Design and Performance Analysis of Microstrip Phased Array Antenna for Vehicular Adhoc Network

Ashenafi Mola Busa

A Thesis Submitted to

The Department of Electronics and Communication Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Master of Science Degree in Electronics and Communication Engineering

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled **Design and Performance Analysis of Microstrip Phased Array Antenna for Vehicular Adhoc Network**” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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APPROVAL SHEET

I/we, the advisors of the thesis entitled "**Design and Performance Analysis of Microstrip Phased Array Antenna for Vehicular Adhoc Network**" and developed by Ashenafi Mola Busa, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Ashenafi Mola Busa have read and evaluated the thesis entitled "**Design and Performance Analysis of Microstrip Phased Array Antenna for Vehicular Adhoc Network**" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Electronics and Communication Engineering

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LIST OF SYMBOLS

εr	dielectric constant of substrate
f	operating frequency
ε_{eff}	effective dielectric constant
Leff	effective length of the patch
c	free space velocity of light, which is 3x108 m/s
h	height of dielectric substrate
W	width of the patch
L	length of the patch
λ	lambda
e	efficiency
σ	conductivity of the conductor
β	phase difference
k	wave vector
D	directivity of the patch antenna
η	radiation efficiency

LIST OF ACRONYMS

AiP	Antenna in Package
CST	Computer Simulation Technology
DGS	Defected Ground Structure
EBG	Electromagnetic Band Gap
GPS	Global positioning systems
HFSS	High Frequency Structural Simulator
HF	High Frequency
HPBW	Half Power Beam Width
ISI	Inter symbol Interference
MMW	Millimeter-Wave
PML	Perfect Matched Layer
PIEA	Planar Inverted E Shaped Antenna
RF	Radio Frequency
RL	Return Loss
RMA	Rectangular Micro stripe Antenna
SMA	Surface mount adapter
VANET	Vehicular Adhoc network
VSWR	Voltage Standing Wave Ratio
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless local Area Networks

ABSTRACT

In recent years, devices in communication systems have necessitated the development of low-cost, light-weight, small, and low-profile antennas capable of good performance across a broad frequency band. Because of their intrinsic qualities that meet the requirements of modern communication devices, this technical advancement has focused significant work on the construction of micro strip patch antennas. In this thesis, the microstrip line feed Rectangular Microstrip Patch Linear Array Antenna is designed at 23 GHz and 60 GHz operating frequency for VANET applications by using phased array for bandwidth enhancement.

Both 23 GHz and 60 GHz operating frequency bands have been allocated to FACS bands by the KCC, which is expected extensively for vehicular communications for short range of communication because of the path loss is minimum over the short distance between vehicles. Firstly we designed our antenna at 23 GHz and 60 GHz operating frequency in which different antenna parameters such as gain, directivity, return loss, polarization, beam width, band width and radiation pattern are analyzed and simulated. The given antenna will prove very useful for VANET to steer the beam in the arrival direction. Further use of 60 GHz frequency makes this antenna more useful as its being unlicensed all over world and providing very high data rates. It is observed that the Single element antenna achieves the gain of 7.77 dB for 23 GHz and 8.77 dB for 60 GHz with the directivity of 8.01 dBi for 23 GHz and 9.07 dBi for 60 GHz, 2x1 elements array achieves the gain of 8.89 dB for 23 GHz and 11.23 dB for 60 GHz with the directivity of 9.11 dBi for 23 GHz and 11.78 dBi for 60 GHz,, 4x1 elements array has the gain of 12 dB for 23 GHz and 13.02 dB for 60 GHz with the directivity of 12.34 dBi for 23 GHz and 13.51 dBi for 60 GHz. The simulation of the design was done with the aid of Computer Simulation Technology (CST) studio version 19 software and matlabR2019a which will be used to calculate the parameters.

Key words: *Micro strip antenna, VANET, phased array, band width, beam width*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Electronics have become increasingly vital in our lives. The flow of information from one place to another is known as communication. Today's information exchange is multi-pointed rather than two-pointed. Wireless communication has advanced significantly in recent decades, and it now plays an important role in making our lives easier. The astonishing progress of antenna technology began in the late 1970s. An antenna is a device that emits electrical energy in the form of microwaves containing some useful information and converts it back into electrical energy from the waves at the other end [1]. Microstrip antennas are becoming increasingly popular because to their small size and flexibility in applications. They typically consist of a rectangular or square metal patch on a thin layer of dielectric (called to as the substrate) on the ground plane[2]. Antenna is an electronic tool in WLAN/WiMAX communication systems since its performance has a direct impact on the quality of wireless communications. Microstrip antenna array is the ideal choice for wireless such usage due to low profile. Because of its low weight and low profile ease of integration, as well as their ease and inexpensive cost, microstrip antenna arrays are frequently employed in a variety of applications. Such characteristics are important design considerations for microstrip antenna array applications.

An antenna is a type of transducer that converts transmission line signals into electromagnetic field space, which is made up of electric and magnetic field patterns traveling in opposite directions. [3]. When the speed of charge increases or decreases, radiation occurs due to a time-varying current. If there is no mobility of charges in an antenna, there will be no radiation. When charges in motion move at a non-uniform pace along a linear conductor, radiation occur. Therefore, if the conducting wire is bent or arched and the charges are traveling at a constant pace, radiations will occur.As stated by, radiation happens when a charge oscillates with time along a straight conductor[4]. For an antenna to work, a voltage source must be connected to two conducting wires on the transmission system, as shown in figure 1.1.

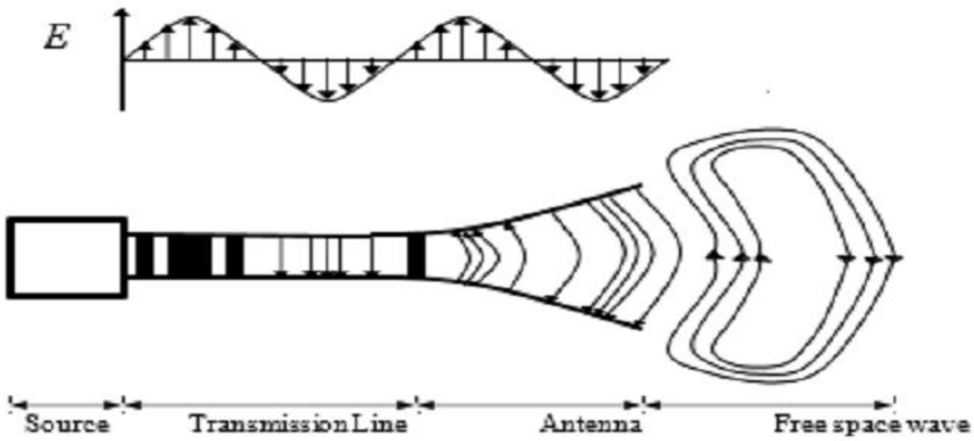


Figure 1.1. Radiation of an Antenna [5]

A sinusoidal electric field is created when a sinusoidal voltage is applied to a transmission line. The magnetic field's strength is indicated by the line of force. This electric line of force displaces free electrons in the wire. Current is generated by charge movement, which in turn generates a magnetic field. The time-varying magnetic and electric fields that flow through the conductor form electromagnetic waves. When waves approach open space, they create free waves, resulting in a connection between the field line's open ends. Electric disruption and electromagnetic waves are also produced by the source. Before open space radiation, propagation begins with the transmission line and antenna. As they enter free space, the electromagnetic waves are sustained by the charges inside the transmission line and antenna. Before entering free space, the waves form closed loops. [4].

Communication efficiency is largely determined by the characteristics of the receiving and sending antennas. Microstrip patch antennas have a number of benefits over other antennas, including their small size, light weight, and simplicity of integration with the other communication devices, which makes them ideal for wireless communication systems[6]. Other advantages discussed by [7] include:

- Conformable to planar and non-planar surfaces.
- Mechanically robust when mounted on rigid surfaces.
- The cost of fabrication is low.
- They support linear and circular polarization.
- Can operate on dual and triple frequency.

However, the microstrip patch antenna has the problem of having a restricted bandwidth, which can be overcome by increasing the substrate thickness. Due to the highest radiation of the microstrip patch, substrates with the lowest dielectric constant are chosen[8]. The most frequent shapes are circular, square, and rectangular because they are easy to analyze and beam scanning may be simply obtained from the patch antenna[9].

1.2. Statement of the problem

On Vehicular traffic is the primary problem of many developing countries like Ethiopia. In this thesis work, first focus on antenna design that is suitable for Adhoc network. In nature Microstrip patch antenna is a problem of low gain and bandwidth. So that modification and enhancement is required in broadness and improve the performance of microstrip patch antenna. Therefore to increase the bandwidth of the antenna we have introduced the antenna arrays in it. Antenna arrays are widely used to scan an antenna system's beam, improve directivity, gain, and a variety of other characteristics that are difficult to do with single element antennas.

1.3. Objective

1.3.1. General Objective

The main objective of this thesis is designing the microstrip patch antenna array at 23GHz and 60 GHz for Adhoc network.

1.3.2. Specific Objective

The objective of this thesis work is to simulate and analyze the performance of 23 GHz and 60GHz. This objective have achieved with following steps:

- Mathematical calculation of various parameters of microstrip antenna arrays such as width, length, microstrip feed line, thickness of copper, Effective dielectric constant, etc.
- Design of single, 2x1 and 4x1 rectangular microstrip patch antenna for 23 GHz and 60 GHz
- The Radiation efficiency, directivity, beam width, band width, return loss, gain, radiation pattern, current distribution, and input impedance of a microstrip antenna array are all examined.

- Performance Analysis of Microstrip Phased Array Antenna for 23 GHz and 60 GHz operating frequency on single, 2x1 and 4x1 linear array patch antenna.

1.4. Significance of the study

The field of wireless communications is always under development to provide new and better services to the end users. The introduction of new services with high bandwidth demands (ultra-high definition video, virtual reality applications, etc.) originated the need for networks with higher capacity. Therefore, the 5^{th}generation of wireless networks (5G) is expected to target 1000 times' higher capacity than 4G wireless communication [10]. The millimeter-wave spectrum (30-300 GHz) must be employed for 5G because millimeter-wave carrier frequencies allow for bigger bandwidth allocations, resulting in better data transfer rates[11] in order to achieve such a major increase in capacity.

Antennas will be a crucial part of the necessary technology for the implementation of this new wireless network, forced to overcome typical difficulties in these bands, such as efficiency and production costs, without sacrificing the radiation characteristics. For this type of network, the antenna must have a high gain, beam steering function to guarantee wireless connections, must also be able to spatially focus the radio signal to a specified direction, so that the energy consumption for data transferring can be efficiently reduced [12] and must be highly efficient to compensate the propagation loss of radio signals over the air. To satisfy these requirements, transmit-arrays are a promising technology [13], since they are thin, planar, light weight and can reach high gain.

1.5. Scope and limitations of the study

The main disadvantage of microstrip patch antenna is that it can only radiate efficiently across a wide frequency range and cannot operate at the high power levels of waveguide, coaxial line, or maybe strip line[13]. Different array topologies, feeding methods, dielectric materials, and ground planes can all help to reduce this. Antenna arrays are widely used to scan an antenna system's beam, improve directivity, gain, and a variety of other characteristics that are difficult to do with single element antennas [14].

1.6. Thesis organization

The rest of these thesis work is organized in the following manner.

The chapter 2 deals with the microstrip antenna details. Its feeding techniques, advantages, disadvantages, applications, different method of analysis and antenna fundamentals its designing parameters. In this I have also explained the importance of 60 GHz and its various features, and finally studies on microstrip antenna.

The chapter 3 deals with overall designing of the 60 GHz microstrip antenna. It operates on the single band, 2x1, and 4x1 of the 55-65 GHz of the V band. It further includes the parameters calculation.

The chapter 4 presents the proposed results and discussions with compression analyses for 23 GHz and 60 GHz.

Finally chapter 5 includes the overall conclusion and future scope of the research. Future work which can be done to further increase the performance of the given antenna.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction of microstrip patch antenna

Planar resonant cavities leak and radiate from the sides of microstrip antennas. Antennas can be etched on soft substrates using printed circuit techniques to provide low-cost, reproducible antennas with a low profile [9]. The antennas constructed on flexible substrates can resist a lot of shock and vibration. To save money on substrates and etching, manufacturers of mobile communication base stations frequently produce these antennas directly in sheet metal and mount them on dielectric poles or foam in a number of methods The patch radiation of a basic antenna is caused by current distribution, while in the case of microstrip antennas, it is caused by the favorable voltage distribution caused by fringing fields. As depicted below, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate with a ground plane on the other [9]. The patch is usually made of conductive metals like copper or gold and can be manufactured into any shape. On the dielectric substrate, the radiating patch and feed lines are normally photo etched. Antenna arrays, as well as their feeding networks, can be photo etched on the substrate. Microstrip circuits use a simple photo etching technique to create a wide range of antennas. The patch antenna is also called as the “voltage radiator”. [15], [16].

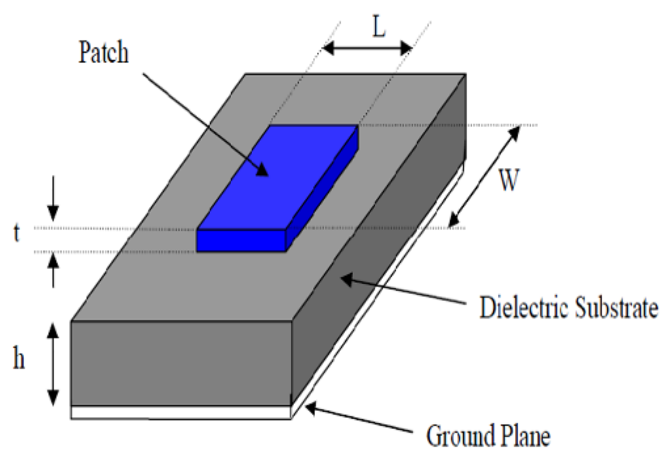


Figure 2.1: Microstrip Patch Antenna [17]

We select a rectangular patch to simplify analysis and performance predictions. The patch can be square, round, triangular, or elliptical in shape. For a rectangular patch, the length L of the patch is usually 0.3333λo < L < 0.5λo, where λo is the free-space wavelength. The patch is selected to be very thin such that t << λo (where t is the patch thickness). The dielectric substrate's height h is generally 0.003 $\lambda o \leq h \leq 0.05\lambda o$. The substrate's dielectric constant is typically in the range of $2.2 \leq \varepsilon r \leq 10$

Advantages of Microstrip Antenna

Important advantages are:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Disadvantages of Microstrip Antennas

- Narrow bandwidth
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

The antenna quality factor of microstrip patch antennas is quite high (Q). Q denotes the antenna's losses, and a high Q indicates a limited bandwidth and low efficiency [9], [12]. By increasing the thickness of the dielectric substrate, Q can be lowered. However, as the wafer thickness increases, a greater proportion of the source's total power is passed to the surface wave. Because it is scattered at the dielectric bends and causes worsening of the antenna properties, this surface wave contribution might be considered an undesired power loss.

Applications

- ❖ Used in telecommunication
- ❖ Used in aircraft, spacecraft & missiles
- ❖ GPS system
- ❖ Telemetry

2.2. Types of microstrip antennas (MSAs)

Microwave communication system applications are being developed in response to rising demand. Based on the structure, there are three types of MSAs. [18]

I. Microstrip patch antennas
II. Microstrip traveling wave antennas
III. Microstrip slot antennas.

I. Microstrip patch antennas: A microstrip patch antenna has a rectangular or square or copper patch on the ground plane atop a thin layer of dielectric (called the substrate). Figure 2.2 depicts the shape of a typical rectangle microstrip antenna (CRMSA).

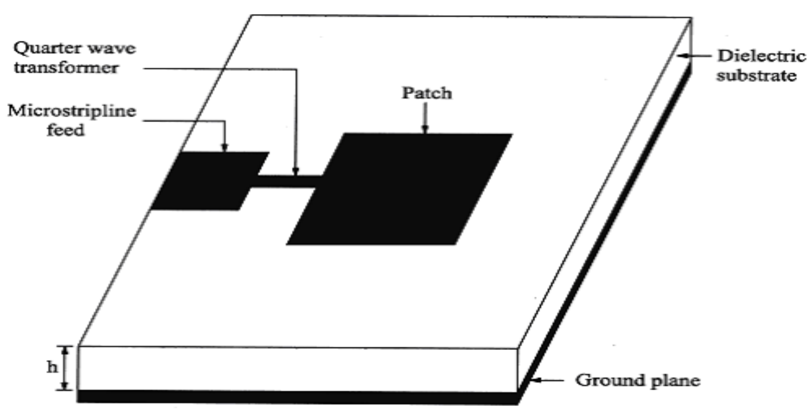


Figure 2.2 Geometry of conventional rectangular microstrip antenna.[18]

II. Microstrip traveling wave antennas: This antenna has a chain-shaped periodic conductor as one of its components. It can be a standard long transverse electric and magnetic (TEM) line that also supports a transverse electric (TE) mode on a ground plane-backed substrate. Traveling waves can be supported by the antennas, and their structure can be constructed so that the primary beam can point in any direction from broadside to end fire. The various configurations of microstrip traveling wave antennas are shown in Fig. 2.3.

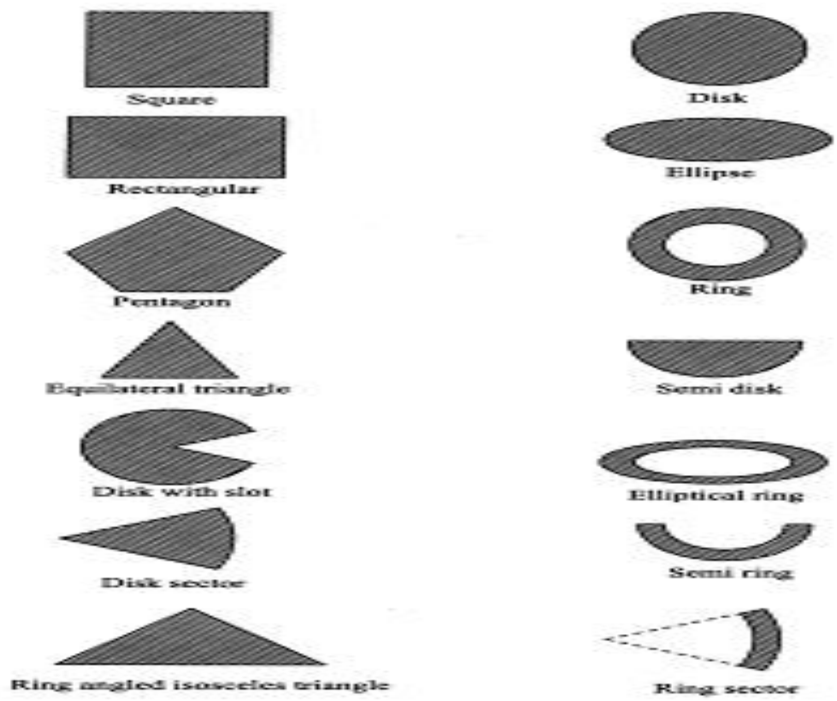


Figure 2.3 various configurations of microstrip patch antennas.[18]

III. Microstrip slot antennas: It includes a slot in the radiating patch fed by a microstrip line. As shown in Fig. 2.4, the slot can be shaped like a rectangle, a circle, or an annular ring. Microstrip slot antennas have the advantage of producing both bidirectional and unidirectional radiation patterns. In the design of MSAs, the patch and slot combinations provide an additional level of flexibility. Because the slots in the MSAs can radiate independently or in phase with the patch, they have a significant impact on the antenna's radiation properties. Narrow slot antennas and wide slot antennas are the two types of Microstrip slot antennas. The slot width is substantially smaller than the slot length of a narrow-slot antenna. Wide slot antennas have a slot width that is proportional to the slot length. Wide-slot antennas have an advantage over narrow-slot antennas in terms of impedance bandwidth.[13]

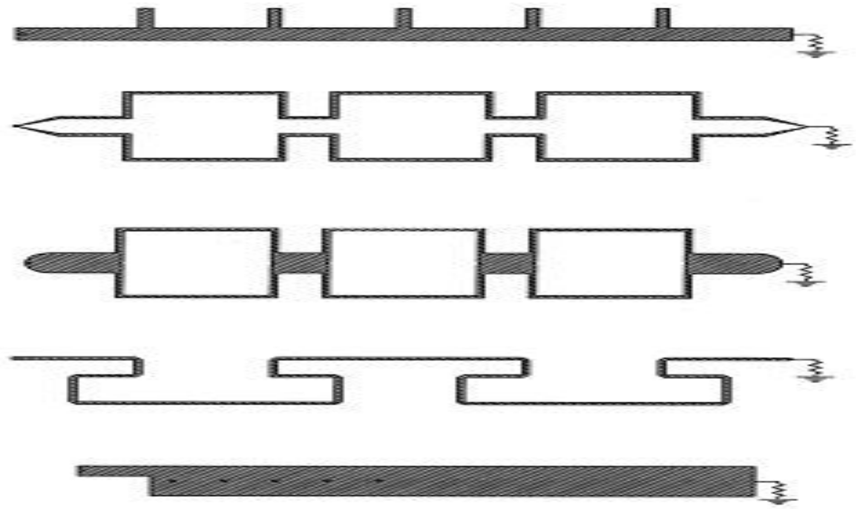


Figure 2.4 various configurations of microstrip traveling wave antennas.[18]

2.3. Fundamentals of Microstrip Patch Antenna Array

An antenna array (sometimes known as a 'phased array') is a collection of two or more antennas. To achieve better performance than a single antenna, the signals from the antennas are merged or processed. The antenna array can be used for a variety of purposes, including:

- increase the overall gain
- provide diversity reception
- cancel out interference from a particular set of directions
- "steer" the array so that it is most sensitive in a particular direction
- determine the direction of arrival of the incoming signal
- To maximize the Signal to Interference plus Noise Ratio (SINR).

