38GHz High Bandwidth and Low Return Loss Microstrip Patch Antenna Design

A Project report is submitted in partial fulfillment of the requirements for the Award of Degree of
Bachelor of Science in Electrical and Electronic Engineering.

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DECLEARATION

I confirm that the project called "Design and Simulation of 5G adaptable CNN Based Antenna for Smart Cities" is my own work done at Daffodil International University. It's part of my studies for a Bachelor's degree in Electrical and Electronic Engineering. This project is original and hasn't been submitted anywhere else. I've considered the possible risks, got the required ethical and safety approvals, and recognized my duties and the rights of everyone involved.

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APPROVAL

The project and thesis entitled "**38GHz High Bandwidth and Low Return Loss Microstrip Patch Antenna Design"** submitted by **Md. Shahriar Hassan Shazzad ID: 201-33-1210** & **Md. Makhraj Uddin ID: 201-33-1148**, Session: Spring 2020 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **May, 2024**.

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Dedicated to

***Our Father & Mother*,**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

IEEE	Institute of Electrical and Electronic Engineers
CNN	Convolutional Neural Network
MU-MIMO	Multi-user multiple-input multiple-output
Kbps	Kilo bites per seconds
TDMA	Time division multiple access
SIR	Signal-to-interference Ratio
Wi-Fi	Wireless Fidelity
RF	Radio Frequency
IoT	Internet of thing
OFDMA	Orthogonal frequency division multiple access
LTE	Long Term Evolution
G	Generation
GSM	Global System for Mobile communication
WPT	Wireless power transfer
ML	Machine Learning
AI	Artificial Intelligence
D	Dimension
CST	Computer Simulator Technology
VSWR	Voltage Standing Wave Ratio
UI	User Interference
MATLAB	Matrix Laboratory

LIST OF SYMBOLS

Hz	Hertz
KHz	Kilo Hertz
MHz	Mega Hertz
GHz	Giga Hertz
mm	Millimeter
cm	Centimeter
m	Meter
ε	Relative permittivity
L	Length
W	Width
C	Speedoflight
dB	Decibel
λ	Lambda
Ω	Ohm
εr	Dielectric Constant

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Abstract

This thesis focuses on improving the effectiveness and appearance of a small antenna used in modern wireless communication networks operating at 38GHz. The antenna is designed to address the need for high-speed data transmission in Bluetooth, Wi-Fi, and other wireless technologies. By addressing issues related to size, bandwidth, and signal strength, the proposed antenna aims to optimize performance for small and lightweight devices. The research project begins with a thorough analysis of existing studies, examining different materials, feeding methods, and antenna designs. Advanced tools are used to simulate and analyze the antenna's design and important characteristics like radiation pattern, bandwidth, and signal loss. The study investigates how various design elements, such as antenna size, material properties, and feeding techniques, affect overall performance. Additionally, practical considerations like cost-effective materials and production methods are explored to achieve an affordable and feasible design. The suggested antenna's performance is then confirmed through extensive testing, comparing the results with simulated data to ensure accuracy. The findings of this study provide valuable information on the best design parameters for improved performance in the 38GHz frequency range, advancing the technology of small antennas. The suggested antenna has potential applications in Internet of Things (IoT) devices, wireless communication systems, and other emerging technologies that require reliable high-frequency connections. This thesis serves as a useful resource for researchers, engineers, and professionals involved in antenna design and wireless communication.

Keywords: 5G Antenna, Smart antennas, Deep learning-based antenna, 5G base station antenna, Antenna design optimization, Reconfigurable antenna, Wireless communication**.**

CHAPTER 1

1.1 Introduction

The 5G generation of mobile communication is a ground breaking technology that has the potential to revolutionize how we connect and communicate in our increasingly interconnected world. To fully leverage the capabilities of 5G networks, new antenna technologies need to be developed to meet the demand for faster data rates, lower latency, and increased network capacity. Enhancing the antenna gain is a key aspect to improve the signal-to-noise ratio (SNR), and this can be achieved by increasing the effective aperture area of the antenna. Consequently, a larger aperture area is required to achieve higher gain in a single antenna.

