The width of the microstrip patch antenna is given as:

$$w = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

c = Speed of light

$f0$ = Resonant frequency

εr = Effective permittivity

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

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

Where

$\varepsilon reff$= Effective dielectric constant

εr = Dielectric constant of substrate

h = Height of the dielectric substrate.

W = Width of the patch

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

The effective length is given as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \text{ ……………………………………(3)}$$

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

The length extension is:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{w}{h}+0.8\right)} \text{ ……………...(4)}$$

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

The actual length is obtained by:

$$L = L_{eff} - 2\Delta L \text{ ……………………………………(5)}$$

Step 6: Calculation of the ground plane dimensions (L_g and W_g):

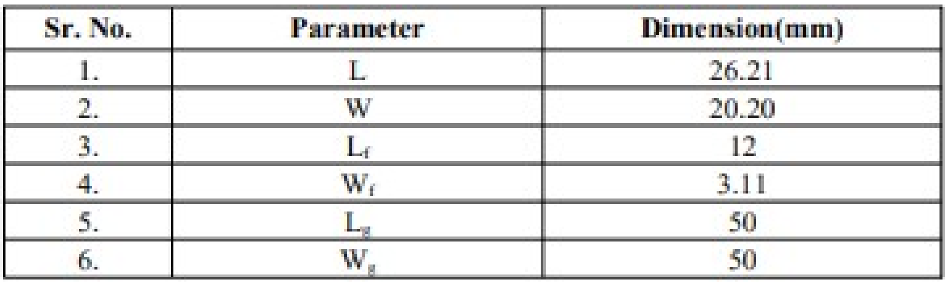
For the design, the ground plane dimensions would be given as:

$$\begin{aligned} L_g &= 6h + l \\ W_g &= 6h + w \end{aligned} \text{ ……………………………………...(6)}$$

Step 7: Determination of strip line feeding:

Strip line fed type feeding technique is used in this design. The feeding point must be located at that point on the patch where the input impedance is 50 ohms for the resonant frequency.

4.5 Obtained parameters after calculations:



Sr. No.	Parameter	Dimension(mm)
1.	L	26.21
2.	W	20.20
3.	L_f	12
4.	W_f	3.11
5.	L_g	50
6.	W_g	50

Table 4.1 Parameters and dimensions

3.8.1 ADS

ADS (Advanced Design System) from Keysight is an electronic design automation software for RF, microwave, and high speed digital applications. It uses some of the most innovative and commercially successful technologies, including Harmonic Balance, Circuit Envelope, Transient Convolution, Keysight Ptolemy, X-parameter, Momentum and 3D EM simulators (including both FEM and FDTD solvers).

ADS provides full, standards-based design and verification with Wireless Libraries and circuit-system-EM co-simulation in an integrated platform for WiMAX, LTE, multi-gigabit per second data links, radar, & satellite applications. ADS combines schematic, layout, circuit, electro-thermal co-simulation and three full-wave 3D EM technologies for IC, package, laminate/PCB and 3D EM component co-design in a single-vendor, integrated platform solution

4.6 Proposed design:

A 1.6 mm FR4 epoxy substrate is chosen. The microstrip patch antenna, is simulated using ADS software for the desired operating frequency of 5G frequency of 5.3 Ghz

Chapter 5

Fabrication and Testing

Chapter 5

5. Fabrication and Testing

5.1 Antenna fabrication

In this topic whole fabrication procedure of the microstrip patch antenna using stripline feeding technique is covered. The fabrication of antenna is done in few steps which are as follows,

Step1: Selection of components

For fabrication of the antenna substrate and SMA connector is selected. After selection of substrate, cut the substrate of the required dimensions.

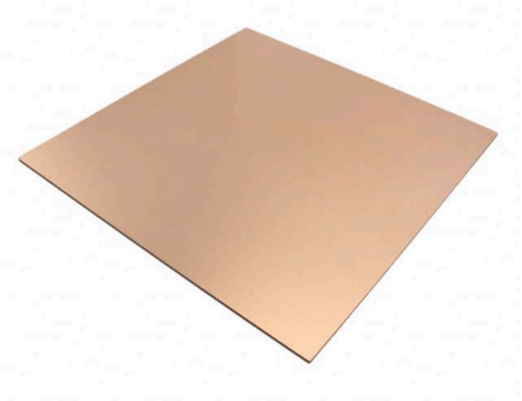


Figure 5.1 FR4 sheet

Step2: Layout drawing on the substrate

After cutting, draw the layout on the substrate, with proper dimension.