Array means a collection of similar entities or set of individual antenna elements connected together to behave as a single unit. Advantage

- Higher Gain
- Beam Steering Capability
- Reliable
- Higher SNR

The radiation pattern of a single element is usually extremely broad, and each element has a low directivity value (gain). In many applications, antennas with very strong directional properties (very high gain) are necessary to meet the needs of long-distance communication. This can only be done by increasing the electrical size of the antenna.[19].

When the dimensions of single pieces are increased, they frequently take on more directive features. Forming an assembly of radiating elements in an electrical and geometrical structure is another technique to increase the antenna's dimensions without increasing the size of individual parts. An array [14] is the name given to the new antenna that has been created. When the dimensions of single pieces are increased, they frequently take on more directive features. Forming an assembly of radiating elements in an electrical and geometrical structure is another technique to increase the antenna's dimensions without increasing the size of individual parts. An array [14] is the name given to the new antenna that has been created.

2.4. Feeding Techniques Microstrip Patch Antenna

Microstrip antennas are resonators with feed lines that must be used to excite their fields [15]. A variety of approaches can be used to feed microstrip patch antennas. These methods can be divided into two groups:

1) Contacting
2) Non-contacting.

In the contacting approach, RF power is provided directly to the radiating patch via a connecting device such as a microstrip wire. Electromagnetic field coupling is used in the non-contacting system to transfer power between the microstrip line and the radiating patch. Microstrip lines, coaxial probes (both contacting systems), aperture coupling, and proximity coupling are the four most commonly utilized feed mechanisms (both non-contacting schemes).

2.4.1. Microstrip-line Feed

In this form of feed technology, a conductive strip is directly attached to the edge of the microstrip patch, as seen below. This type of feed configuration has the benefit of allowing the feed to be etched on the same substrate as the patch, resulting in a planar structure. The goal of the inset cut in the patch is to match the impedance of the feed line to the patch without the use of any extra matching components [12], [13]. This is accomplished by carefully managing the inset position. As a result, this is a simple feeding scheme, as it allows for straightforward manufacturing and modeling, as well as impedance matching. However, when the dielectric substrate thickness grows, surface waves and spurious feed radiation increase as well, limiting the antenna's bandwidth. Unwanted cross-polarized radiation is also produced by the feed radiation.

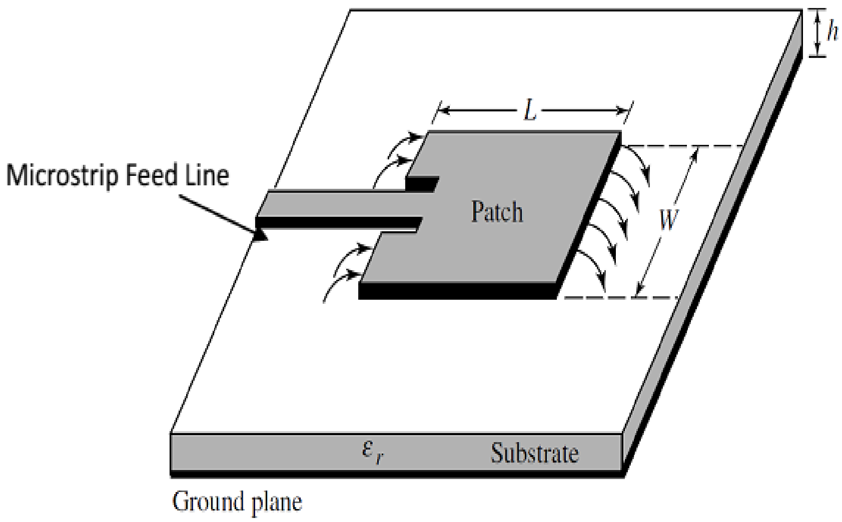


Figure 2.5: Microstrip line Feed[20]

2.4.2. Coaxial Feed

Microstrip patch antennas are commonly fed using coaxial feed, also known as probe feed. As shown in Figure 2.6, the coaxial connector's inner conductor extends through the dielectric and is attached to the radiating patch, while the outside conductor is connected to the ground plane. The main advantage of this technique of feeding is that the feed can be placed anywhere inside the patch to match the input impedance.

This feed mechanism is easy to construct and emits very little unwanted radiation. It has a restricted bandwidth and is difficult to replicate because a hole must be cut in the substrate and the connector protrudes outside the ground plane, making it non-planar for thick substrates ($h > 0.02\lambda_o$). Additionally, the greater probe length makes the input impedance more inductive on thicker surfaces, producing matching difficulties. The both microstrip line feed and also the coaxial feed suffer from various drawbacks when used with a thick dielectric substrate that provides significant bandwidth, as shown above.

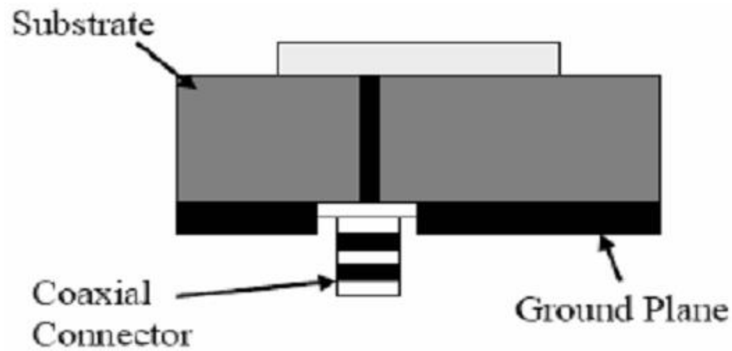


Figure 2.6: Coaxial Feed [20]

2.4.3. Proximity Coupled Feed

The electromagnetic coupling strategy is another name for this type of feed technique. The feed line is placed between two dielectric substrates, with the radiating patch atop the upper one. Due to the overall increase in the thickness of the microstrip patch antenna, this feed approach minimizes spurious feed radiation and delivers extremely high bandwidth (as high as 13 percent). This approach also allows for the use of two separate dielectric medium to maximize individual performance, one for the patch and the other for the feed line.

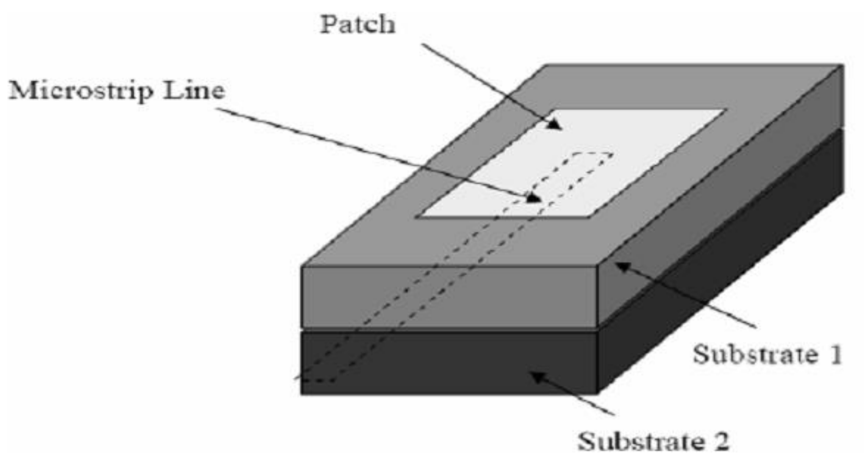


Figure 2.7: Proximity Coupled Feed [21]

Matching can be aided by controlling the length of the feed line and the width-to-line ratio of the patch. Due to the two dielectric layers that must be oriented properly, the main disadvantage of this feed method is that it is difficult to build. The antenna's overall thickness has also risen.

2.4.4. Aperture Coupled Feed

In this form of feed technology, the ground plane separates the radiating patch from the microstrip feed line, as seen below. The patch is connected to the feed line via a slot or aperture in the ground plane. Due to the symmetry of the design, the coupling aperture is typically centered under the patch, resulting in decreased cross polarization. The amount of coupling from the feed line to the patch is determined by the shape, size, and location of the aperture.

The ground plane separates the patch and the feed line, which reduces spurious radiation. A thick, low dielectric constant material is used for the bottom substrate and a thin, high dielectric constant material is used for the top substrate to optimize patch radiation. The main disadvantage of this feed method is that it is difficult to create because to the numerous layers, which increases antenna thickness.

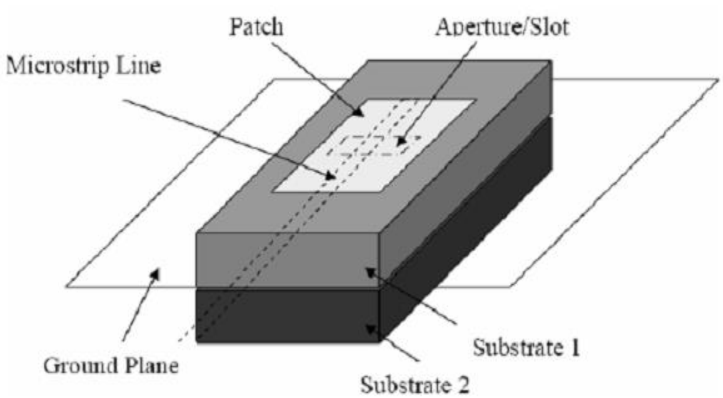


Figure 2.8: Aperture Feed [22]

2.5. Different methods of analysis

- Transmission line model
- Cavity model
- Finite Difference Time Domain Method
- Method Of Moments
- Spatial and Spectral Domain

The transmission line model, cavity model, and complete wave model (which comprises substantially integral equations/Moment Method) are the most commonly used models for the analysis of Microstrip patch antennas. The transmission line model is the most basic of them all, and while it provides useful physical information, it is less precise. The cavity model is more accurate and provides better physical understanding, but it is also more complicated.

Single elements, finite and infinite arrays, stacked components, arbitrary shaped elements, and coupling can all be treated using complete wave models, which are exceedingly accurate and versatile.

2.5.1. Transmission Line Model

The microstrip antenna is represented by two slots of width W and height h separated by a transmission line of length L in this configuration. A microstrip is a non-uniform line made up of two dielectric materials, usually the substrate and air.

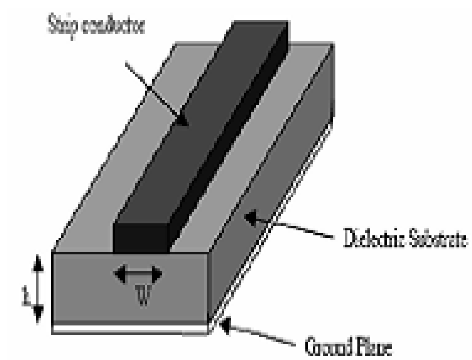


Figure 2.9: Microstrip Line [13]

With the exception of a few lines that extend into the air, the majority of the electric field lines are found in the substrate. As a result, because the phase velocities in the air and the substrate are different, this transmission line cannot support a pure transverse electric- magnetic (TEM) mode of transmission. The quasi-TEM mode would be the primary mode of propagation instead [13], [12]. As a result, an effective dielectric constant must be computed in order to account for fringing and wave propagation in the line.

2.5.2. Cavity Model

The transmission line model discussed in the preceding section is simple to use, but it has several drawbacks. It's especially effective for rectangular design patches because it ignores field differences at the radiating borders. The cavity model can be used to solve these drawbacks. The internal portion of the dielectric substrate is represented in this model as a cavity with electric walls on the top and bottom. The following observations for thin substrates (h<<λ) form the basis for this assertion.

- In the region bordered by the patch metallization and the ground plane, the electric field is only z directed, and the magnetic field contains just the transverse components Hx and Hy. The electric walls at the top and bottom are based on this observation.

2.5.3. Full Wave Analysis

Because of their rigor and accuracy, full wave methods are gaining popularity. This is based on a Somerfield type integral equation and a time domain solution of the Maxwell equation. Popular numerical methods include spectrum-domain integral equation analysis, space-domain integral equation analysis, and the finite difference time domain (FDTD) technique [12]. The integral equation approaches involve one crucial assumption: the dielectric substrate and ground plane are infinite in size. As a result, when the substrate and ground plane are many wavelengths apart, the solution is more precise. For antennas of finite size, the FDTD approach is more efficient. The following are some of the most important elements of Full Wave Analysis:

- Predicts the characteristics of Microstrip antennas at higher frequencies.
- It also lowered the coefficient matrix's and computations' order.
- Calculates the resonant frequency as well as the radiation properties and pattern.
- Versatile as it is used for all types of antenna structures.
- It provides more accuracy than any other method.
- Completeness, as it includes the effects of all types of losses.
- Because these are numerically intensive, careful programming is required to reduce calculation costs.

2.5.4. Finite Difference Time Domain

For printed antennas, FDTD is the most appropriate numerical analytical technique. FDTD is versatile because any integrated semiconductor device in the antenna can be incorporated in the analysis at the device-field interaction level. As a result, active antennas can be accurately analyzed. In contrast to other numerical techniques, FDTD solves Maxwell's equations directly, without any analytical pre-processing. As a result, almost any antenna geometry can be examined. Because this technique is numerically heavy, careful programming is essential to keep computing expenses to a minimum. The FDTD analysis of open region problems like antennas requires the domain to be shortened to conserve computer resources. To truncate the antenna's physical domain, absorbing boundary conditions, either analytical ABC or material ABC, are used. With minimal reflection, the material ABC, in the form of PML, can achieve a considerable domain truncation. The design of the PML should work with the FDTD approach used for the rest of the antenna. PML formulations come in a range of flavors. The two varieties of PML are split-field and non-split-field. [12], [13]. Non-split-field types are easier to code and so are preferred. The most promising of the various PML formulations now available appears to be uniaxial PML. All FDTD algorithms are affected by computational error, and the amount of error is proportional to the spatial and time step sizes utilized. The error is calculated using numerical dispersion. The FDTD methodology is one of many grid-based differential numerical modeling techniques (finite difference methods). Using central-difference approximations to the space and time partial derivatives, the time-dependent Maxwell's equations (in partial differential form) are decomposed. The resulting finite-difference equations are leapfrogged solved in software or hardware: The electric field vector components in a volume of space are solved at one point in time, followed by the magnetic field vector components in the same spatial volume at the next point in time, and so on until the desired transient or steady-state electromagnetic field behavior has fully evolved. The following are some of the most important characteristics:

- FDTD is a popular numerical method, because of relatively easy implementation.
- No analytical pre-processing and modeling is required.
- Applied to all shapes of geometries.
- E and H fields are calculated everywhere in the computational domain.
- To simulate an unbounded computing environment, absorbing boundary conditions are used.
- FDTD belongs to grid-based differential numerical modeling methods.
- Time and space steps must satisfy CFL condition
- To make computational domain finite we use ABCs and special absorbing materials like PML, which are used to implement absorbing boundary conditions.
- E and H fields are time-stepped or updated resulting in a marching-in-time process

❖ Allows users to specify materials at any time within the computational domain.

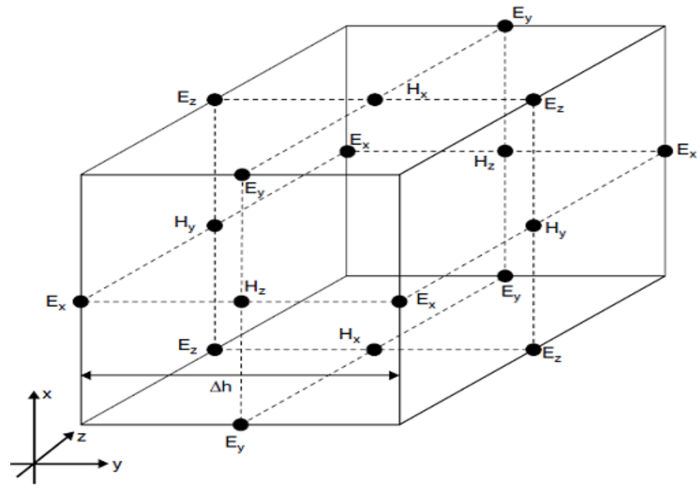


Figure 2.10: Geometry of Yee's cell used in FDTD analysis [13]

2.6. Antenna Parameters

2.6.1. Radiation Pattern

An antenna's radiation pattern is a plot of the antenna's far-field radiation qualities as a function of the spatial co-ordinates defined by the elevation angle and azimuth angle. The spatial co-ordinates are used to generate this pattern plot. The ratio of power radiated to the unit solid angle is known as radiation intensity. An antenna that radiates uniformly in all directions is referred to as a "isotropic antenna." In any direction, the power density S is given by equation 2.1;

$$S = \frac{P}{4\pi r^2} \qquad [2.1]$$

P is the total power radiated by the isotropic antenna, and r is the sphere's radius.

Equation 2.2 gives the radiation intensity for an isotropic antenna Ui.

$$Ui = r^2 S = \frac{P}{4\pi} \qquad [2.2]$$

Despite the fact that an isotropic antenna is difficult to achieve, it is used as a reference. Practical antennas are directional, emitting greater power in certain directions while emitting less power in others.

The radiation pattern of an omnidirectional antenna remains constant in the H-plane, which is the E-plane, but varies in the orthogonal plane. The radiation pattern of a directional antenna is depicted in Figure 2.11.

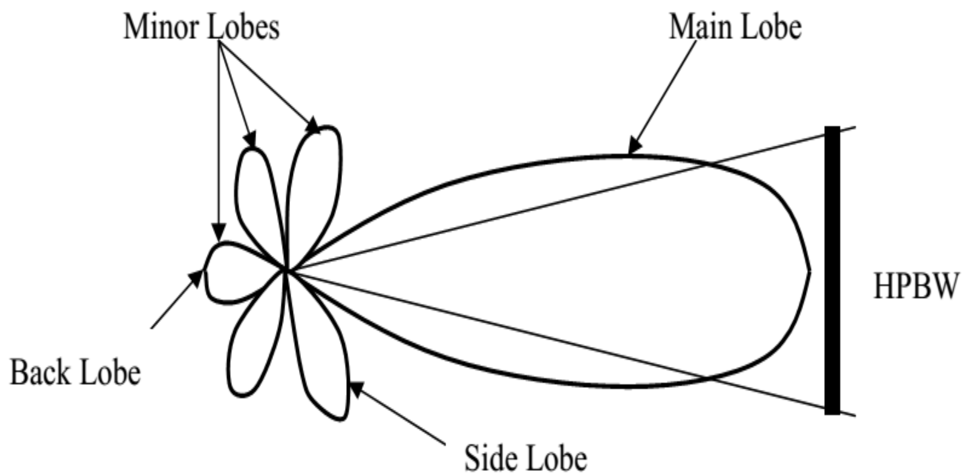


Figure 2.11: Directional Antenna Radiation Pattern [14]

The figure 2.11 indicates:

- The angle subtended by the half power of the lobe where we have maximum radiation is the half power beam width.
- The Main Lobe is the lobe that contains the strongest radiation direction.
- Minor lobes are lobes that occur in addition to the primary lobe and constitute unwanted radiation.
- The minor lobe directly opposite the main lobe is known as the back lobe.
- Side lobes are the largest of the minor lobes and are located close to the main lobe.

In most wireless systems, minor lobes are undesirable; hence an efficient antenna design should restrict the number of minor lobes to a minimum.

2.6.2. Directivity

The ratio of the antenna's radiation intensity in a specific direction to the mean radiation intensity in all directions is known as directivity. The ratio of an omnidirectional source's radiation intensity toward a specified direction or position to that of an isotropic source is known as directivity. Equation 2.3 calculates directivity.

$$D = \frac{4\pi U}{p} = \frac{U}{U_i} \qquad [2.3]$$

Where D denotes an antenna's directivity, P denotes the power emitted, Ui denotes the isotropic source's radiation intensity, and U denotes an antenna's radiation intensity. If the maximum intensity's direction is known, the maximum intensity can be computed using equation 2.4.

$$D_{max} = \frac{U_{max}}{U_i} = \frac{4\pi U_{max}}{p} \qquad [2.4]$$

where D_{max} is the maximum directivity of an antenna and U_{max} is the maximum radiation intensity of an antenna. Because it is the ratio of two intensities of a given radiation, an antenna's directivity is independent of its orientation. Directivity is given in decibel (dB). You can determine an antenna's directivity based on its radiation pattern. An antenna with a thin main lobe has better directivity than one with a broad main lobe, and is therefore more directive.