Among various advancements, the 38 GHz microstrip patch antenna stands out as a promising option for high-frequency, high-bandwidth communication applications, owing to its compliance with millimeter-wave licensing requirements. This makes it well-suited for certain 5G applications that operate in the millimeter-wave bandwidth. Although the 38GHz band presents challenges due to its specific propagation characteristics, it offers a balance between propagation and data transmission capabilities.

The focus of this article is primarily on microstrip patch antennas, which are preferred for 5G applications due to their compact size, thin profile, and ease of integration. These antennas can provide tailored radiation patterns, effective gain, and increased bandwidth. However, reducing the size of an antenna while maintaining its performance can be difficult. One approach to address this challenge is to enhance the antenna's shape using techniques such as coplanar waveguide (CPW) [2]. The primary objectives of this study involve comprehending the underlying principles of microstrip patch antenna theory and developing a high-performance antenna tailored specifically for 38GHz applications. By conducting a comprehensive literature review, exploring theoretical foundations, employing a meticulous design methodology, and conducting rigorous simulations and tests, this research aims to make significant contributions to the ever-evolving field of wireless communication. The ultimate goal is to bridge the gap between theory and real-world application by offering practical solutions and enhancing readers' understanding of the intricacies of 38 GHz microstrip patch antennas within the framework of 5G communication systems. The paper will cover essential topics such as design approaches, optimization techniques, and efficiency methods for measurement.

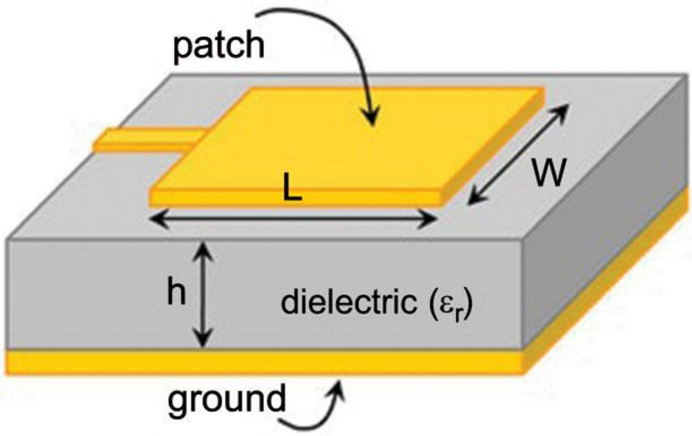


Figure 1.1 Configuration of the Radiant Resonance Patch Antenna

This thesis focuses on the Radiant Resonance Patch Antenna configuration, which involves a detailed exploration of precisely calibrated design parameters to achieve optimal performance at the 38 GHz frequency range. The efficiency of the antenna is influenced by factors such as the substrate material, thickness, and ground plane dimensions. The geometry and dimensions of the antenna are carefully adjusted to ensure resonance at the desired frequency. The radiation pattern design and polarization orientation are adaptable to various application requirements, allowing for flexibility in deployment scenarios. Impedance matching, an important aspect of efficient power transmission, is achieved by carefully tuning the feed locations and sizes. A well-designed ground plane contributes to the desired radiation pattern and maximizes antenna efficiency. Computer Simulation Technology (CST) is utilized as an advanced tool to simulate and optimize the configuration with meticulous attention. The iterative process guarantees excellent radiation efficiency, gain, and bandwidth, while also achieving resonance within the targeted frequency range. This comprehensive exploration of setup parameters contributes to the advancement of wireless communication systems by providing valuable insights into the complexities of microstrip patch antenna design. The thesis serves as a comprehensive guide for researchers and technicians seeking to enhance antenna performance in high-frequency applications.

1.2 Enhance the performance of the Antenna

The design of a 38 GHz microstrip patch antenna can be enhanced by considering application-specific requirements and focusing on efficient and relevant performance factors.