Step3: Etching and soldering

Etching of antenna is important process in design of antenna, there are many method of etching of antenna but here we used by using iron chloride anhydrous. After making the layout put the PCB into etching solution. Take it out and wash it. Etching of the substrate is done for getting the required geometry. Then SMA connector is soldered on the substrate. Now final design is ready.

Figure 5.2 Etching Tray

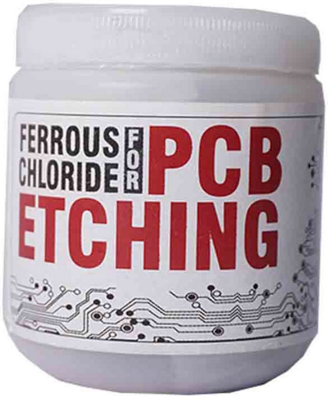


Figure 5.3 Etching powder(Iron chloride anhydrous)

(a) **(b)**

Figure 5.43 Final Design of antenna a) Front view, b) Back View

5.2 Antenna testing

Testing of the antennas is done by using R&S®ZVL Vector Network Analyzer in RF and Microwave lab. The R&S®ZVLVNA is a powerful and portable network analyzer in the compact class. It is the instrument to combine the functions of a network analyzer, spectrum analyzer and power meter in a single box.

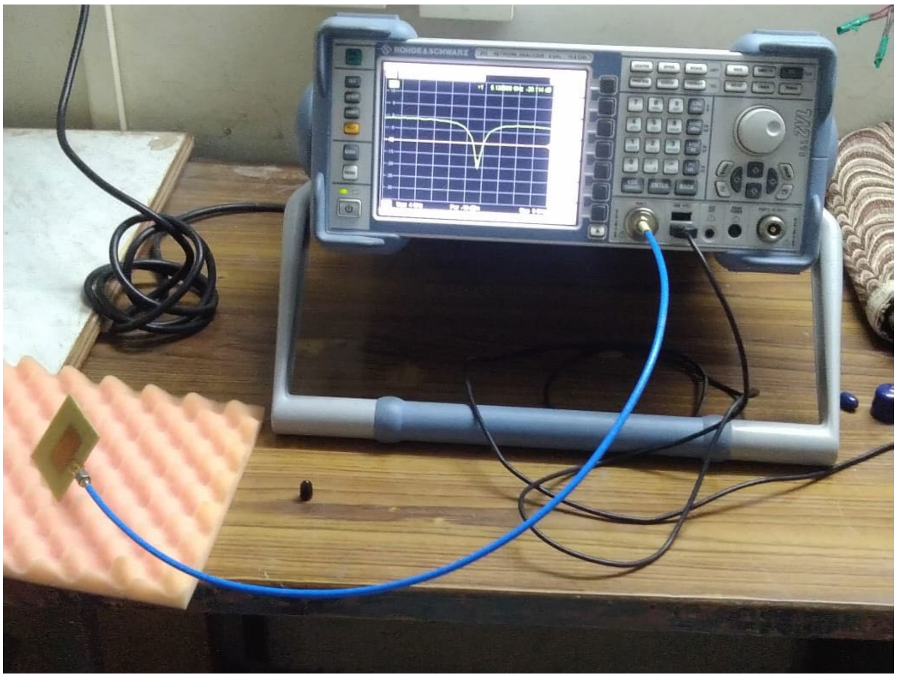


Figure 5.5 Testing antenna using R&S®ZVL Vector Network Analyzer

Figure 5.6 R&S®ZVL Vector Network Analyzer

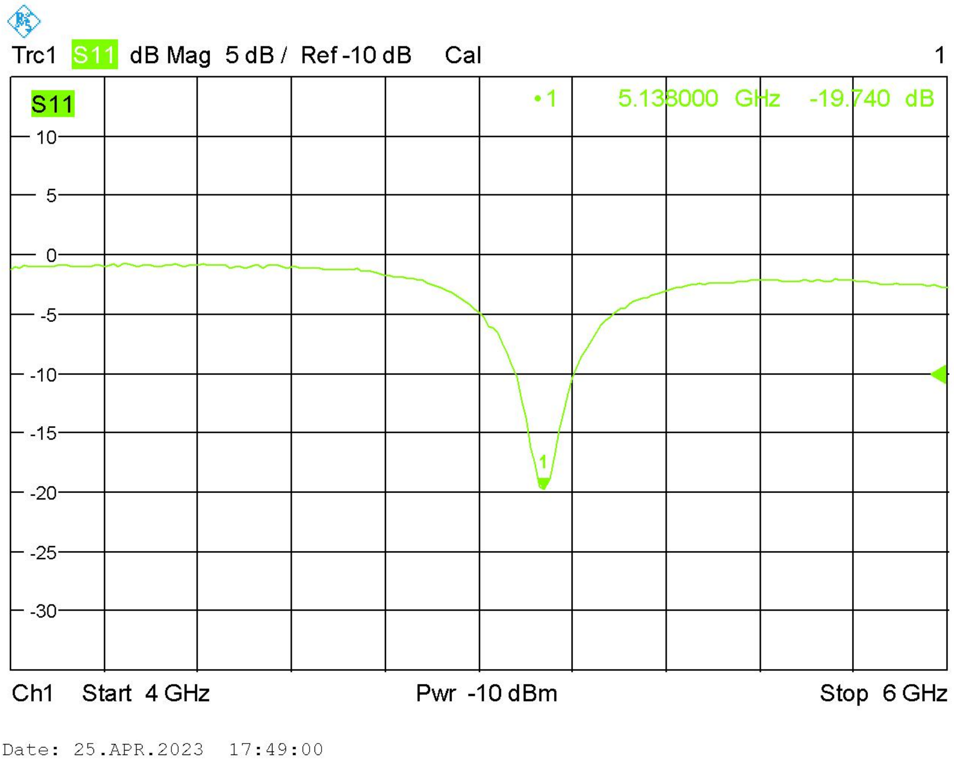


Figure 5.7 Tested Results of Proposed Antenna Design

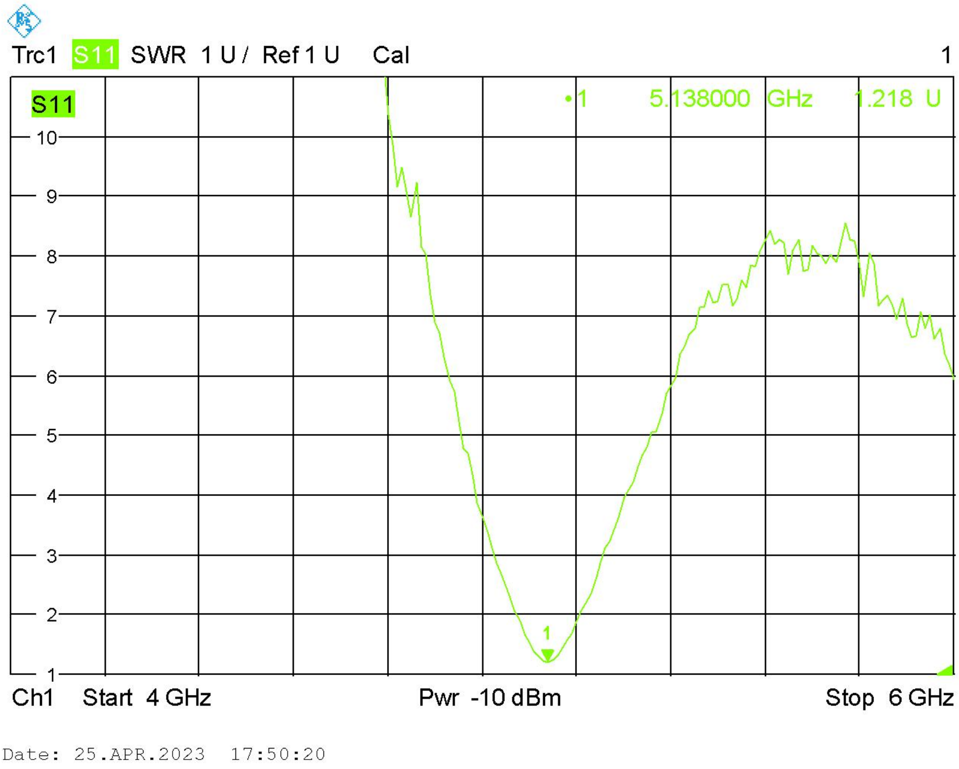
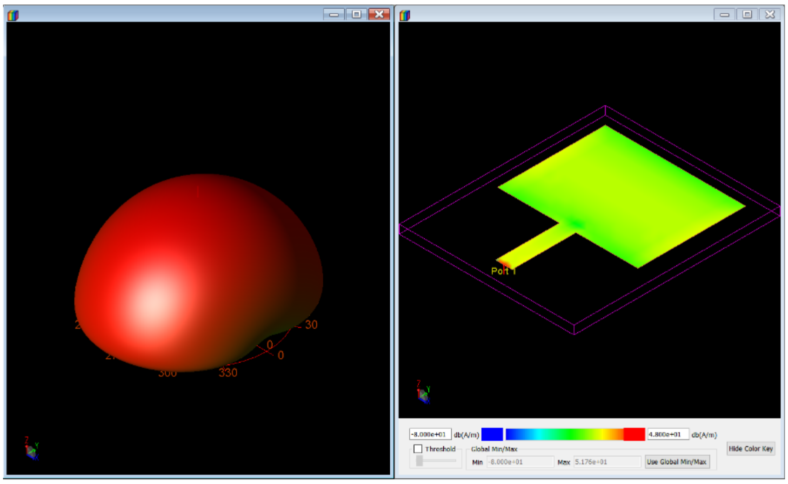