2.6.3. Input impedance

As defined by [25], The impedance of an antenna at its terminals, or the ratio of voltage to current at the pair of terminals, is known as input impedance. Input impedance can be defined as the ratio of the relevant components of the electric and magnetic fields at a location. The equation 2.5 gives the input impedance.

$$Z_{in} = R_{in} + j\, X_{in} \qquad [2.5]$$

Z_{in} denotes the antenna input impedance, R_{in} denotes the antenna resistance, and X_{in} denotes the antenna reactance. X_{in} is the imaginary part of the impedance that represents the near-field power stored in the antenna. R_{in} denotes the resistive component of the input resistance, which is made up of loss and radiation resistance. Because of dielectric or conducting losses, the power wasted in the loss resistance is lost as heat in the antenna, whereas the power associated with the radiation resistance is radiated by the antenna.

2.6.4. Voltage standing wave ratio

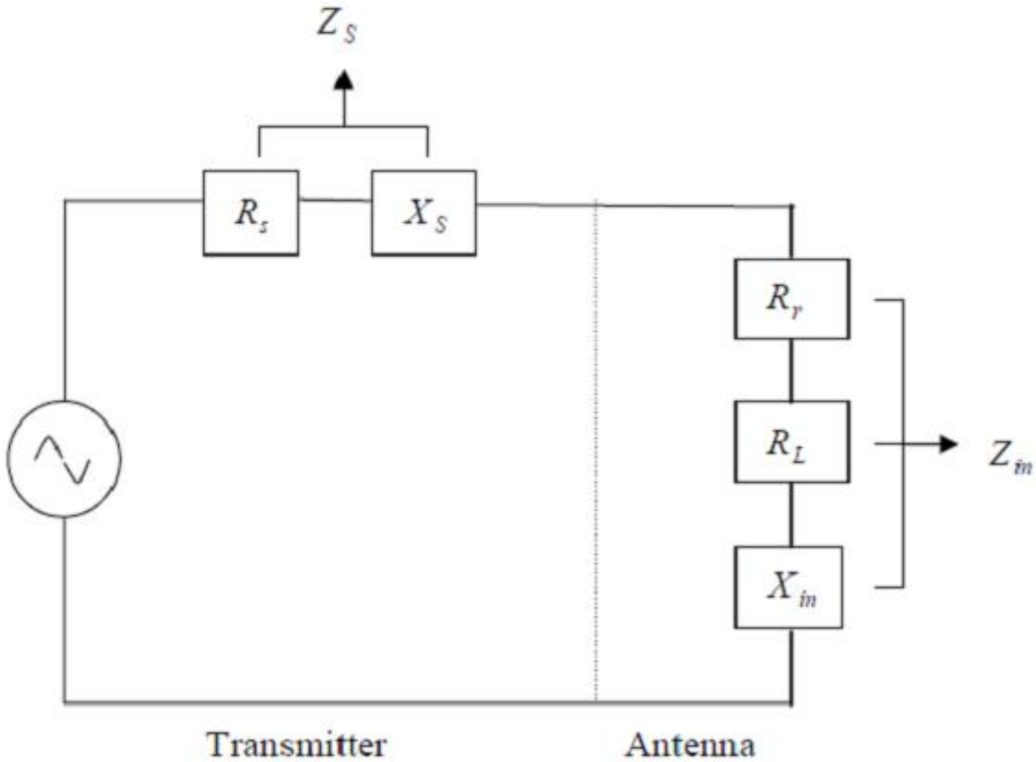


Figure 2.12: Transmitting Antenna Circuit [26]

An efficient antenna requires a maximum flow of electricity between the antenna and the transmitter. If the antenna and transmitter impedances are well matched, more power will be transmitted. When the transmitter impedance is the complex conjugate of the antenna impedance, the most power is supplied. The condition is given by equation 2.6

$$Z_{in} = Z_s * \qquad [2.6]$$

Where $Z_{in} = R_{in} + jX_{in}$ *and* $Z_s* = R_s + jX_s$

When electricity is reflected owing to a mismatch, standing waves are formed. The voltage standing voltage wave ratio characterizes standing waves (VSWR). VSWR is determined by [27] in equation 2.7;

$$VSWR = \frac{1 + \Gamma}{1 - \Gamma} \qquad [2.7]$$

Where Γ is the reflection coefficient, Vr is the reflected wave's amplitude, and V_i is the incident wave's amplitude. VSWR measures the impedance mismatch between the antenna and the transmitter. When the VSWR is high, it means there's a lot of mismatch, and when the VSWR is unity, it means there's no mismatch at all. A functional antenna's VSWR should be less than 2 in order for it to successfully radiate and transmit.

2.6.5. Return loss

Since no power is returned as reflection, this is a measure of how much power is lost to the load. When there is a mismatch between the antenna and the transmitter, the reflected wave forms a standing wave. The return loss is a measurement of how well the antenna and transmitter were matched. Equation 2.8 is used to express the RL.

$$RL(dB) = -20log10\Gamma \qquad [2.8]$$

The RL = infinity when the reflection coefficient is 0, indicating that no power is returned or reflected. The VSWR of 2 is allowed for an antenna to function effectively because it produces a return loss of -9.54 dB, as stated.

2.6.6. Antenna efficiency

Antenna efficiency is a statistic that considers both the losses at the antenna's terminals and the antenna's architecture. Wave reflection due to mismatch, as well as dielectric and conduction losses, are all taken into consideration by the efficiency factor. Equation 2.9 gives the total efficiency of an antenna.

$$e_t = e_d e_c e_r \qquad [2.9]$$

The efficiency of conduction is e_c, the efficiency of reflection is e_r, and the efficiency of dialectic is e_d. The antenna radiation efficiency e_{cd}, which is defined as the ratio of radiation resistance Rr to power transmitted to RL and Rr and may be expressed using the equation 2.10, is the result of combining conduction and reflection efficiency.

$$e_{cd} = e_d e_c = \frac{R_r}{R_r + R_L} \qquad [2.10]$$

2.6.7. Antenna gain

The antenna gain is inversely proportional to the antenna directivity. The ability of an antenna to radiate energy in a favored direction in comparison to other directions is referred to as directivity. The efficiency of an isotropic radiator is 100 percent since the gain is equal to the antenna's directivity. In some directions, all antennas emit more radiation than in others.

Equation 2.11 gives the gain of an antenna.

$$G\ (\Theta, \emptyset) = e_{cd} D\ (\Theta, \emptyset) \qquad [2.11]$$

2.6.8. Polarization

Polarization is a property of an electromagnetic wave that describes the direction of the wave over time and is proportional to the magnitude of the electric field vector. Antenna polarization is also known as polarization of the field vector. Linear and circular polarization are two different types of polarization[4]. Figure 2.13 shows linear polarization

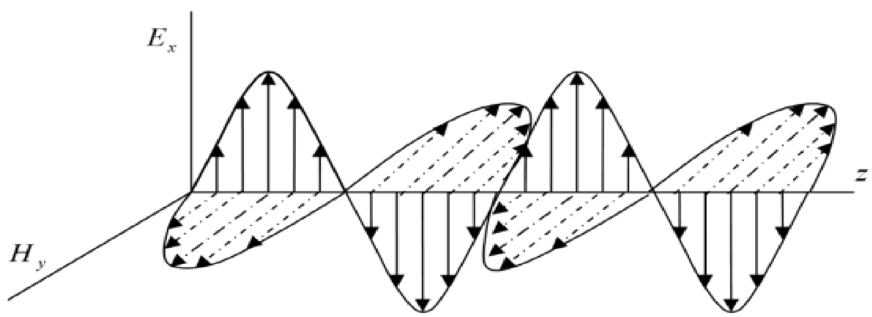


Figure 2.13: Linearly Polarized Wave [28]

An electric field vector that is linearly polarized takes a forward and backward path along a line. The electric field vector rotates in a circular direction when a wave is circularly polarized, while the length remains constant. If the motion is clockwise, the wave is right hand circular polarized, and if the motion is anticlockwise, the wave is left hand circular polarized, as seen in figure 2.14.

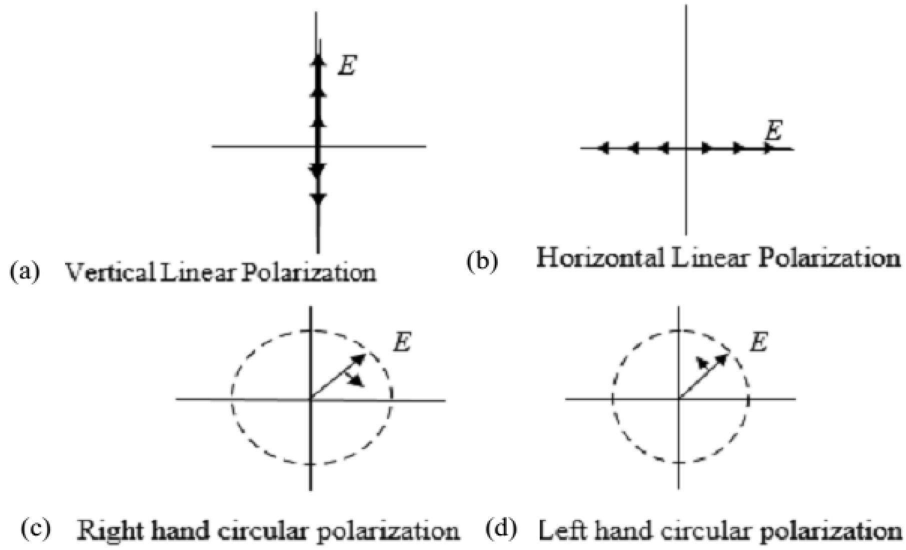


Figure 2.14: Polarization Schemes [28]

2.6.9. Bandwidth

This is the electromagnetic frequency range in which an antenna can receive and transmit electromagnetic waves successfully. A frequency range on each side of the resonance frequency in which the radiation pattern, input impedance, polarization, beam width, and gain values are identical to those of the resonant frequency is referred to as bandwidth. The voltage standing wave ratio is used to calculate the efficiency of an antenna. Because the return loss is roughly -9.54 dB, an antenna with a VSWR of 2 or less can operate well.

2.7. Beam Forming

Beamforming is a technique for sending radio signals in a certain direction using an array of antennas. Antenna arrays that use beamforming detect the direction of interest and send/receive a greater beam of signals in that specific direction, rather than broadcasting energy/signals in all directions. This technology is widely utilized in radars and sonar, as well as medicinal and communications applications, particularly 5G, where extremely high data rates are required and beamforming is the only method to achieve them. In this procedure, the signal to be sent is sent to each antenna element separately. Each signal's phase and amplitude are then constructively and destructively combined, focusing the energy into a narrow beam or lobe [29].

2.8. Inter-networking of Vehicles

One of the IoT-enabled revolutions is the Internet of Vehicles (IoV). In order to accomplish the vision of "from smartphone to smart automobile," the Internet of Vehicles (IoV) is evolving from Vehicular Adhoc Networks (VANETs) [15]. Traditional VANETs were created solely to increase traffic safety and efficiency by providing real-time communication between vehicles equipped with advanced wireless access technologies, either with or without the usage of Road Side Units (RSUs).

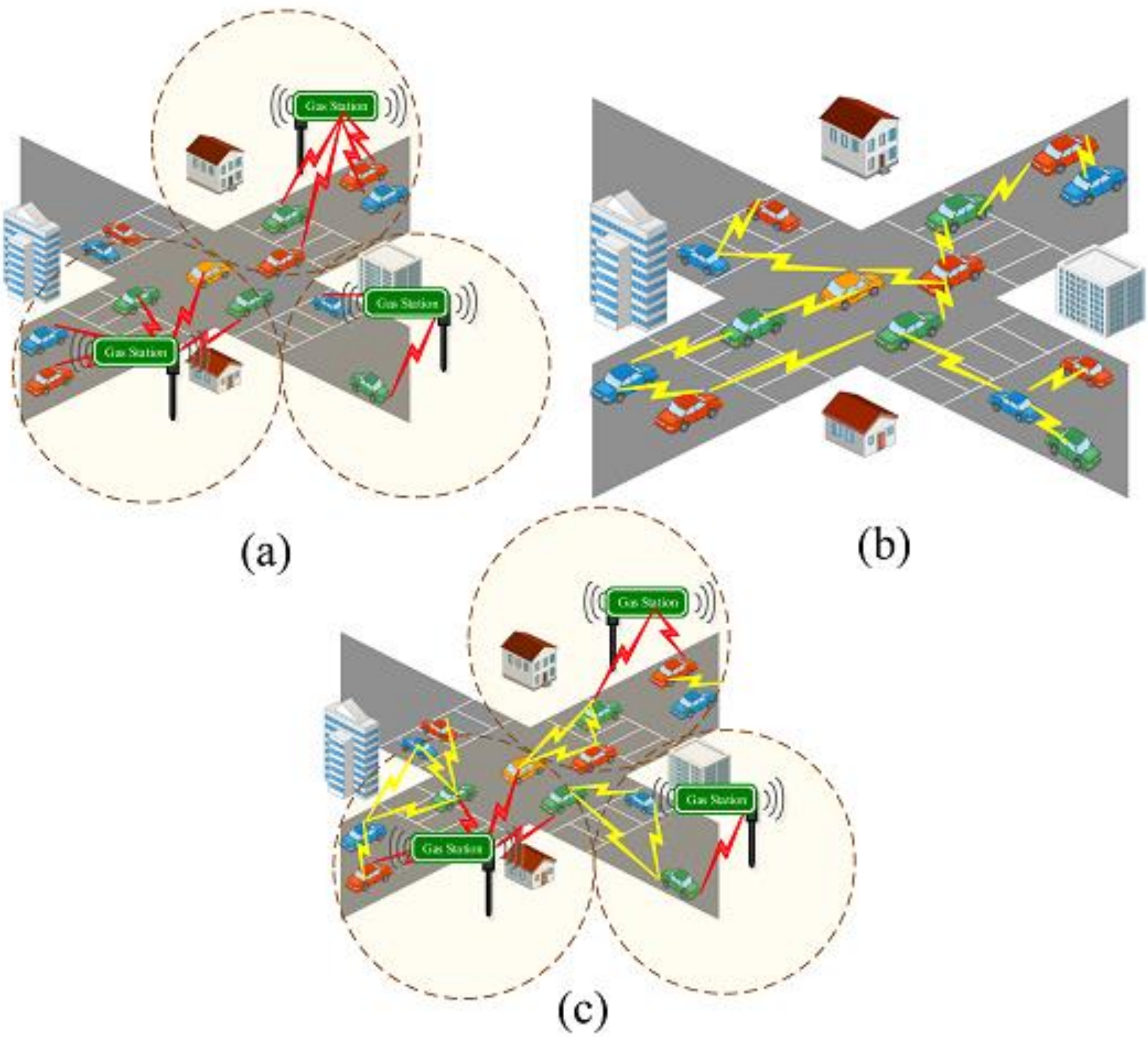


Figure 2.15. The communication architectures of VANETs: (a) WAVE base Wi-Fi; (b) Adhoc; (c) Hybrid.[30]

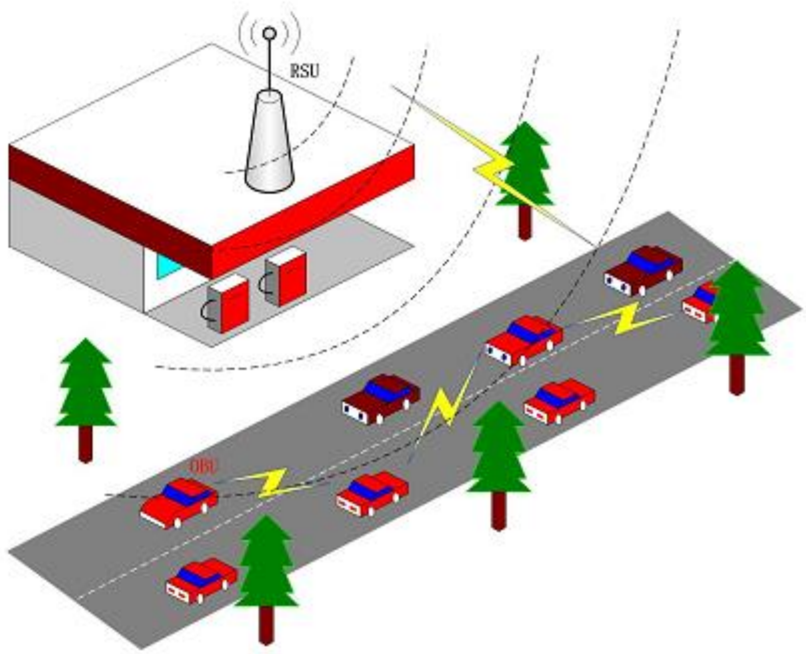


Figure 2.16. System model in VANETs.[31]

We look into a popular system model in VANETs. As seen in Fig. 2.16. Consider a VANET made up of N OBUs passing across the coverage of an RSU. When an OBU is in range of a certain RSU, it can send and receive messages from that RSU. Additionally, OBUs within its one-hop range may be able to speak with each other. To begin, we'll suppose that every VANET OBU has a half-duplex transceiver that can switch between the CCH and SCH channels to send and receive safety and non-safety messages. It can only broadcast or listen at the same time. Second, we'll suppose the RSU has two half-duplex transceivers installed (transceiver A and B). The CCH channel is always being monitored by Transceiver A. The current SCH interval would be used to save the rendezvous information. [32]. Transceiver B has the ability to switch between various SCH channels as well as the CCH channel. To avoid the multi-channel concealed terminal problem, it broadcasts the rendezvous information in the next RSU interval [17].

2.9. Importance of 60 GHz frequency

One of the most exciting opportunities for circuit, antenna, and communication system inventors in the coming decade is millimeter-wave (MMW) technology for the 60-GHz band [21]. At 60 GHz, a new era of growing communication systems begins, enabling uncompressed high-definition media transfers, sensing and radar applications, and near-instantaneous access to enormous data libraries at speeds of several tens of gigabits per second. Millions of 60-GHz communication devices will be created and sold in the future due to customer demand for these applications.

These properties make 60 GHz communication ideal for gigabit wireless data transfer over short distances. The research of skin and proximity effects, substrate losses, and wired connection dispersion at carrier frequencies ranging from 60 GHz to hundreds of GHz shows that wireless connectivity will be necessary in the near future, in addition to offering massive bandwidth for future WPANs and WLANs. Some of the important properties of 60GHz are as follows: Unlicensed use of the 60-GHz millimeter-wave (55-65GHz) spectrum is available worldwide. Has path loss and used for short range applications

- High data rates of around 25Gbps
- It has dense frequency reuse pattern
- Higher frequency leads to smaller size of components
- It uses high gain and wide area coverage antennas
- The MMW band offers a wide spectrum capacity, a tiny antenna structure, and the ability to transfer more data than any other antenna. It also boasts a bandwidth of 20 times that of any other antenna.
- Due to oxygen absorption, signals are muted, providing interference immunity and good security.
- Used for indoor and underground communications
- Used in dense populations, radio astronomy, microwave and VANET
- Large spectrum of 7GHz is available
- MMW waves travel solely by line of sight, are blocked by building walls and gets attenuated.
- It comes in the V band of the Millimeter wave band which ranges from 50 to 75 GHz
- It suffers from the problem of weak penetration.

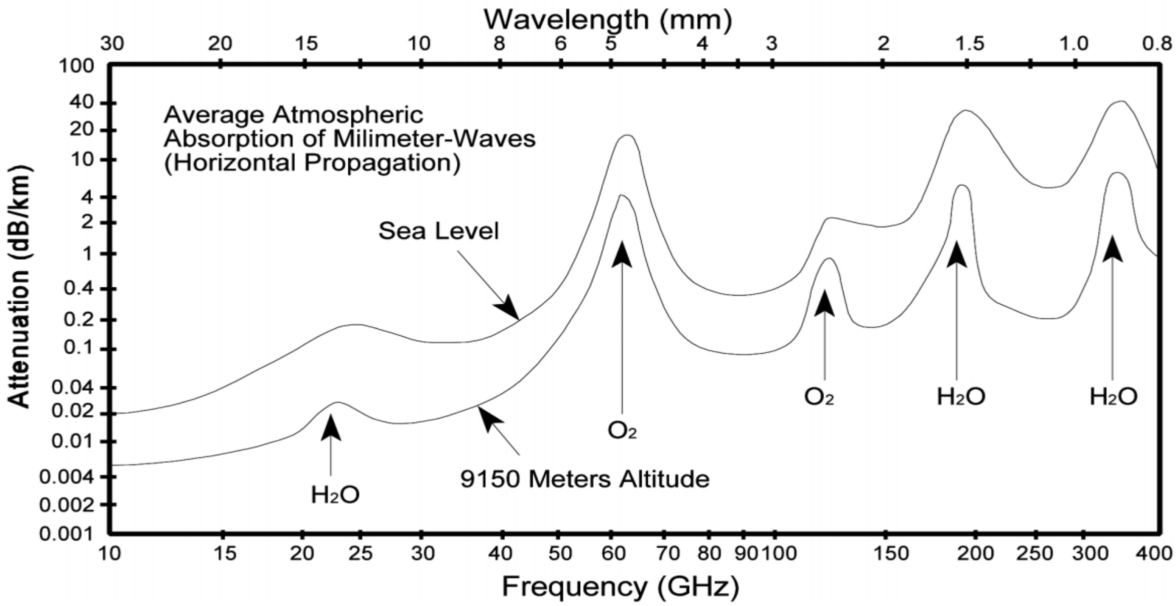


Figure 2.17 Atmospheric and molecular absorption at mmWave frequencies [33]

2.10. Related Work on Microstrip Antenna

Many scholars have investigated and published their findings on many antenna factors such as radiation characteristics, impedance bandwidth enhancement, gain, enhancing radiation pattern, compactness, and polarization of MSAs in the form of research papers. It was quite helpful in comprehending the ways for increasing the aforementioned antenna characteristics.
The following is a brief description of the work published by researchers on MSAs.