The following are some of the areas where modifications may be thought about:

Improvement of Bandwidth:

Analyze the bandwidth of the 38 GHz microstrip patch antenna and brainstorm strategies to broaden it. This could involve adjusting the size of the patch or exploring advanced methodologies, such as incorporating metamaterials, to achieve a wider bandwidth.

Efficiency of Radiation:

Enhancing the radiation efficiency of the antenna can be achieved through design optimization. This may involve refining the substrate material, adjusting the feed system, or enhancing the ground plane to minimize losses.

Gain and Directivity:

To enhance the communication range of the antenna, it is important to increase its directivity and gain. This can be achieved through careful design adjustments, streamlining the feed network, or exploring advanced techniques such as incorporating a reflecting element or implementing a higher-gain feeding mechanism.

Control of Polarization:

Evaluate the polarization characteristics of the antenna and customize them to meet the specific needs of the application. This could include rotating the patch to achieve the desired polarization.

Size reduction or miniaturization:

Explore techniques to maintain or improve the performance of the antenna while reducing its overall size. This may involve employing intricate geometries, utilizing advanced materials, or implementing compact design methodologies.

Multiple Band Function:

Consider implementing modifications that enable the antenna to operate efficiently across multiple frequency bands. This capability is particularly valuable for applications that require flexibility in frequency usage.

Optimizing Substrates:

Take into account the substrate thickness and material selection in order to optimize the antenna's performance. opt for materials with lower losses and higher permittivity to achieve better overall results. Explore various dielectric components to identify the material that best aligns with the antenna's specific needs.

Design Optimization:

Antenna performance using Defective Ground Structure (DGS), focuses on optimizing DGS units' shape, size, and placement. Experiment with various shapes (e.g., rectangular, circular) to fine-tune resonant frequency and bandwidth. Place DGS units where electromagnetic fields are strongest, such as under feed lines, maintaining symmetry to avoid unwanted cross-polarization. Use simulation tools like HFSS or CST Microwave Studio and optimization algorithms (GA, PSO) to refine the design, and validate with prototype measurements to ensure improved bandwidth, gain, and return loss.

Feeding Methods:

Conduct research on innovative feeding strategies, such as exploring alternative feed lines or incorporating advanced feeding mechanisms like aperture coupling. These approaches can impact radiation efficiency and impedance matching of the antenna.

More Advanced Modeling and Simulation:

Utilize advanced modeling tools to optimize the performance of the antenna. This involves conducting parametric studies and employing electromagnetic simulation tools to identify the most effective design modifications for maximizing performance.

Environmental Factors to Be Considered:

Assess the antenna's ability to withstand and operate effectively under different environmental conditions. Consider variables such as humidity, temperature fluctuations, and exposure to outdoor elements that may affect the antenna's performance.

Expense-effectiveness:

Examine the production expenses of the antenna and seek ways to maintain or enhance performance within budget constraints. This may involve utilizing cost-effective materials or production techniques. Continuous advancements in these areas can lead to the development of a refined and optimized 38 GHz microstrip patch antenna design, often achieved through iterative design iterations and simulation analyses. Each improvement should be carefully evaluated to ensure alignment with the intended application's goals and specifications.

1.3 Aims/ Objectives

Creation of an Antenna with High Bandwidth:

The primary goal of this endeavor is to create an antenna utilizing microstrip patches functioning at 38GHz, aiming for a wide bandwidth to satisfy the requirements of contemporary wireless communication systems.

Optimize to Boost Data Rates:

To guarantee efficient and reliable high-speed data transmission in communication applications, it is essential to optimize the antenna configuration for enhanced data rates.

Enhancement of Radiation Properties:

The aim is to improve the antenna's radiation properties, including gain, directivity, and radiation pattern, to enhance link reliability and extend signal coverage.

Investigating Novel Feeding Methods:

The task is to explore and assess novel feeding techniques for microstrip patch antennas, with the objective of improving radiation efficiency, impedance matching, and overall effectiveness.

Adaptability and Control of Polarization:

The objective is to research polarization control techniques and develop an antenna that can be easily adjusted to different polarization conditions, providing versatility for various interaction scenarios.