Figure 5.8 Result of Antenna Testing for SWR wave



-8.000e+01 db(A/m) 4.800e+01 db(A/m)

☐ Threshold

Global Min/Max: Min -8.000e+01 Max 5.176e+01

Figure 5.9 Simulated Antenna Results

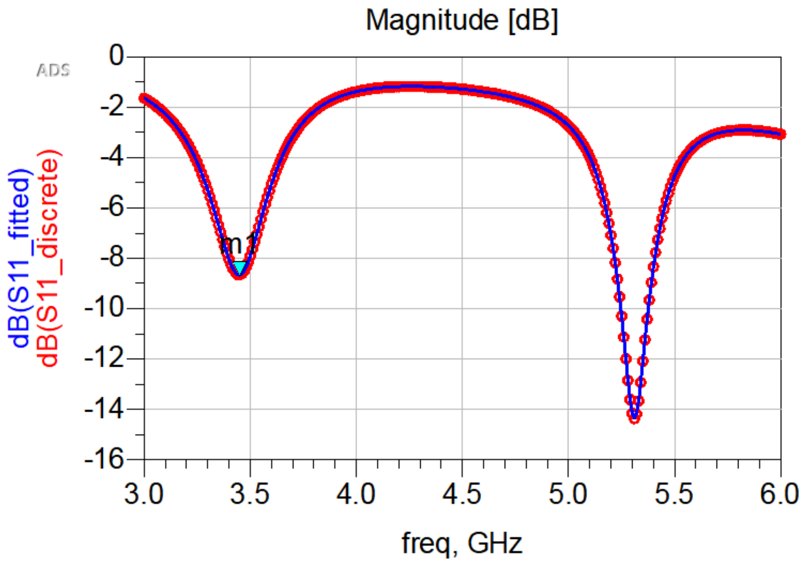


Figure 5.10 Simulated Output of the Antenna

Chapter 6

Conclusion and Future Scope

Chapter 6

6. Conclusion and Future Work

In the project proposed microstrip patch antenna for 5G communication. The designed antenna is simple in terms of design and easy to implement. The antenna resonates at 5.3Ghz frequency and its gain is seen to be of 1dB with return loss as -8.661dB. The return loss value is found to be good and gain value is found to be okay to work also it shows good radiation. Antenna works successfully and gives the output. The work done can be useful for future 5G communication. The antenna design structure was very simple 50mm×50mm×1.6mm and can be easily designed.

Currently antenna is working at resonance frequency of 5.3Ghz. But still the antenna can be improved as per the requirement of the application. The antenna can be improved by choosing more quality substrate. Also the improvement can be done by reducing the dimension so that antenna will resonate with higher frequency and will take lesser space and consume lesser power. By reducing the dimensions we can have improvement in radiation, efficiency, directivity and more effective.

Chapter 7
Achievements

Chapter 7

7. Achievements

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CERTIFICATE

This is to certify that the paper titled

Design and Analysis of Microstrip Antenna for 5G Application

is authored by

Om Nalamwar, Tejas Chavhan, Vaibhav Mhasal, Yash Gangane, Naman Sharma, Dhiraj Tulaskar

in the IEEE National Students' Conference on Innovation In Rural Development organized by IEEE Students' Branch, Shri Sant Gajanan Maharaj College of Engineering, Shegaon held on 20th - 21st April 2023.

Prof. Komal Vyas Conference Co-chair	Dr. P. R. Wankhede Conference Chair	Dr. M. N. Tibdewal Convener	Dr. S. B. Somani Organising Chair

Cert: SSGMCE/IEEE/INSCIRD23/EE-14/2023

Figure 7.1 Research Paper published in IEE National Students Conference on Innovation In Rural Development

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