[19] Presents a simple high gain 60 GHz antenna that is high gain, low profile, and inexpensive cost. The 60 GHz ISM band is covered by the antenna's 10-dB return loss matching bandwidth (57-64 GHz). The gain of the bore sight antenna is 11 dB. The proposed antenna structure is well suited to low-power, short-range wireless communication applications. The suggested antenna does not have any vias. The design simplicity eases and relaxes any fabrication process requirements.

Microstrip Array Antenna with Ultra-Wideband for 5G Millimeter-wave [21] describes uses and proposes a design for a 5G millimeter-wave ultra-wideband microstrip array antenna employing a stepped line cut and U-slot combination. The proposed design employs a proximity coupling feeding mechanism to improve bandwidth performance. To determine the bandwidth improvement, the suggested antenna bandwidth performance is compared to that of a standard antenna array design. When compared to traditional design, numerical and simulation results reveal a considerable boost in bandwidth performance. The suggested antenna may operate in the 28 GHz frequency spectrum, with a bandwidth of 4.47 GHz and a gain of 8.71dB. These results prove that the proposed antenna design can be used for 5G technology applications in the millimeter-wave band.

To fulfill the demands of long-distance communication, several applications necessitate antennas with extremely high gain. A single antenna has a lower gain or directivity. An antenna array is a way for increasing gain and directivity. This can be accomplished by increasing the antenna's size. When the size of a single antenna are increased, it frequently results in more directional qualities. An antenna array is another approach for boosting antenna dimensions without increasing the size of individual elements. It's one of the most prevalent techniques for merging the radiation from a group of comparable antennas where wave interference is a factor. The findings of single feed and dual feed microstrip patch antenna arrays are compared in this work [22]. Microstrip patch antennas come in a variety of geometrical shapes and can be used in a variety of applications. Two more of their various advantages are its light weight structure and compatibility with microwave integrated circuits. Furthermore, because of the simplicity of the construction, these antennas are appropriate for low-cost production. This is also one of the main reasons why microstrip patch antennas are utilized in wireless communication systems. In addition, microstrip patch antennas can support dual and circular polarizations, dual-frequency operation, a wide bandwidth, and feed line flexibility. As a result, this project presents a microstrip rectangular patch antenna that has been optimized (by changing parameters and adding a slot) for Bluetooth and ZigBee applications.

The software environment for designing and comparing antenna performance is Computer Simulation Technology (CST) microwave studio. Based on the findings and analysis, it's clear that the optimized patch antenna has a smaller return loss than a standard patch antenna. Furthermore, the optimized patch antenna has a lower VSWR than the circular patch [23].

In [34] The microstrip antennas are commonly used due to the fact they may be compact and it is simple to acquire a unidirectional radiation pattern. The patch antennas' bandwidth, on the other hand, is somewhat limited, limiting their application in wideband systems. A simple compact wideband patch antenna with rectangular slot is proposed in this study a rectangular patch tapered from a microstrip feeding structure and a truncated ground plane make up the antenna that was created. The suggested antenna is etched onto a 35mm x 28mm x 1.6mm FR4 printed circuit board. Using ADS simulation software, the settings are tuned. At a resonant frequency of 6.8 GHz, a minimal return loss of -18dB is achieved. The antenna directivity is 5.17dBi and gain of the antenna is 0.085dBi.

[25] Inside this paper Antennas are a necessary component of wireless communication. Antennas come in a variety of shapes and forms, and they are used in a variety of applications. Microstrip patch antennas are becoming increasingly used in advanced electronics products. The research of several types of microstrip antennas was the subject of this paper. Return loss, VSWR, bandwidth, resonant frequency, and gain are all important factors to consider when evaluating antenna performance. A good return loss value is less than -10dB. VSWR has a significant range of 1-2. CST Microwave Studio is cutting-edge software for designing and simulating various types of antennas, filters, and other components.

Microstrip antennas are built in a variety of shapes, ranging from rectangular to triangle and then to triangle with slot. The proposed antenna layout was successful in providing coverage for the 5G wireless technology. The triangle with slot antenna has the lowest return loss of -29.23dB, and the triangle antenna has the highest gain of 8 dB at 61.93 GHz. This antenna is designed for use in a 5G wireless communication system with a short range and high data rate. [35].

In paper [36] a micro strip patch antenna with a centered frequency of 38GHz and 54GHz and bandwidths of 1.94GHz and 2GHz, respectively, for future 5G communication technologies, with a low-cost substrate and small patch size perfectly suited for miniaturized devices. It's made up of a Rogers RT5880 (lossy) substrate with a dielectric constant of 2.2, a loss tangent of 0.0013, and a standard thickness of 0.508mm, as well as a PEC patch and a PEC ground. The substrate is 6mmx6.25mm in size, and the patch is 2mmx2mm in size. The technique of microstrip-line feeding is applied. Using tapered line feeding, a four-element array with a spacing of 4mm was proposed to achieve 12 dB gain for mobile data applications on millimeter wave frequencies of 38.6GHz, 47.7GHz, and 54.3GHz, with bandwidths of 3.5GHz, 2.5GHz, and 1.3GHz. The antenna's overall dimensions are 6mmx6.25mmx0.578mm. CST Microwave Studio is used to simulate the suggested antenna design.

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

Designing of the rectangular microstrip patch array antenna at 23 GHz and 60GHz operating frequency, includes the single frequency band. The frequency band I have taking from 55-65 GHz for 60 GHz and 20-30 GHz for 23 GHz is operating frequency for this thesis work. Because the 60 GHz frequency is unlicensed and enables large data speeds, it is a good choice, therefore I have using this frequency for VANET. It operates in the millimeter band's V-Band, is unlicensed everywhere, and hence is free of any congestion or traffic. A half-wavelength segment of rectangular microstrip transmission line makes up the rectangular patch antenna. The antenna's resonant length is slightly shorter due to the expanded electric "fringing fields," which increases the antenna's electrical length slightly. [37], [4]. The linear polarization of microstrip antennas is inherent. We're particularly interested in the rectangular microstrip antenna because it has the highest impedance bandwidth and, in comparison to the others, is very easy to analyze and fabricate. In this thesis work we have used two patch and four patch element because of energy saving.

3.2. Materials

In this thesis work, software such as MATLAB/R2017a for parameter calculation and Simulation Using CST (computer simulation technology) Microwave Studio for designing, is used.

3.3. Design Methodology

The steps taken to achieve the design of the antenna are:

3.3.1. Design of Single Rectangular Microstrip Patch Antenna

The detailed design specifications for the single element RMSA are:

i. The operating frequency (fr) is for VANET application. For this design project, 60 GHz in the V band has been chosen as the operating frequency.

ii. The substrate material that is a substrate selected for this thesis Rogers RT Duroid 5880 was utilized for the design of the single element RMSA. At a 60 GHz operating frequency, the dielectric constant and loss tangent of RT Duroid 5880 are Ɛr = 2.2 and tangent loss = 9*10-4, respectively.

iii. The height (h) or the thickness, because the antenna should not be bulky, the dielectric substrate of a microstrip patch antenna is crucial. The RMSA's height is determined by the information provided by [27] as:

$$h \leq \frac{0.3c}{2\pi f\sqrt{\varepsilon r}} \qquad [3.1]$$

The following are the detailed technique and design equations for the single element, single band rectangular microstrip patch antenna:

Step 1. Design of elemental width (W): The elemental width of RMSA is given by [4],

$$w = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r + 1}} \qquad [3.2]$$

Step 2. Design of extension length (Δl): The extension length Δl is usually deducted from the calculated length L of RMSA in order to retain the actual length of the patch constant.

$$\Delta L = 0.412h\left(\frac{(\varepsilon reff + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon reff - 0.258)(\frac{w}{h} + 0.8)}\right) \qquad [3.3]$$

Where Ɛreff is the effective dielectric constant [3].

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \qquad [3.4]$$

Step 3. Design of elemental length (L): The preceding equations (3.3) and (3.4) are used to calculate the extension length (l) and effective dielectric constant (Ɛreff), respectively. The elemental length of RMSA is calculated using the equation [4],

$$L = \frac{c}{2fr\sqrt{\varepsilon reff}} - 2\Delta l \qquad [3.5]$$

Step 4. Design of microstrip line feed: The 50 Ω microstrip line feed is designed by calculating the values of W/h ratio for the known values of characteristic impedance Z_0 and Ɛr. The design equations are [4],

$$\frac{Wf}{h} = \frac{8e^A}{e^{2A} - 2} \qquad for\ \frac{wf}{h} < 2 \qquad [3.6]$$

$$\frac{Wf}{h} = \frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\mathcal{E}r - 1}{2\mathcal{E}r}\left\{\ln(B - 1) + 0.39 - \frac{0.61}{\mathcal{E}R}\right\}\right] \qquad for\ \frac{wf}{h} > 2 \qquad [3.7]$$

Where,

$$A = \frac{Z0}{60}\sqrt{\frac{\mathcal{E}r + 1}{2}} + \frac{\mathcal{E}r - 1}{\mathcal{E}r + 1} \qquad [3.8]$$

And

$$B = \frac{377\pi}{2Z0\sqrt{\mathcal{E}r}} \qquad [3.9]$$

The above equations (3.6) to (3.9) the width of microstrip line feed W_f is determined by multiplying the value of h to the value obtained from equation (3.6) or (3.7) as per their $\frac{Wf}{h}$ condition. The L_f is the length microstrip line feed and it is obtained from effective guide wavelength λ_g. In order to keep minimum loss in microstrip line feed the length L_f is commonly taken as $\lambda_g/4$) for single element RMSA.

The L_f is extended to any value which acts as connecting link between patch and source. It is given by [4],

$$Lf = \frac{\lambda_g}{4} \qquad [3.10]$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{\mathcal{E}_{reff}}} \qquad [3.11]$$

Where, $$\mathcal{E}reff = \mathcal{E}r - \frac{\mathcal{E}r - \mathcal{E}e}{1 + G\left(\frac{fr}{fp}\right)} \qquad [3.12]$$

$$G = \left(\frac{Z_0 - 5}{60}\right)^{-\frac{1}{2}} + (0.004xZ_0) \qquad [3.13]$$

$$f_p = \frac{Z_0}{2\mu_0 h} \qquad [3.14]$$

$$\mu_0 = 4\pi \times 10^{-9}$$

And $$\lambda_0 = \frac{c}{f_r}$$ [3.15]

The figure (Fig.3.1 illustrates a 50 microstrip line feed with a length Lf and a width W_f that was built using the above technique and is connected to the rectangle radiating patch's width W at the center point (Cp). The patch's impedance at Cp may or may not be equal to 50. Because of the impedance mismatch, the microstrip line feed should not be connected to this point. The matching transformer is used between Cp and 50 **Ω** microstrip line for better impedance matching

Step 5. Design of quarter wave transformer: The quarter wave transformer is a key circuit component in microstrip systems. The quarter wave transformer is named after its length, which is one fourth of the guiding wavelength (λg). The quarter wave transformer is in charge of converting the impedance of two different sections.

$$Z_t = \sqrt{Z_1 x Z_3}$$ [3.16]

This transformer is used to transform the different between the two impedances and also for the possible impedance mismatch.

The below equations are used to determine the impedance R_{in} at Cp along the width of RMSA [37],

$$Rin \cong \frac{(\,120\lambda 0)^2 + \left(\frac{377h}{\sqrt{\varepsilon rL}}\right)^2 tan^2\beta l}{240 * L * \lambda 0(1 + tan^2\beta l}$$ [3.17]

Where,

$$\beta = \frac{2\pi\sqrt{\varepsilon r}}{\lambda 0}$$ [3.18]

$$l = \frac{\boldsymbol{\theta\pi}}{180\beta} = \frac{w}{2}$$ [3.19]

Z_t is the impedance of quarter wave transformer, $= \sqrt{(Rin\ \times Z0)}$. W_t is the width of quarter wave transformer obtained by using equations (3.6) to (3.9). L_t is the length of quarter wave transformer obtained by using equations (3.10) to (3.16) by replacing Z_0 by Z_t.

The Fig. 3.1. Shows the designed geometry of center fed single element conventional RMSA.

Step 6. Design of ground plane: The ground plane dimensions should be [4],

$$Lg = 6h + L \qquad [3.20]$$

$$Wg = 6h + W \qquad [3.21]$$

The size of the ground plane of single element antenna is taken as Lg × Wg = 15mm×8mm, in this work and are quite larger than the required ground plane size. Taking into account, the size of the substrate is taken as 15mm×8mm. The Fig. 3.1. Shows the rectangular radiating element along with the feed network is etched on the top surface of the substrate and the ground etched on the bottom surface of the substrate.

The goal of this section is to create a single micro strip patch antenna that includes a patch, quarter wave transformer, and feed line. A rectangular patch antenna is utilized in the patch antenna design. The feed line will be a 50- feed line since a 50- surface mount adapter (SMA) connection will be needed to link it to the coaxial cable. A matching network, which is a quarter-wave transformer, will feed the feed line to the patch [4].

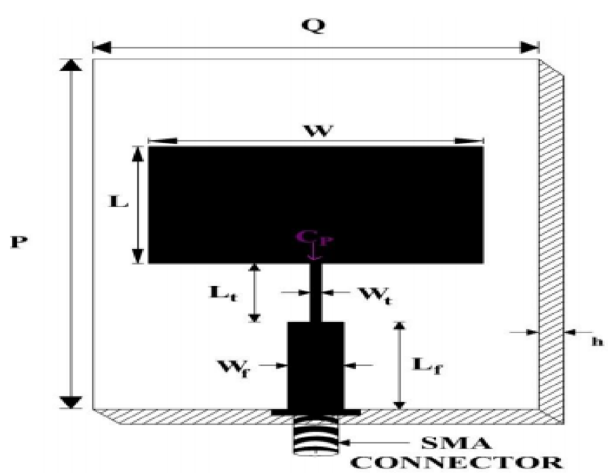


Figure 3.1 Geometry of center fed single element conventional RMSA.[4]

Table 3.1 summarizes the results of the design calculations for various patch, ground plane, and edge feed line dimensions for the single element edge fed RMSA.

Table 3.1: Single Patch Antenna Design Specifications.

Parameters	Value
Dielectric constant	2.2
Loss tangent	0.0009
Height of substrate	1.588 mm
Length of patch	0.553 mm
Width of patch	1.9764 mm
Height of patch	0.035 mm
Width of microstrip line (QWT)	4.961 mm
Length of microstrip line (QWT)	9.37 mm
Frequency of operation	60 GHz
Edge feed width	1.64 mm
Edge feed length	2.35 mm
Feeding Impedance	50 Ω
Width of ground plane	8 mm
Length of ground plane	15 mm
Number of antenna	1

Antenna Array for Access-point-Type Device

Antenna arrays are composed of group of similar antenna elements. The "grouping" of antennas increase the gain compared to a single element antenna. At the same the radiated power is more concentrated to one certain direction. This is due to reduced beam-width compared to the single element antenna. The radiation characteristics of an antenna array can be determined by the antenna element separation and orientation. Also the phase and amplitude difference between antenna elements control the radiation pattern and gain of the antenna array. Electronic control of these phase and amplitude differences allows the beam forming control. This means that the radiated power can be transmitted to the direction where the receiver is. The electronic control of phase and amplitude differences allows the active tracking of mobile target. This is the main idea of apply this kind of antenna system for a man-machine interface.

The proposed beam-forming array is composed of four elements, which are equally spaced but non-uniformly excited. This section presents the array factor (AF) derivation, which is based on the isotropic point sources. Isotropic point sources can be considered as ideal an antenna, which radiates the power to all direction. The array factor consists of orientation and separation information of point sources while the element factor gives the radiation characteristic of given antenna element. The antenna radiation pattern can be calculated by multiplying the array factor with the element factor of given antenna [1].

Array Factor for N Elements

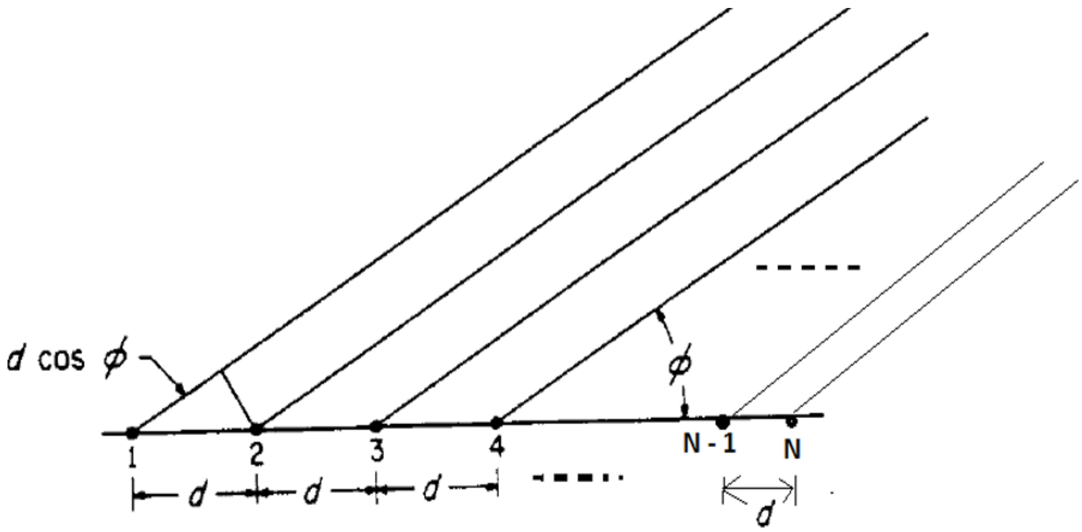
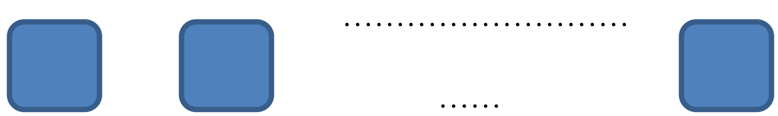


Figure 3.2. An N-element linear array of non-directional radiators



E_0e^{j0} $E_0e^{j\alpha}$ …… $E_0e^{j(N-1)\alpha}$

$$E_T = E_0e^{j0} + E_0e^{j\psi} + \cdots \ldots \ldots . + E_0e^{j(N-1)\psi} \qquad [3.20]$$

$$\psi = \alpha + \beta d cos\theta \qquad [3.21]$$

$$\beta = \frac{2\pi}{\lambda} \qquad \alpha = -\beta d cos\theta \qquad \theta = cos^{-1}\left(\frac{\alpha}{-\beta d}\right)$$

The maximum radiation takes place at $\psi = 0$

$$|E_T| = \left|\frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}\right| \quad [3.22]$$

Pattern Multiplication

$$\left\{\sin\theta \frac{\sin\left(\frac{kW}{2}\cos\theta\right)}{\cos\theta}\right\}\cos\left(\frac{kL}{2}\sin\theta\sin\phi\right) \; single\ patch\ for\ \ H-plane$$

$$\left\{\frac{\sin\left(\frac{kh}{2}\cos\phi\right)}{\frac{kh}{2}\cos\phi}\right\}\cos\left(\frac{kL}{2}\sin\phi\right) \qquad single\ patch\ for\ \ E-plane$$

$$Array\ patter = AF\ x\ (pattern\ of\ \ single\ patch\ antenna) \quad [3.23]$$

Now consider the array shown in Figure 3.2, which is receiving a signal from a plane wave incident at angle θ to the plane of the array.

3.3.2. Design of a 2x1 Rectangular Microstrip Patch Antenna Array

The 2x1 array is fed using a symmetrical one-dimensional parallel feeding approach with proper impedance matching. The characteristic impedance (Z_0) of a microstrip line connected to a 50 source (input port) is 50. At the T-junction, the 50 microstrip line splits into two microstrip lines. The two microstrip lines' characteristic impedance is given as [38]:

$$Z_0 = nZ_S \quad [3.24]$$

The number of microstrip transmission lines coming from a node connected to a source generator is the factor n.

The characteristics impedance of a quarter-wave transformer (Z_Q) is given by [39] as:

$$Z_Q = \sqrt{Z_0 Z_1} \quad [3.25]$$

Where: Z_0= characteristics impedance of the 50 Ω line, and Z_1 = characteristics impedance of the 100 Ω line.

Table 3.2 summarizes the results of the design calculations and specifications for various patch, ground plane, and parallel feed line network dimensions for the 2x1 edge fed RMSA.

Table 3.2: 2x1 Patch Antenna Design Specifications.

Parameters	Value
Dielectric constant	2.2
Loss tangent	0.0009
Height of substrate	1.588 mm
Length of patch	0.553 mm
Width of patch	1.9764 mm
Height of patch	0.035 mm
Width of microstrip line (QWT)	4.961 mm
Length of microstrip line (QWT)	9.37 mm
Frequency of operation	60 GHz
Edge feed width	1.64 mm
Edge feed length	2.35 mm
Feeding Impedance	50 Ω
Width of ground plane	13 mm
Length of ground plane	15 mm
Number of antenna	2

3.3.3. Design of a 4x1 Rectangular Microstrip Patch Antenna Array

This section describes the design of a 4x1 (four-element) single-band rectangular microstrip antenna array. The edge fed 4x1 array has the same design characteristics as the 2x1 array. Table 3.3 summarizes the results of the design calculations and requirements for the 4x1 edge fed RMSA's varied patch, ground plane, and parallel feed line network dimensions.

Table 3.3: 4x1 Patch Antenna Design Specifications.

Parameters	**Value**
Dielectric constant	2.2
Loss tangent	0.0009
Height of substrate	1.588 mm
Length of patch	0.553 mm
Width of patch	1.9764 mm
Height of patch	0.035 mm
Width of microstrip line (QWT)	4.961 mm
Length of microstrip line (QWT)	9.37 mm
Frequency of operation	60 GHz
Edge feed width	1.64 mm
Edge feed length	2.35 mm
Feeding Impedance	50 Ω
Width of ground plane	25 mm
Length of ground plane	15 mm
Number of antenna	4

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Introduction

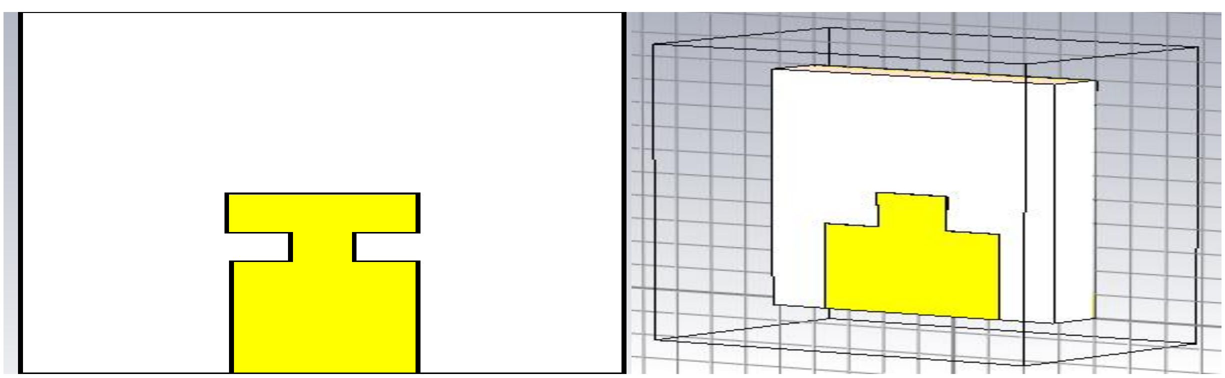
After selecting the substrate parameter, calculating some model parameter and designing rectangular microstrip patch antenna array, the computer simulations are carried out by using CST MW studio 2019 for all the configurations are defined in previous chapter. Performing the relevant computer simulations for each of these situations separately, the corresponding gain, directivity, return loss, beam width, band width and radiation pattern of polarized rectangular microstrip antenna for single patch, 2x1, and 4x1 patch antenna are computed by varying the operating frequency of the substrate material

The Edge feed microstrip antenna arrays were constructed and simulated using CST Microwave Studio, and the results are given below.

4.2. Simulation Result for Single Element Patch Antenna

4.2.1 Discussion of Single Rectangular Microstrip Patch Antenna

The design procedure will be based on the previous chapter's explanation. Figure 4.1 shows the antenna structure that needs to be designed. This structure is going be simulated in CST studio version 2019 and the parameters are going to be calculated using matlabR2019a. Tables and figures are used to display the findings of the computer simulations that were run. Finally, the findings will be reviewed and contrasted based on the parameters chosen.

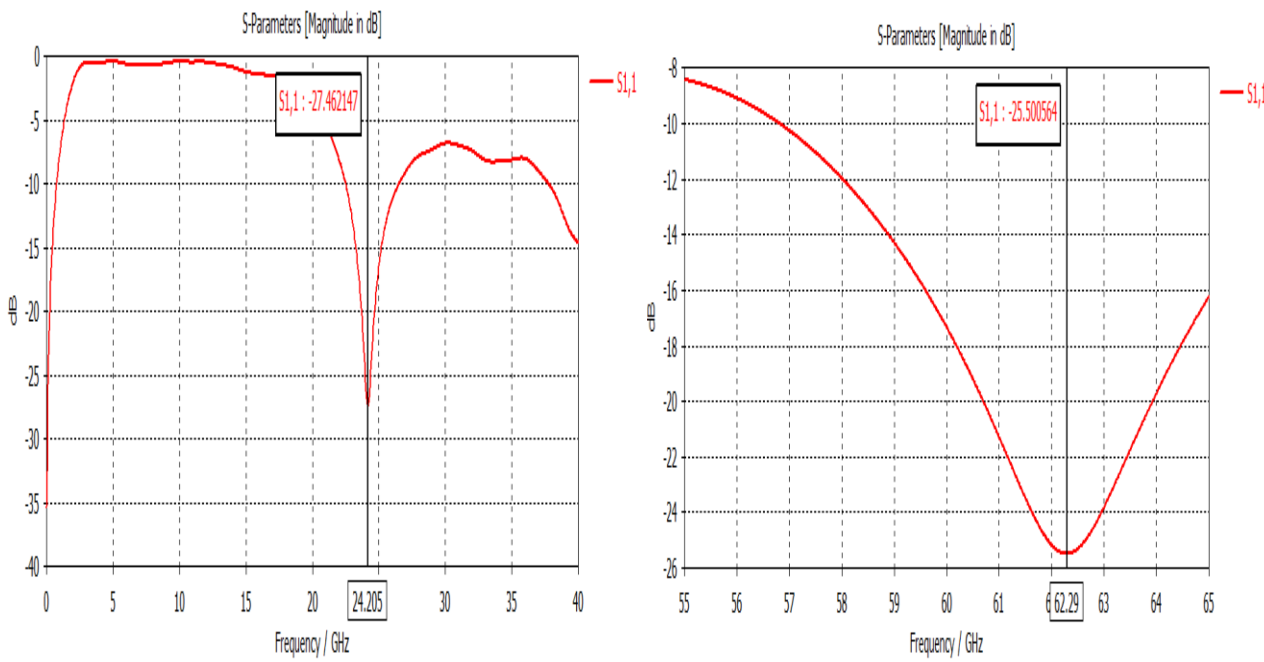


(a) (b)

Figure 4.1: Designed Antenna structure for single patch (a) for 23 GHz and (b) for 60 GHz layout.

Return loss of the microstrip antenna at 23 GHz and 60 GHz for single patch

It is a parameter that is used to calculate the power reflected by the antenna as a result of antenna mismatch. There is nothing to radiate by the antenna if the return loss is 0dB because the power delivered to the antenna is totally absorbed by the antenna, or the power input equals the power reflected. There is a response taken from the magnitude of S11 (dB) vs frequency during the creation of developing polarized rectangular micro strip antenna. The return loss is the term for this. When $\Gamma = 0$ and RL = ∞ dB, this implies that there is no power that is returned or reflected, but when $\Gamma = \infty$ and RL = 0 dB, this shows that the power that is sent is entirely reflected back. For practical applications, VSWR = 2 is regarded to be acceptable as the return loss. The return loss of the microstrip antenna at 23 GHz is -27.462 and 60 GHz is -25.5005 dB.



(a) (b)

Figure 4.2: Return Loss for single rectangular MPA (a) for 23 GHz and (b) for 60 GHz

From the above result, it is shows return loss is very less at the radiated -27.46 dB for 23 GHz and -25.50 dB for 60 GHz frequency. This indicates that the antenna exhibits perfect radiation.

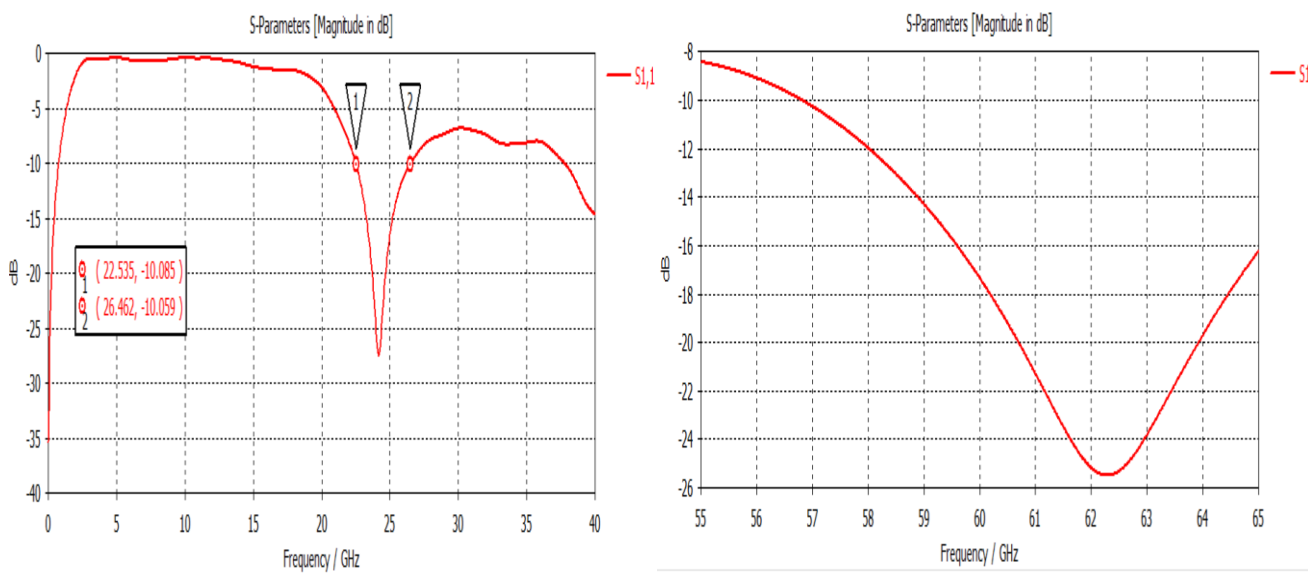
Bandwidth of microstrip antenna at 23 GHz and 60 GHz

The range of frequencies across which the return loss is greater than -10 dB is referred to as the antenna's bandwidth. As a result, the return loss vs frequency plot can be used to compute the antenna's bandwidth. The suggested patch antenna has a bandwidth of 17.56 percent GHz for 60 GHz and 16.22 percent for 23 GHz.

$$\text{Bandwidth} = \frac{(\text{fH} - \text{fL})}{\text{fr}} * 100 \qquad [4.1]$$

Bandwidth = 17.56 %

The bandwidth of the given microstrip antenna is low therefore its value can be increased by decreasing the dielectric constant of the material or by increasing the width of the given patch. The bandwidth can also be increased by using different slots in the patch [4].

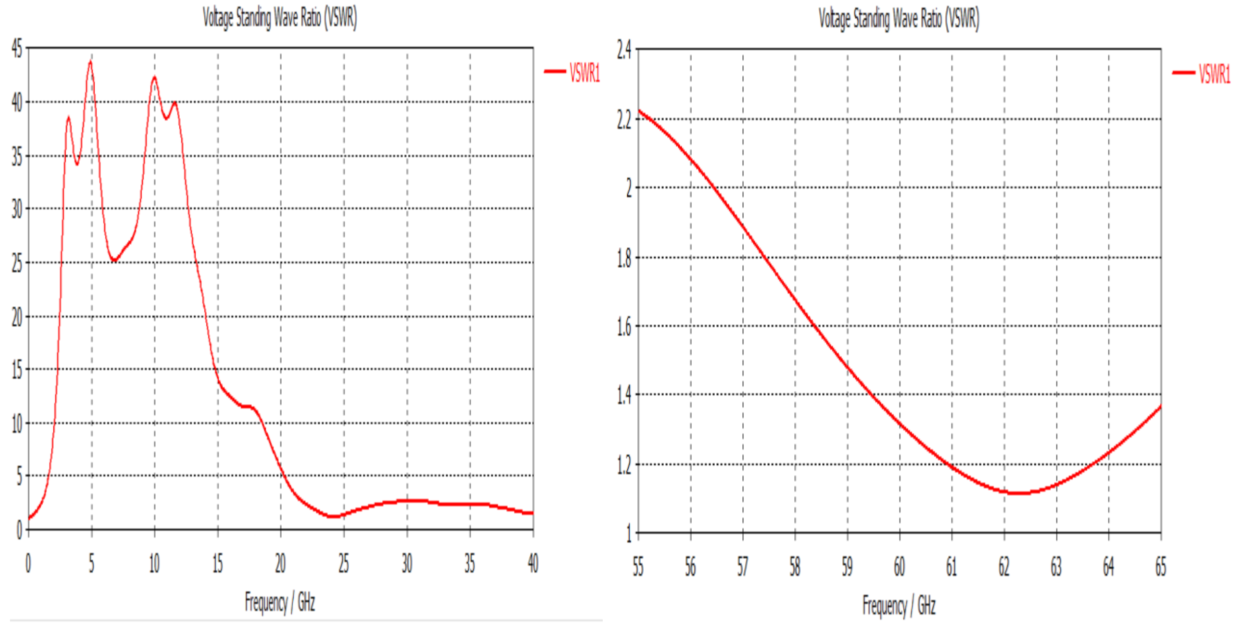


(a) (b)

Figure 4.3: Bandwidth for single rectangular MPA (a) for 23 GHz and (b) for 60 GHz

VSWR (voltage standing wave ratio) of microstrip antenna

The Voltage Standing Wave Ratio (VSWR) is an acronym for Voltage Standing Wave Ratio. This is examined in order to determine the antenna's impedance matching. A good antenna is meant to have a VSWR of less than 2. The antenna's computed VSWR is 1, indicating that it is perfectly matched, since the source and load impedances are correctly matched for optimal power transmission in the given circuit.

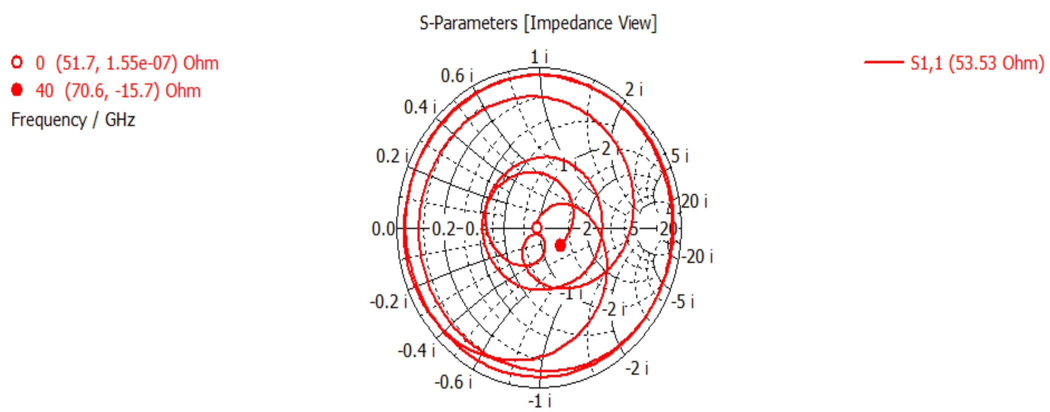


(a) (b)

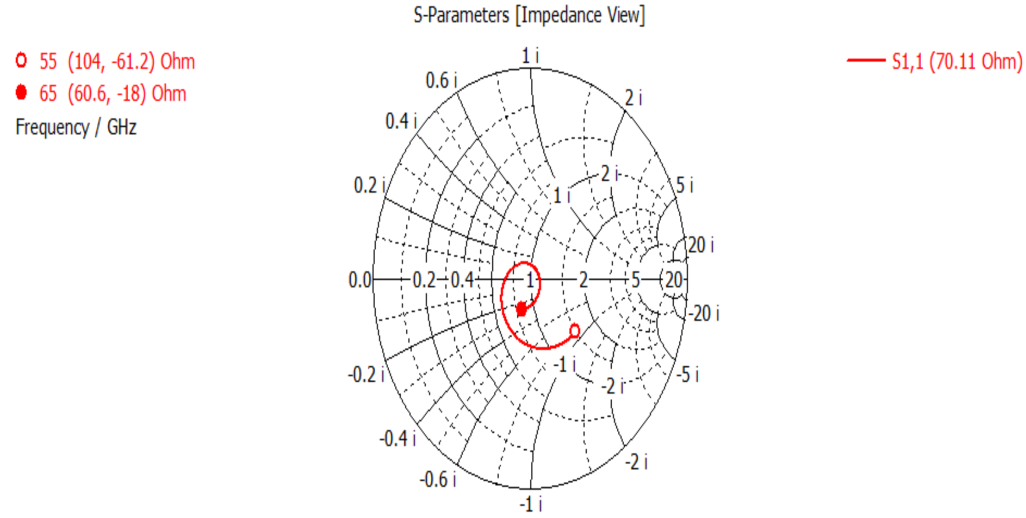
Figure 4.4: VSWR for single rectangular MPA (a) for 23 GHz and (b) for 60 GHz

Smith Chart showing S parameter

It gives the circuit representation of the antenna. Upper side gives the value of inductor, middle one gives the resistor and lower gives the capacitor value.



(a)

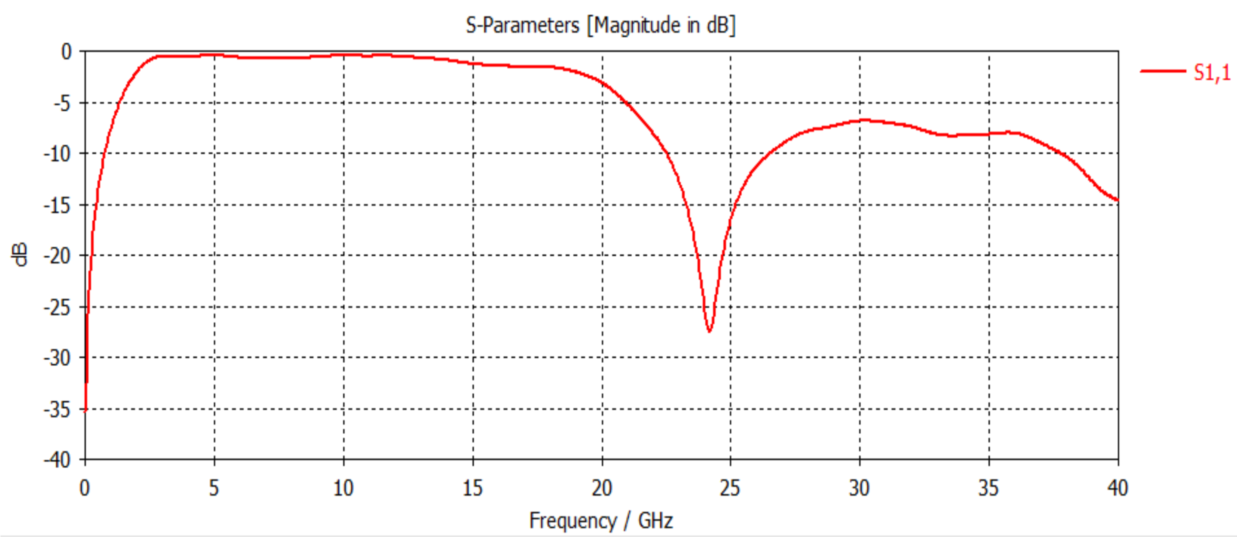


(b)

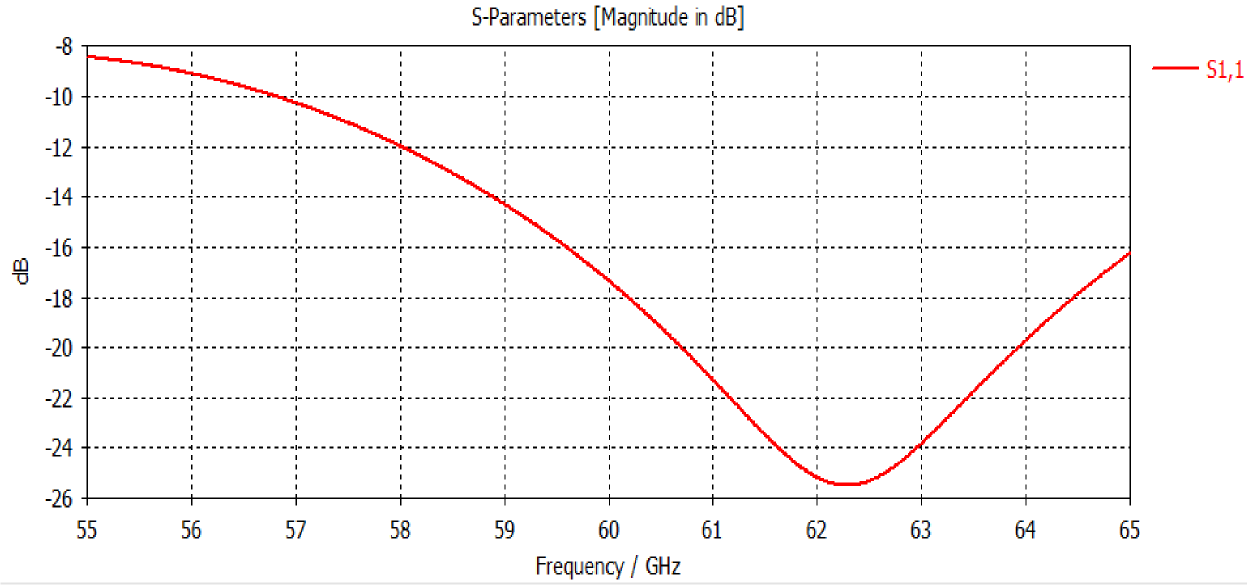
Figure 4.5: Smith Chart for single rectangular MPA at (a) for 23 GHz and (b) for 60 GHz

In the Smith chart, Fig. 4.5 displays the same input reflection coefficient (S11) result. The system's impedance is also resistive at the input, as shown by the Smith chart. The impedance of the system at the resonant frequency is indicated by the marker.

S11 (Reflection Coefficient) parameter in the linear



(a)



(b)

Figure 4.6: Reflection Coefficient single rectangular MPA at (a) for 23 GHz and (b) for 60 GHz

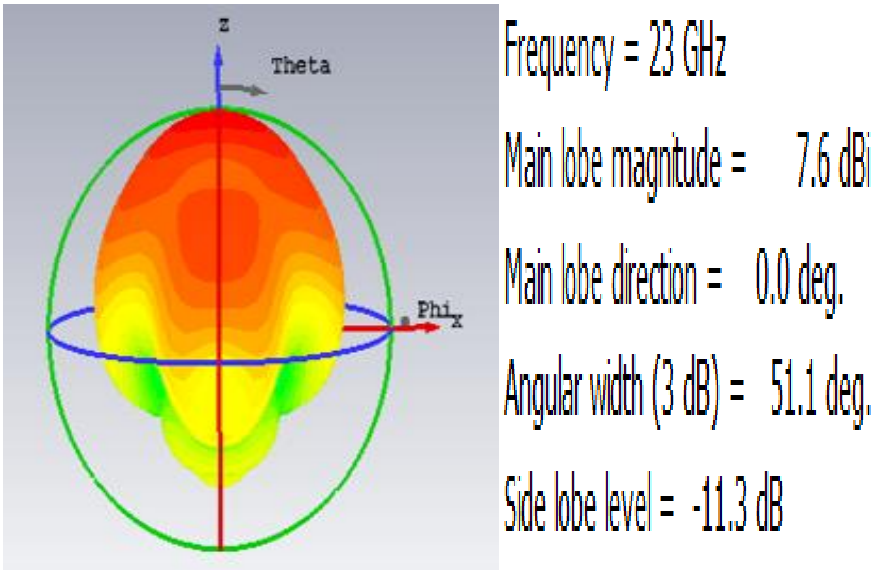
Figure 4.6 displays the behavior of the S11 parameter, also known as the input reflection coefficient, throughout a frequency range. The patch resonates at 23 GHz and 60 GHz, and has lowest loss at the resonant frequency, i.e. -27.5 dB for 23 GHz and -25 dB for 60 GHz, as shown in the figure.

Directivity of the microstrip antenna in the far field region

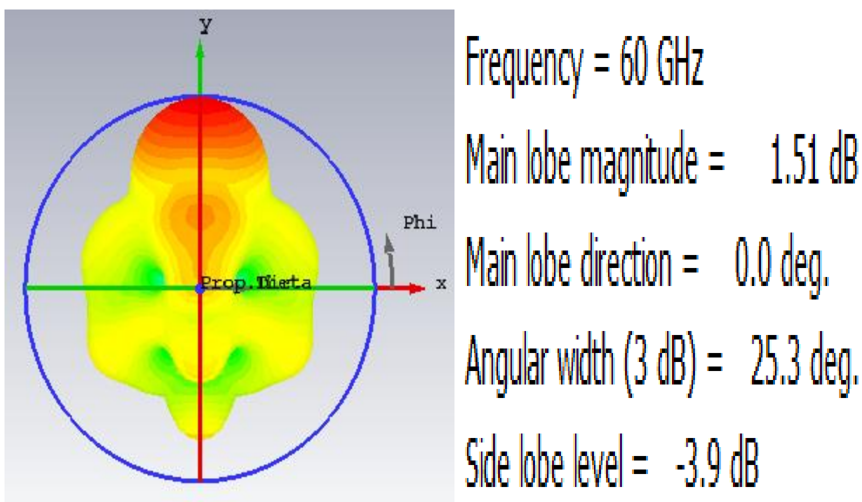
The antenna's directivity denotes the quantity of radiation intensity or gain intensity, i.e. the simulated antenna radiates 8.01 dBi for 23 GHz and 9.07 dBi for 60 GHz more in one direction than the isotropic antenna. The total radiation efficiency of the antenna needs to be lesser than the antennas radiation because it is a product of impedance mismatch loss and the antenna efficiency.

Radiation Pattern

The radiation pattern is the spatial distribution of a quantity that describes an antenna's electromagnetic field. This distribution can be represented graphically or as a mathematical function. [4]. The radiation pattern is normally determined in the far-field region and is typically represented using the spherical coordinate system [4]. The corresponding far field radiation pattern are simulated and measured. The obtained result are present below:



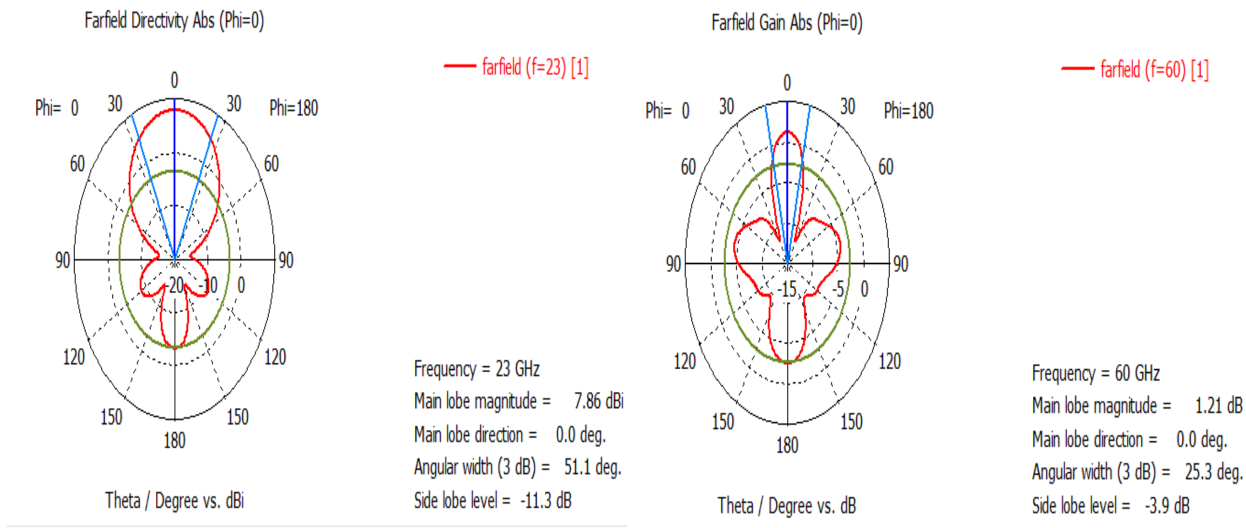
(a)



(b)

Figure 4.7: Radiation pattern of antenna for single rectangular MPA at (a) for 23 GHz and (b) for 60 GHz

Figure 4.7 shows radiation pattern of rectangular micro strip antenna for single patch at 23 GHz and 60 GHz. It is clear that the antenna is a directional antenna with a zero-degree orientation for both. The antenna's far field directivity is shown by the main lobe magnitude. The angular width (i.e. 3dB) bandwidth or half power beam width is 25.3 degree for 60 GHz and 51.1 degree for 23 GHz.



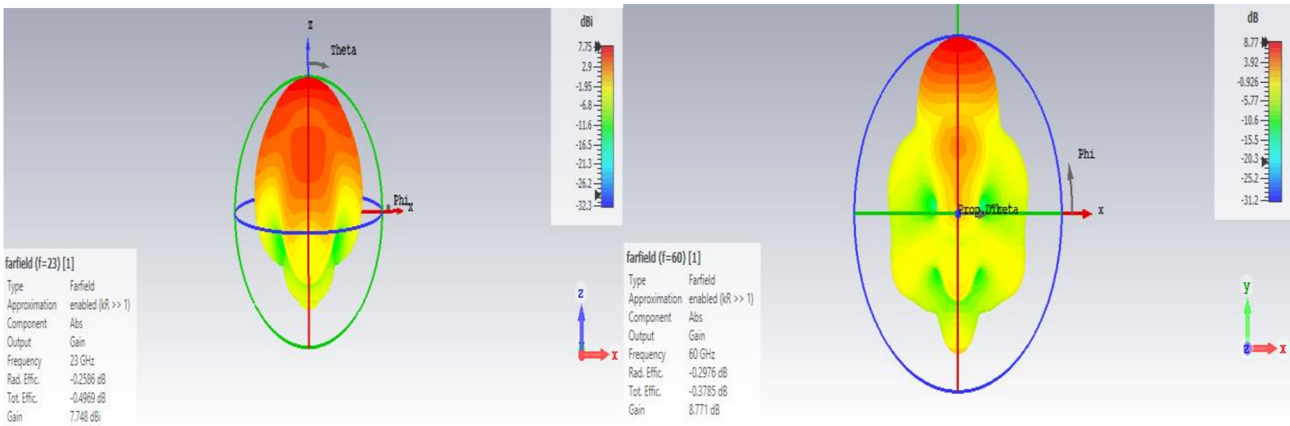
(a) (b)

Figure 4.8: Polar Radiation Pattern Coordinate System and Angles for single rectangular MPA at (a) for 23 GHz and (b) for 60 GHz

Gain of the microstrip antenna in the far field region

The antenna gain in a single direction is higher than an isotropic antenna that radiates in all directions. MPAs have a modest gain because antenna gain is controlled by substrate thickness and relative dielectric constant [40]. Gain is related to substrate thickness and inversely proportional to r. As shown in Figure 4.9, the gain of the planned single rectangular MPA is 7.75 dB for 23 GHz and 8.77 dB for 60 GHz.

To increase the overall gain of the antenna, the antenna arrays are used which helps to increase the overall gain of the given antenna. The slots of different types are also used to increase the overall gain of the given antenna [21].



(a) (b)

Figure 4.9: Gain for single rectangular MPA at 23 GHz and 60 GHz (a) for 23 GHz and (b) for 60 GHz

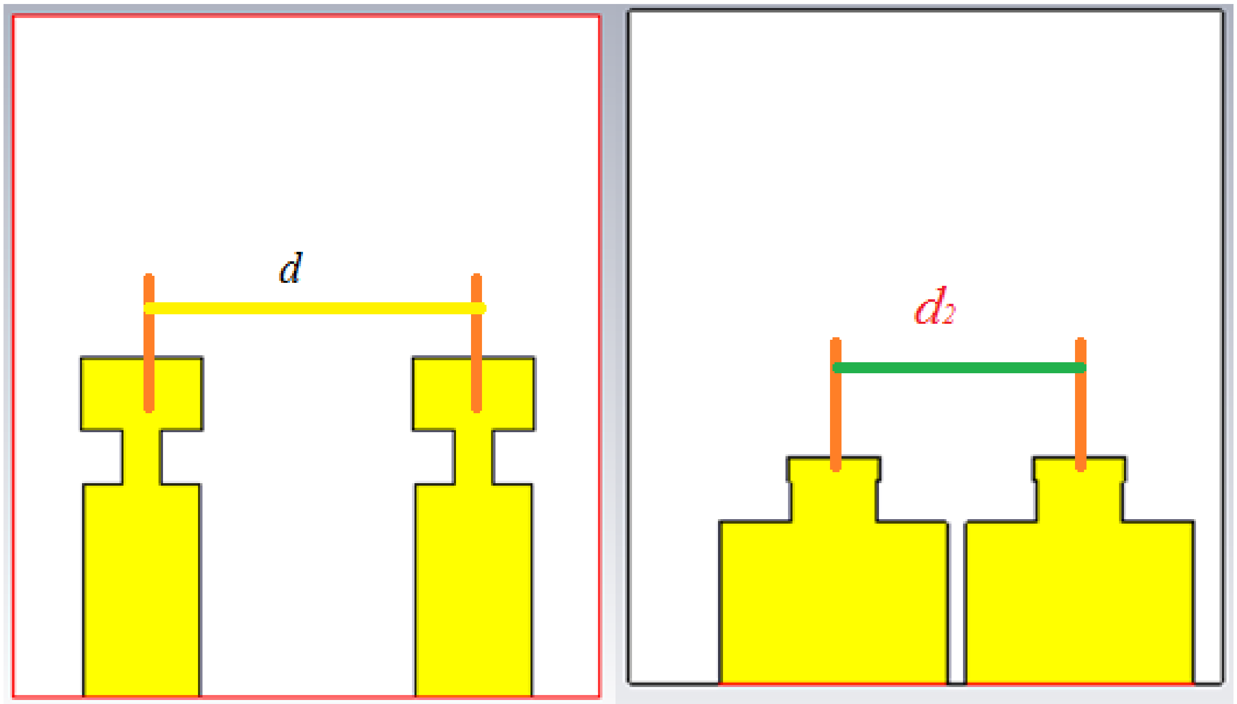
Figure 4.9 shows how much amount of power is radiated from the antenna. The maximum radiation is obtained based in the frequency applied. If the value obtained is 7.75 dB for 23 GHz and 8.77dB for 60 GHz.

Table 4. 1: Comparison analysis of 23 GHz and 60 GHz for single patch.

Frequency	23 GHz	60GHz
Gain	7.75 dB	8.77 dB
Directivity	8.01 dBi	9.07 dBi
VSWR	1.08	1.12
Band width	16.22 %	17.56 %
Return loss	-27.46 dB	-25.50 dB
Radiation efficiency	94.2 %	93.3 %
Beam width	51.1 deg	25.3 deg

4.3. Simulation result for 2x1 rectangular microstrip antenna array

4.3.1 Discussion of 2x1 Rectangular Microstrip Patch Antenna

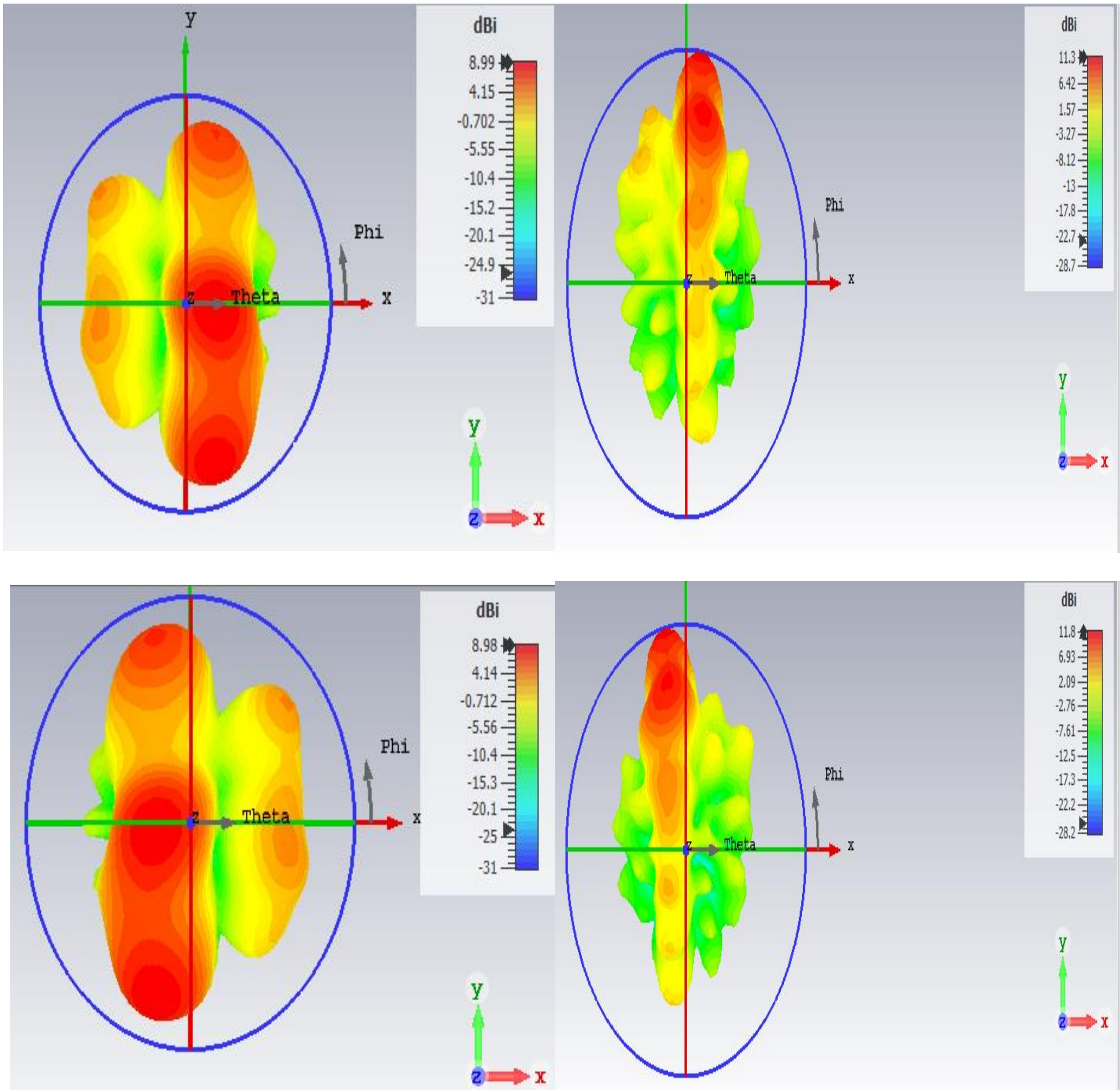


(a) (b)

Figure 4.10: Designed Antenna structure for 2x1 patch (a) for 23 GHz and (b) for 60 GHz layout.

Figure 4.10 shows the configuration of 2x1 linear rectangular patch antenna array for both 23 GHz and 60 GHz. where, *(d)* expresses the distance between two patch antennas for 23 GHz and *(d2)* for 60 GHz.

$$d = \frac{\lambda}{2} \quad \text{And} \quad d_2 = \frac{3\lambda}{2}$$



(a) (b)

Figure 4.11. 3D gain of 2x1 rectangular microstrip antenna array (a) for 23 GHz and (b) for 60 GHz

This describes how much amount of power is radiated from the antenna. The maximum radiation is obtained based in the frequency applied. If the value obtained is not optimized then the performance of antenna is low. The gain is high on the direction of arrival of the incoming signals. If the value obtained is 8.99 dB for 23 GHz and 11.8 dB for 60 GHz.

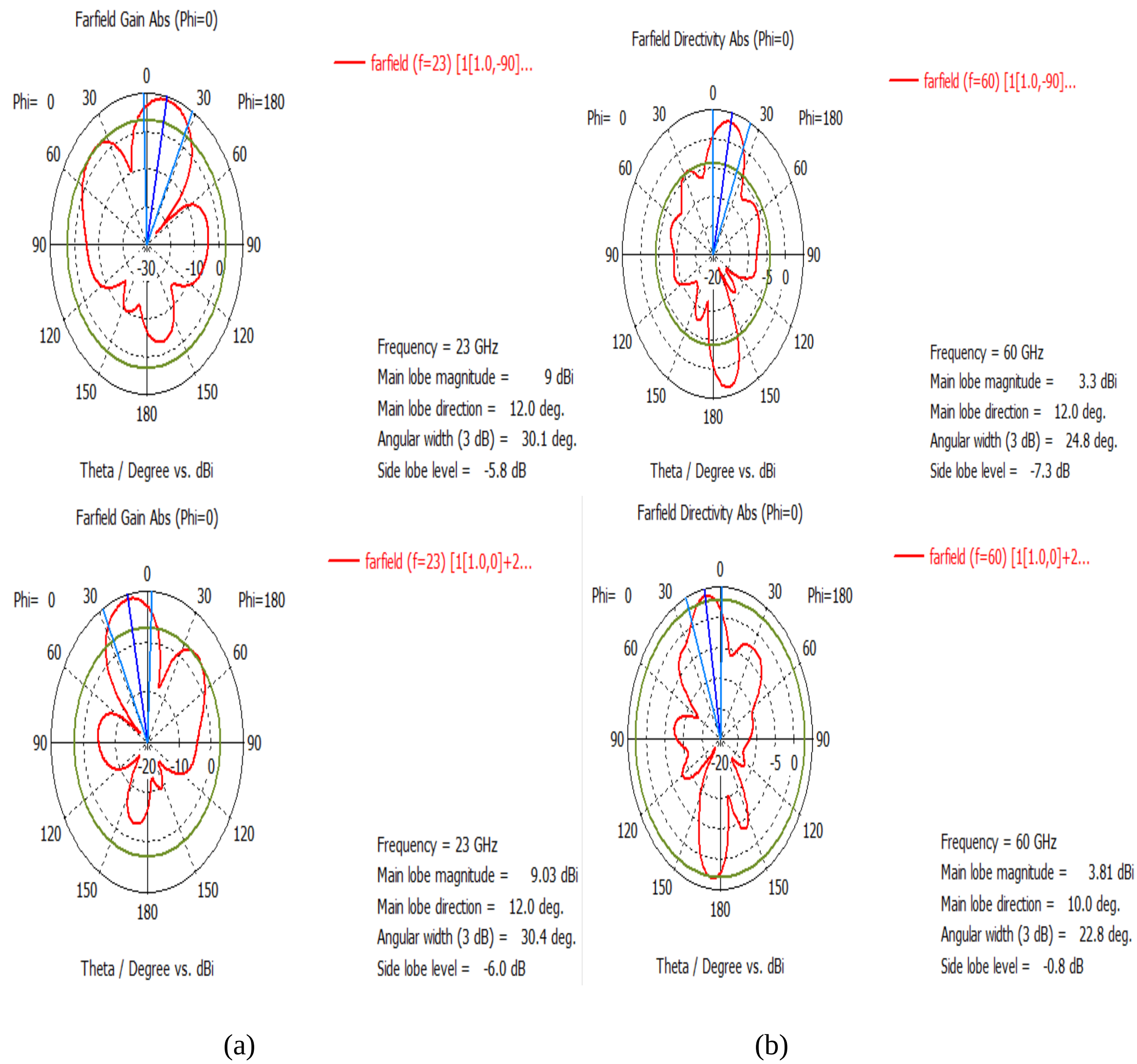
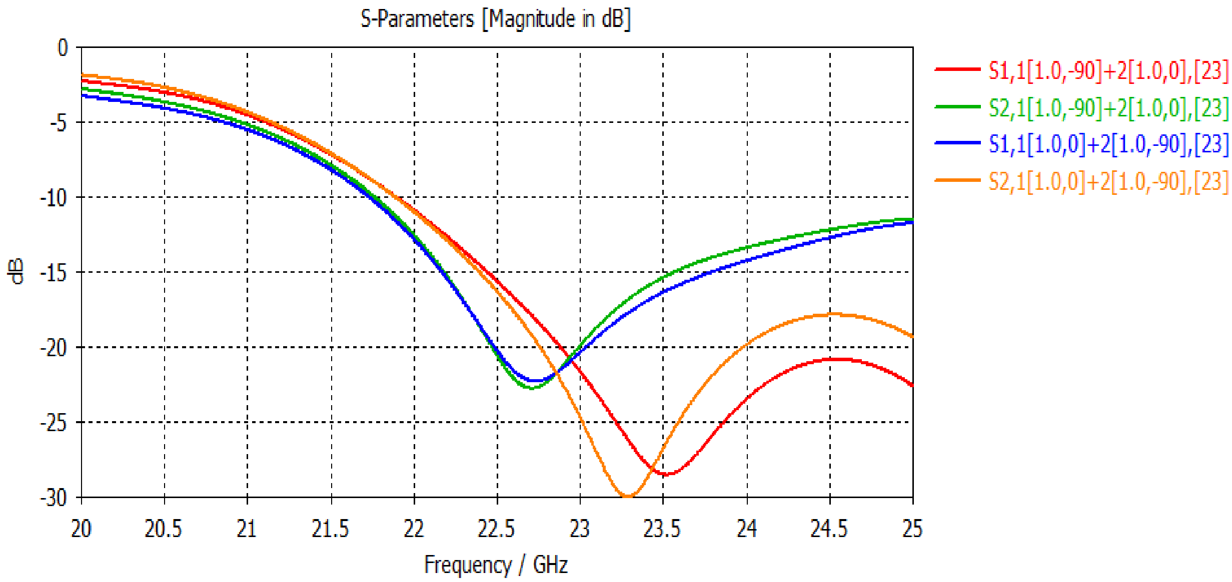
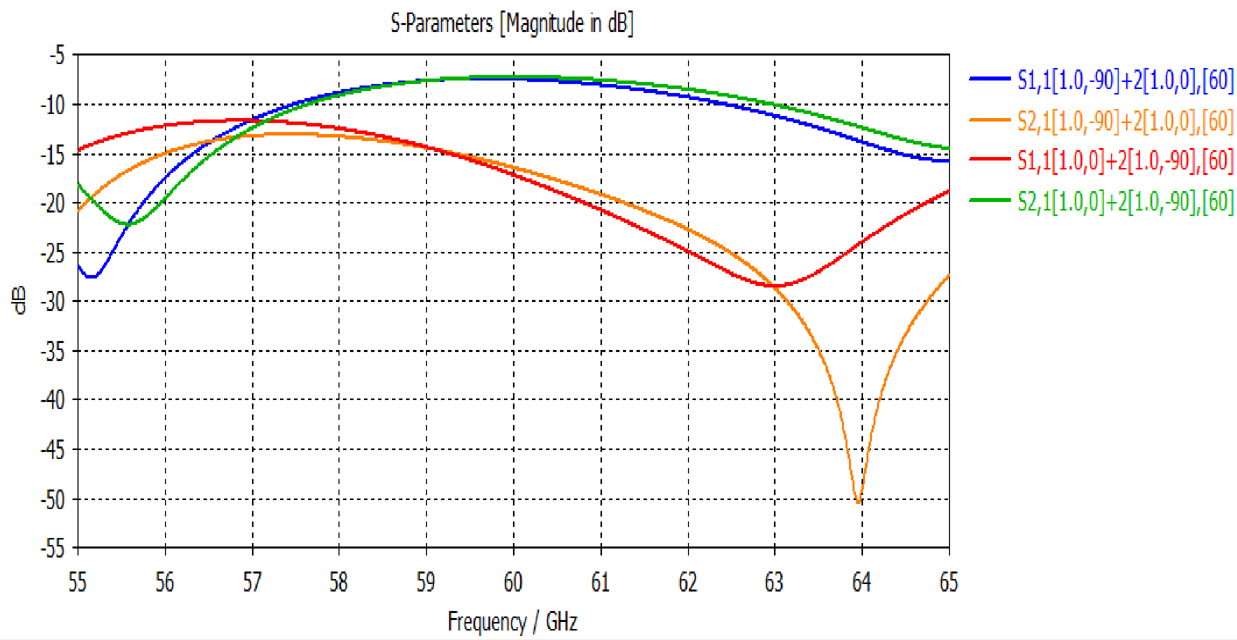


Figure 4.12: Polar Radiation Pattern Coordinate System and Angles for 2x1 patch antenna (a) for 23 GHz and (b) for 60 GHz

Figure 4.12 shows the radiation pattern for both 23 GHz and 60 GHz. It can be seen that the radiation patterns in both designs are in broadside direction. The side lobes appear clearer in those designs. In this case at both 23 GHz and 60 GHz resonant frequency the main lobe magnitude is 9.03 dBi on 23 GHz, 3.81 dBi on 60 GHz and its direction is 12 degree.



(a)



(b)

Figure 4.13: Return Loss for 2x1 patch antenna for (a) for 23 GHz and (b) for 60 GHz

From the above result, it is shows return loss is very less at the radiated -29.99 dB for 23 GHz and -49.89 dB for 60 GHz frequency.

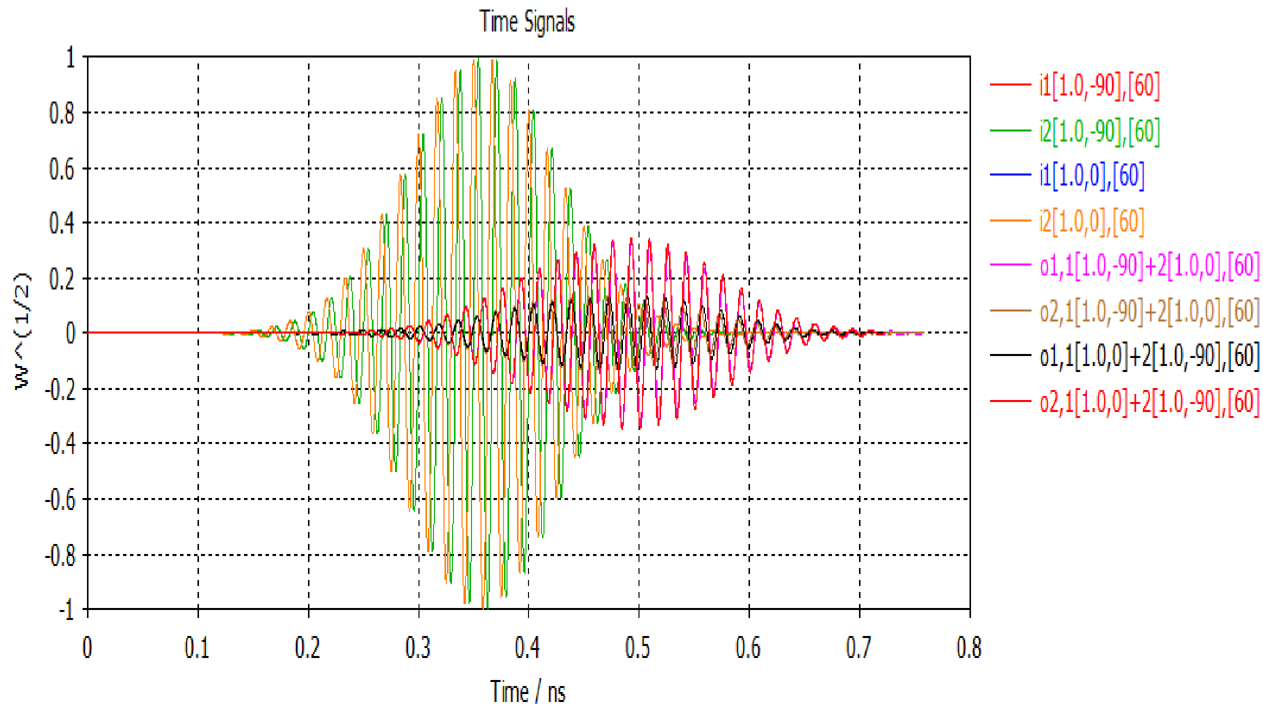


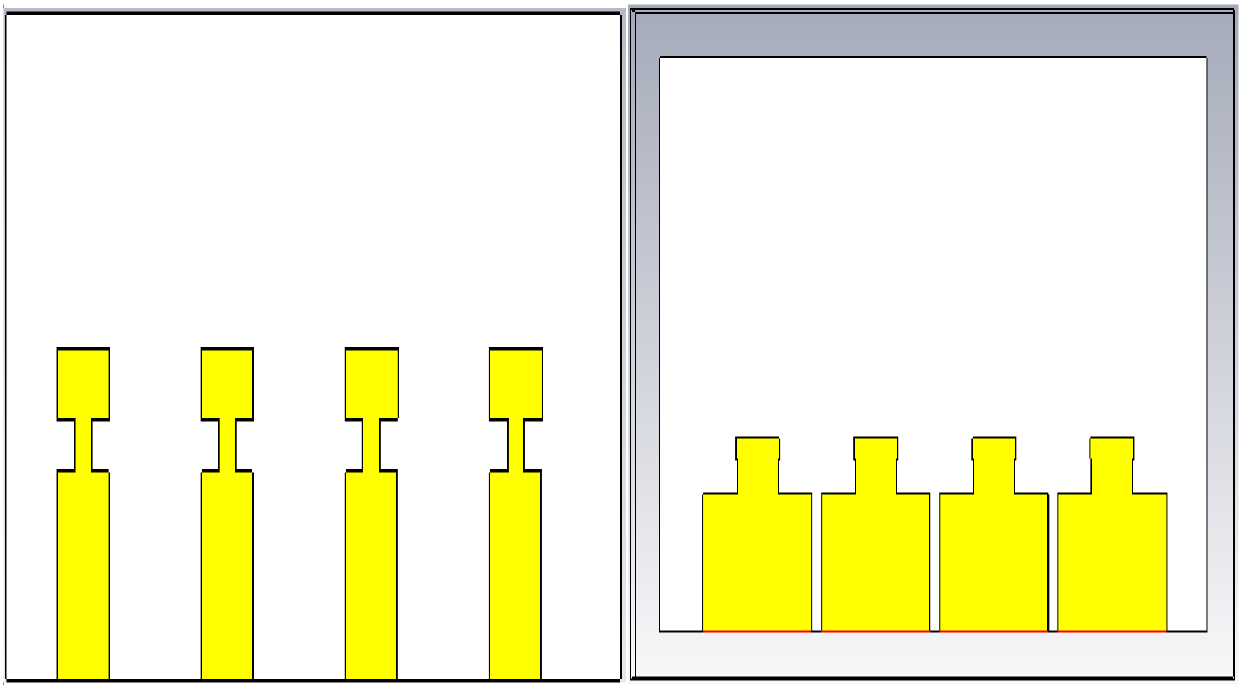
Figure 4.14: Port signal for both 23 and 60 GHz patch antenna on 2x1 element

Table 4.2: Comparison analysis of 23 GHz and 60 GHz for 2x1 patch.

Frequency	23 GHz	60GHz
Gain	8.89 dB	11.23 dB
Directivity	9.11 dBi	11.78 dBi
VSWR	1.21	1.18
Band width	17.43 %	18.11 %
Return loss	-37.51 dB	-49.89 dB
Radiation efficiency	92.5 %	92.1 %
Beam width	30.1 deg	24.8 deg

4.4. Simulation Result of 4x1 Rectangular Microstrip Antenna Array

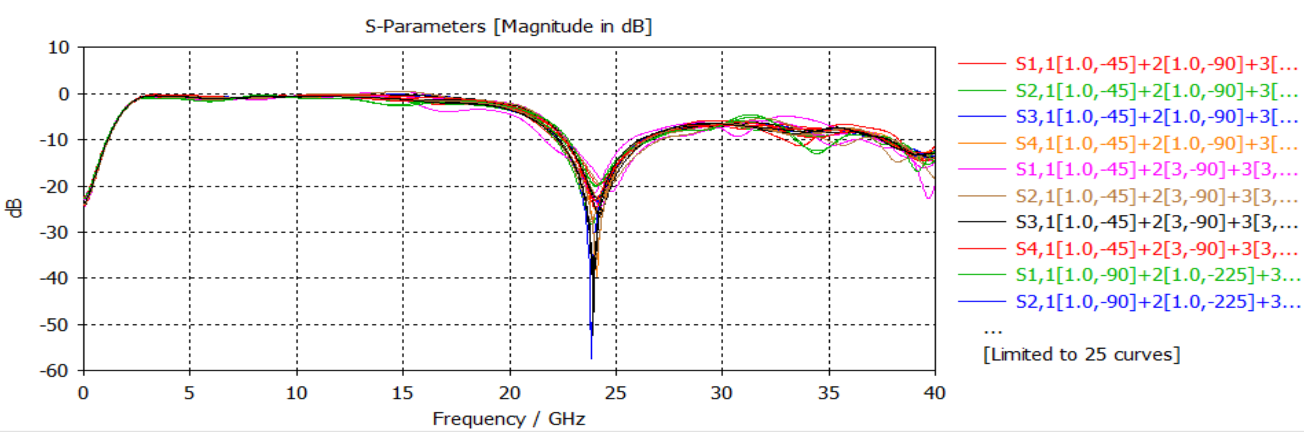
4.4.1 Discussion of 4x1 Rectangular Microstrip Patch Antenna



(a) (b)

Figure 4.15: Designed Antenna structure for 4x1 patch antenna (a) for 23 GHz and (b) for 60 GHz layout.

Figure 4.15 shows the configuration of 4x1 linear rectangular patch antenna array for both 23 GHz and 60 GHz. The dimensions of quarter wave transformer are based on calculations



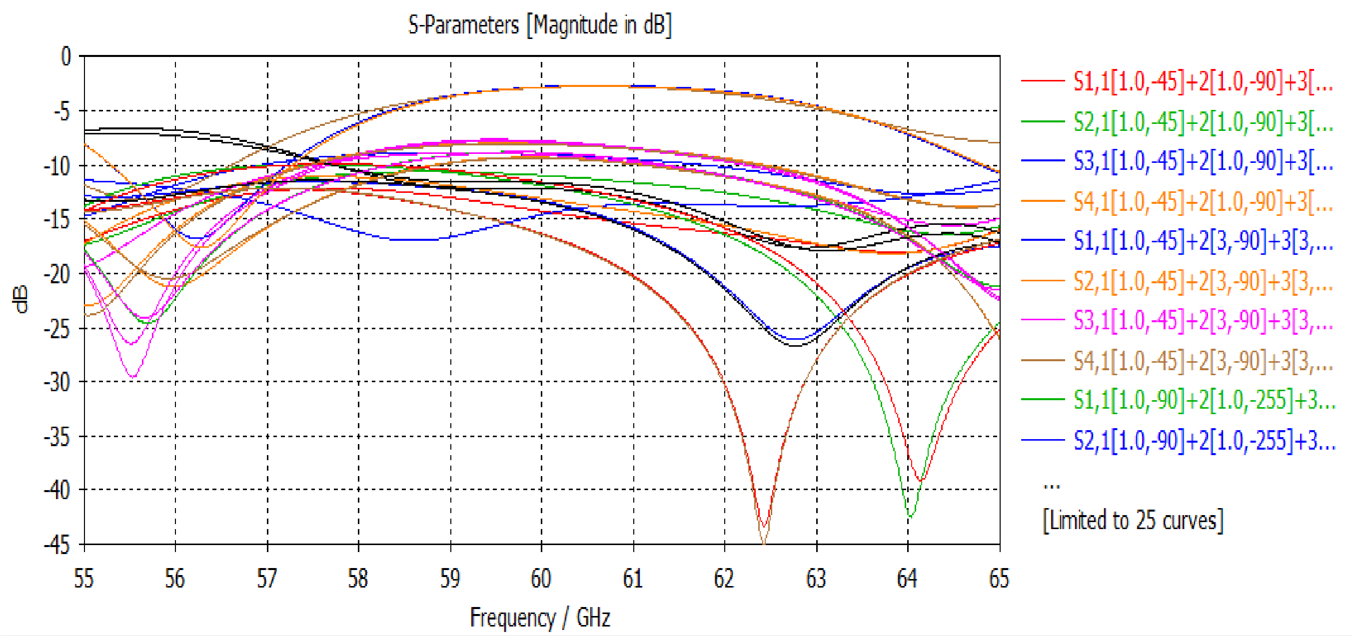
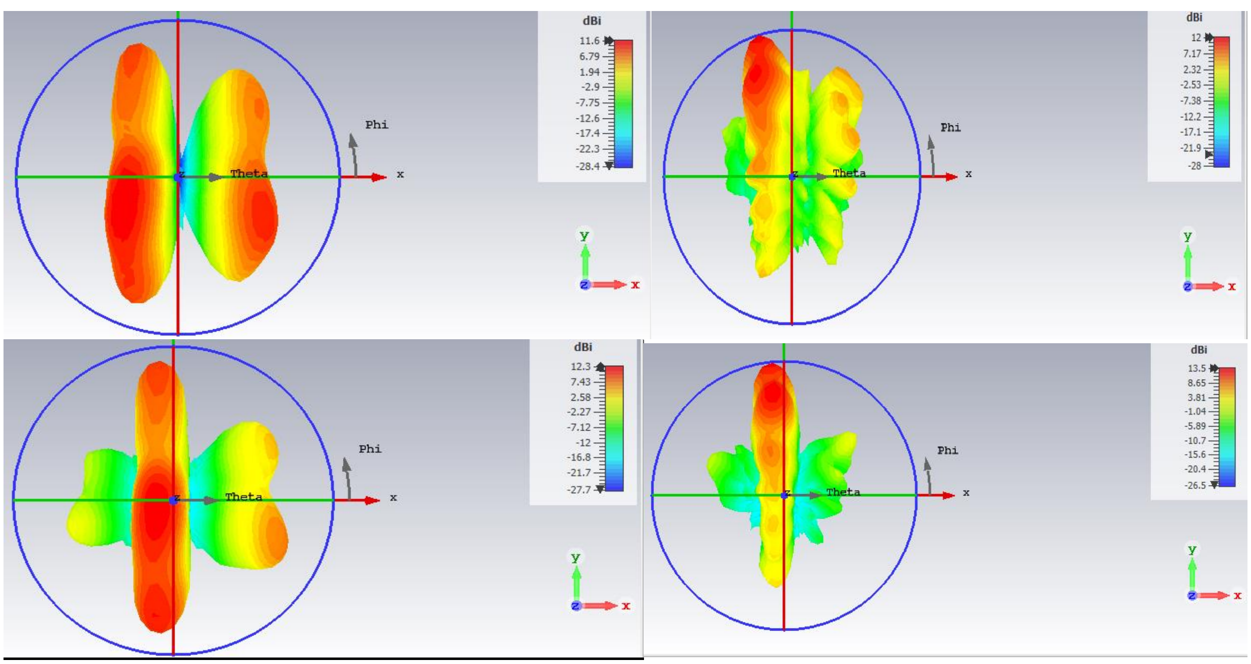
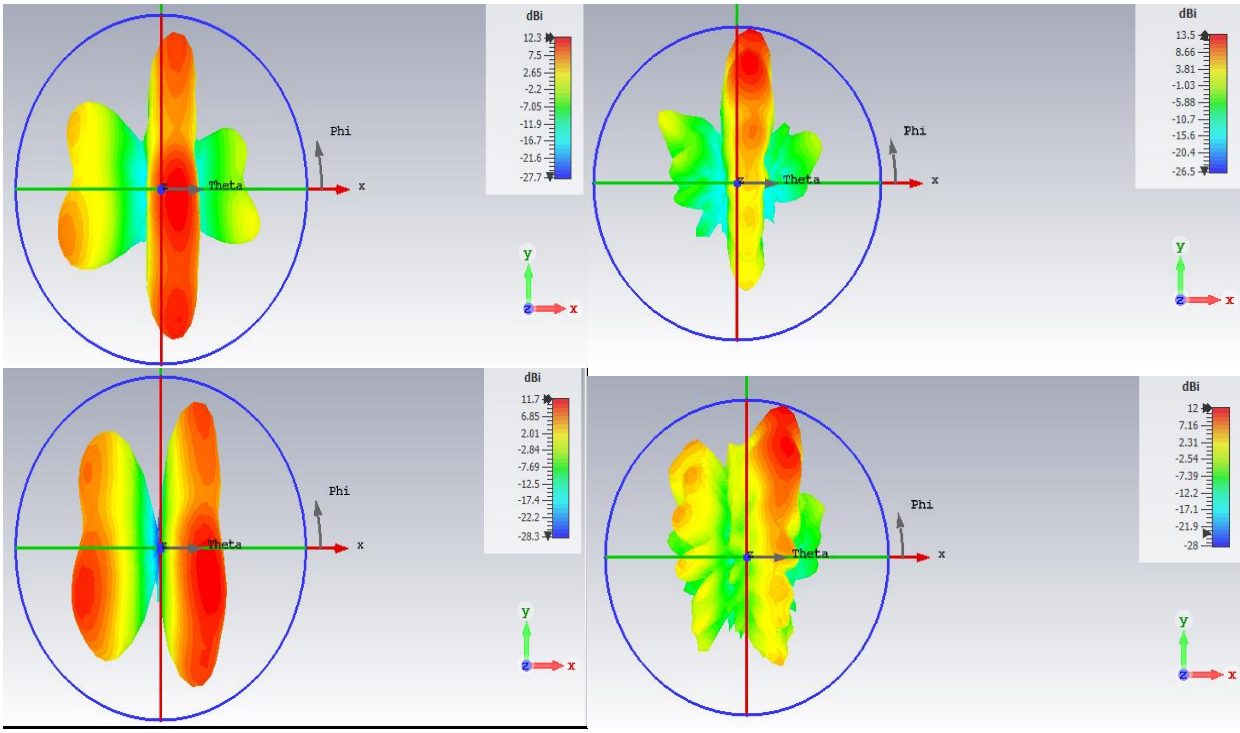


Figure 4.16: Return Loss for 4x1 patch antenna for 23 GHz and 60 GHz





(a) (b)

Figure 4.17. 3D gain of 4x1 rectangular microstrip antenna array (a) for 23 GHz and (b) for 60 GHz

Figure 4.17 shows We may modify the phase of the signal in each individual antenna element in an array using electrically variable phase shifters, which guides the array's far-field radiation pattern in space without the need for any mechanical rotation.

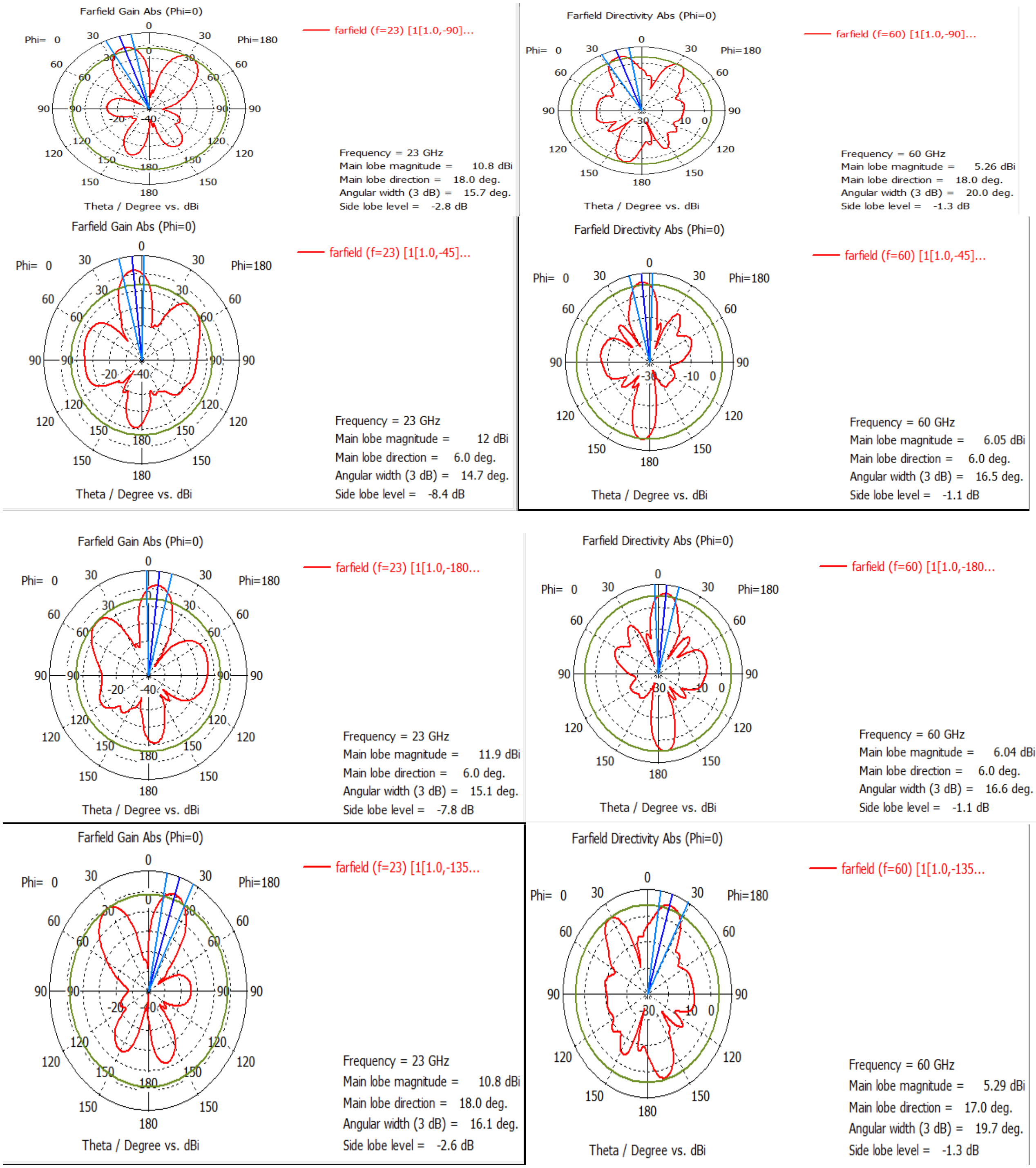


Figure 4.18: Polar Radiation Pattern Coordinate System and Angles for 4X1 patch antenna for 23 GHz and 60 GHz

Figure 4.18 shows the radiation pattern for both 23 GHz and 60 GHz. It can be seen that the radiation patterns in both designs are in broadside direction. The side lobes appear clearer in those designs. In this case at both 23 and 60 GHz resonant frequency the main lobe magnitude is 12 dBi on 23 GHz, 6.05 dBi on 60 GHz and its direction is 18 degree.

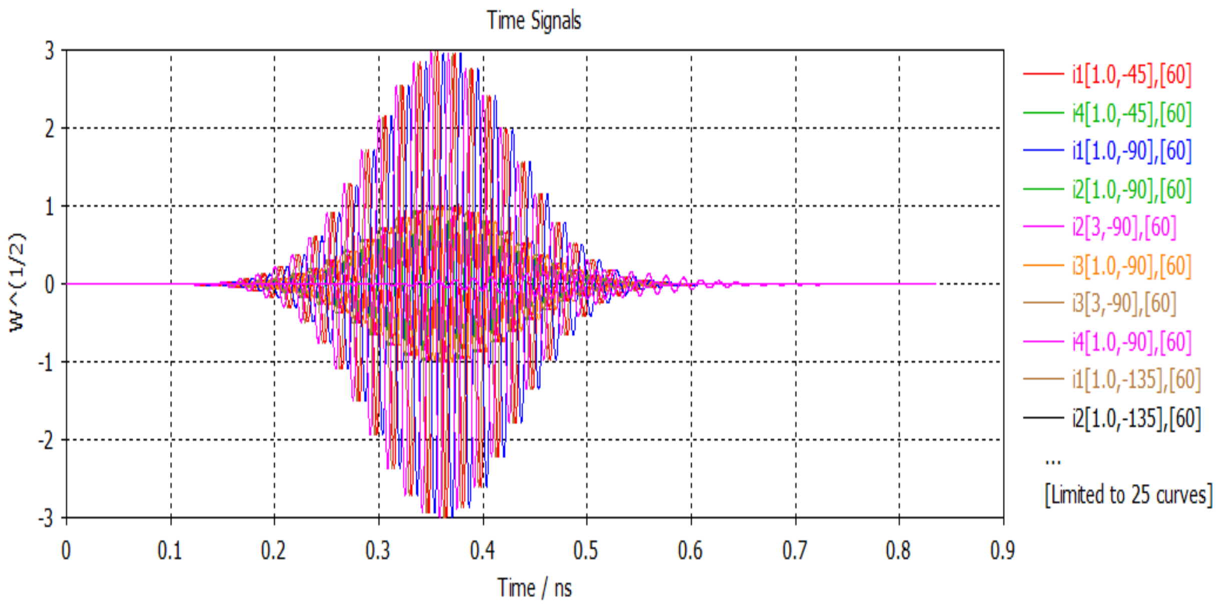


Figure 4.19: Port signal for four element at 23 and 60 GHz patch antenna

Table 4.3: Comparison analysis of 23 GHz and 60 GHz for 4x1 patch.

Frequency	23 GHz	60GHz
Gain	12 dB	13.02 dB
Directivity	12.34 dBi	13.51 dBi
VSWR	1.488	1.212
Band width	17.38 %	19.21 %
Return loss	-57.33 dB	-44.02 dB
Radiation efficiency	90.4 %	90.4 %
Beam width	15.7 deg	20.0 deg

As we can see from Table 4.1, 4.2 and 4.3 in all conditions the rectangular micro strip patch array antenna have achieved a better performance than that of single micro strip antenna. By analyzing the bandwidth efficiency with single patch antenna, the performance of the rectangular micro strip patch array antenna explored in this study is good radiation pattern, low return loss, and more directives. This comparison is made for the same dialectic substrate with the same thickness, however as the frequency of the dialectic substrate is increased, the directivity of the patch array antenna increases somewhat, increasing the bandwidth efficiency. This accomplishes the goal set forth in the thesis proposal. Those performance metrics of rectangular micro strip patch array antenna compare with 23 GHz and 60 GHz. The performance of my design is comparable with the 23 GHz rectangular microstrip antenna array element in those performance metrics. For this thesis my contribution is to visualize the return loss, beamforming, the radiation pattern and the directivity by designing of single patch antenna and rectangular micro strip patch array antenna.

It is observed that the Single element antenna achieves the gain of 7.77 dB for 23 GHz and 8.77 dB for 60 GHz with the directivity of 8.01 dBi for 23 GHz and 9.07 dBi for 60 GHz, 2x1 elements array achieves the gain of 8.89 dB for 23 GHz and 11.23 dB for 60 GHz with the directivity of 9.11 dBi for 23 GHz and 11.78 dBi for 60 GHz,, 4x1 elements array has the gain of 12 dB for 23 GHz and 13.02 dB for 60 GHz with the directivity of 12.34 dBi for 23 GHz and 13.51 dBi for 60 GHz. All presented antennas are good competitors for future 5G Communications and can be used for the 5G systems like VANET, WiMax and other applications.

5. CONCLUSION AND FUTURE WORK

5.1. Conclusion

Rectangular micro strip patch antenna array has been designed and simulated for V Band. Background information on micro strip patch antennas has been given, followed by a review of the literature on micro strip antennas and how they might be used to benefit the desired application. A single, 2x1 and 4x1 micro strip patch antenna array for both 23 GHz and 60 GHz has been successfully designed according to its design specifications, simulated and analyzed. The bandwidth, return loss, VSWR, and radiation pattern of the design antenna have all been evaluated. In this section, we'll go over some of the design's unique features. The gain, directivity, and patterning of a micro strip patch antenna on a low dielectric constant substrate (i.e. RT/duroin 5880) have been improved significantly. The design was simulated to meet the best possible result by varying different phase shifter and frequency change. (The use of rectangular patch geometry provided good directivity and simplicity in design process by using micro strip feed line techniques.) Based on the simulation obtained, beam formed micro strip antenna successfully simulated and designed at 23 GHz and 60 GHz frequency using computer simulation technology (CST) version 19 and matlab software for parameter calculation.

From the comparison analysis four element rectangular microtsrip patch antenna arrays have better performance than that of single and two element rectangular microstrip patch antenna arrays because of high gain, high directivity and high bandwidth. So I have concluded that despite of its advantages microstrip antenna finds its great importance in wireless communication like VANET mainly because of its light weight and conformal nature and further the 60GHz frequency is going to be next big frequency in the world.

5.2. Future work

In future the results like gain, bandwidth and directivity can be further refined or more optimized for better results. The optimization procedure solely depends on the field where we want to use our antenna, whether it is VANET or in communication systems. According to the requirements we do further optimization of the parameters. We can further use some other software's for further validation of our parameters and better results. We can further do experimental testing and the fabrication process as well.

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7. Appendix

Code for parameter calculation of microstrip patch antenna array, micro strip line and beam steer butler matrix

```
clc;
clear all;
close all;
c=3.0e+08; %free space velocity in meters/sec
% z0= input('enter the value of zo (in ohms):'); % Characteristic impedance of the mictrostrip
line
% h= input ('enter the value of h (in mm):'); % thickness of the dielectric substrate (ex: for glass
epoxy, h=1.6 mm)
% t= input ('enter the value of t (in mm):'); % thickness of the conductor foil (ex: for glass epoxy,
t=0.02 mm)
% x= input ('enter the value of x (in cm):'); % feed position for the patch in cm
% f= input ('enter the value of f (in MHz):'); % frequency in MHz
% Er=input ('enter the value of Er:'); % relative permittivity of the dielectric substrate (ex: for
glass epoxy, Er=4.3)


z0=50
% h=0.8
h=1.5880
% h=0.127
t=0.035
x=0
f=60000
% f=23000
% f=2400
del=0.0009
% Er=4.4
Er=2.2
Er=abs(Er*(1-sqrt(-1)*tan(del)))
```

```
omega=2*pi*f*(1e+06);
mu0=(4*pi)*(1e-07);
mur=1;
mu=mu0*mur;
Rs=sqrt((omega*mu)/(2*sigma))
[w,Eeff,lambda0,lambdag]=microstrip_line(z0,h,f,Er);
QWT_w
p=0.0001;
 [Ue,Uh]=radiation_pattern_patch(L,W,lambda0,theta,phi);
figure(1);
polar2(theta,Uh,[min(Uh) max(Uh)],'-b');
title('H-Plane Amplitude Pattern');
figure(2);
polar2(phi,Ue,[min(Ue) max(Ue)],'-b');
title('E-Plane Amplitude Pattern');
figure(3);
polar2(theta,Uh.^2,[min(Uh.^2) max(Uh.^2)],'-b');
title('H-Plane Power Pattern');
figure(4);
polar2(phi,Ue.^2,[min(Ue.^2) max(Ue.^2)],'-b');
title('E-Plane Power Pattern');
figure(5);
polar2(theta,20*log10(Uh),[-10 0],'-r');
title('H-Plane Amplitude(dB) Pattern');
grid;
 figure(6);
polar2(phi,20*log10(Ue),[-10 0],'-r');
title('E-Plane Amplitude(dB) Pattern');
grid;
 figure(7);
polar2(theta,10*log10(Uh.^2),[-10 0],'-r');
title('H-Plane Power(dB) Pattern');
```

```
grid;
 figure(8);
polar2(phi,10*log10(Ue.^2),[-10 0],'-r');
title('E-Plane Power(dB) Pattern');
grid;
figure(9);
plot(theta*(180/pi),20*log10(Uh),'-r');
title('H-Plane Amplitude(dB) Pattern');
grid;
 figure(10);
plot(phi*(180/pi),20*log10(Ue),'-r');
title('E-Plane Amplitude(dB) Pattern');
grid;
 figure(11);
plot(theta*(180/pi),10*log10(Uh.^2),'-r');
title('H-Plane Power(dB) Pattern');
grid;
figure(12);
plot(phi*(180/pi),10*log10(Ue.^2),'-r');
title('E-Plane Power(dB) Pattern');
grid;
```

```
function [w,Eeff,lambda0,lambdag]=microstrip_line(z0,h,f,Er)
% 'h' in mm
d=(60*pi*pi)/(z0*sqrt(Er));
lambda0=3.0e+08/(f*1.0e+06); %freespace wavelength in meters
                    %frequency in MHz
if z0>(44-2*Er)
  wh=(exp(H)/8-1/(4*exp(H)))^(-1);
end
if z0<(44-2*Er)
  wh= (2/pi)*((d-1)-log(2*d-1))+((Er-1)/(pi*Er))*(log(d-1)+0.293-(0.517/Er));
end
```

```
if z0<(63-2*Er)
      Eeff= Er/(0.96+Er*(0.109-0.004*Er)*(log10(10+z0)-1));
end
lambdag=lambda0/sqrt(Eeff); %guide wavelength in meters
```

```
%BEAM STEERING USING BUTLER MATRIX
clear all;
close all;
clc;
 n=input('Enter the number of elements in the array: ');   % number of elements
 theta=0:pi/180:2*pi;       %for plotting
  alpha21r=[0,-90];  %Butler matrix for 2-element array
alpha21l=[-90,0];
 alpha41r=[-45,-90,-135,-180];  %Butler matrix for 4-element array
alpha42l=[-135,0,-225,-90];
alpha42r=[-90,-225,0,-135];
alpha41l=[-180,-135,-90,-45];

%Butler matrix for 8-element array
alpha84r=[-180 -337.5 -135 -292.5 -90 -247.5 -45 -202.5];
alpha83r=[-135 -247.5 0 -112.5 -225 -337.5 -90 -202.5];
alpha82r=[-112.5 -180 -247.5 -315 -22.5 -90 -157.5 -225];
alpha81r=[-112.5 -135 -157.5 -180 -202.5 -225 -247.5 -270];
for j=1:8
alpha81l(j)=alpha81r(9-j);
alpha82l(j)=alpha82r(9-j);
alpha83l(j)=alpha83r(9-j);
alpha84l(j)=alpha84r(9-j);
end
if (n==2)
   alpha=[alpha21l;alpha21r];
```

```
end
if (n==4)
   alpha=[alpha42l;alpha41l;alpha41r;alpha42r];
end
if (n==8)
   alpha=[alpha84l;alpha83l;alpha82l;alpha81l;alpha81r;alpha82r;alpha83r;alpha84r];
end
for i=1:n
   [dip,finsigma,TFP]=beam_butler(n,theta,alpha(i,:));
subplot(2,2,1);polar(theta,dip);
title('Polar plot for element factor')
subplot(2,2,3);polar(theta,TFP);
title('Polar plot for total field pattern')
%hold on;
pause(4);
TOT_TFP(i,:)=TFP;
end
subplot(2,2,4);
for i=1:n
    polar(theta,TOT_TFP(i,:));
    hold on;
end
hold off;
```