Objective:

Optimization of Frequency:

Achieving optimal performance within the intended frequency range involves fine-tuning the design parameters of the microstrip patch antenna to resonate accurately at the target frequency of 38GHz.

Improvement of Bandwidth:

To achieve a high bandwidth enabling the antenna to accommodate a wide range of wireless frequencies and data speeds, a systematic approach involving thorough study and implementation of design enhancements is essential.

Enhancement of Radiation Performance:

Investigate and implement methods aimed at enhancing the antenna's radiation characteristics. This involves improving the ground plane, adjusting the physical size of the patch, and exploring alternative approaches to increase radiation efficiency.

Assessment of the Feeding Mechanism:

Explore various feeding mechanisms, including coaxial probe feed, microstrip line feed, and other innovative methods, to determine the most efficient approach for achieving optimal power transfer and impedance matching.

1.4 Significance of High-Bandwidth Antennas:

Speeds of Data Transmission:

Increasing demand for fast data transfer speeds, spurred by data-intensive applications, multimedia streaming, and technological advancements, underscores the importance of high-bandwidth antennas. These antennas enable swift and seamless transmission by facilitating faster data rates.

Help with Cutting-Edge Communication Technologies:

High-bandwidth antennas play a crucial role in enabling cutting-edge communication technologies like 5G networks and beyond. These antennas facilitate the use of high-frequency bands necessary for enhanced connectivity and performance, thus driving the advancement of such technologies.

Services for Wireless Broadband:

High-bandwidth antennas are pivotal in providing reliable and fast internet access, catering to the increasing demand for broadband wireless services in urban as well as rural areas. They play a crucial role in promoting global connectivity and narrowing the digital divide by ensuring that high-speed internet is accessible to all.

Connectivity for the Internet of Things (IoT):

As the number of IoT devices continues to rise, broadband antennas are essential for managing the multitude of data streams they generate. High-bandwidth antennas play a crucial role in facilitating effective communication within IoT networks, benefiting various sectors such as smart cities, healthcare, agriculture, and industrial applications.

High-Rate Utilizations:

Transmitters with high bandwidth, such as the 38GHz microstrip patch antenna, are indispensable in applications that utilize higher frequencies, such as satellite communication, backhaul lines, and point-to-point communication. Leveraging these frequency ranges ensures reliable and productive communication capabilities.

Enhanced Reliability and Signal Quality:

The enhanced transmission quality and reliability offered by high-bandwidth antennas lead to improved communication systems characterized by reduced interference and greater resilience to adverse environmental conditions.

1.5 Thesis Organization

The thesis having seven chapters. Those chapter carries particular discussion about introduction, procedures, simulation, results etc.

Chapter 1 provides an overview of the thesis, outlining the background and summarizing the problems to be addressed as well as the objectives of the study. It also details the methodology for implementation and the process of implementation.

Chapter 2 delves into a comprehensive literature review, identifying research gaps and comparing the current work with existing literature. This chapter highlights the uniqueness of the proposed work compared to previous studies, aiming to identify the best approach to achieving the goals of the thesis.

Chapter 3 focuses on the materials and methodology employed for the specific antenna design and other techniques utilized in the system. It elaborates on the design process, various antenna parameters, and system analysis conducted through simulations.

Chapter 4 presents the results obtained from the project simulations and discusses their implications. It examines the findings throughout the thesis and analyzes their impact on the overall project objectives and related terms.

Chapter 5 addresses project management aspects, including time scheduling, cost management, and resource allocation required for the implementation of the project. It evaluates the cost-effectiveness of necessary resources.

Chapter 6 evaluates the impact of the project, both locally and globally, including ethical and environmental considerations. Safety issues, applications of the project, and its potential impact on society are discussed in this section.

Chapter 7 provides the final discussion, offering insights into potential improvements for the system and recommendations for future researchers. It also explores new features that could be incorporated into the system in future studies, concluding with a summary of future research directions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, we will delve into the literature review, aiming to gain a comprehensive understanding of the subject matter. The primary objectives of the literature review are to provide a solid comprehension of the topic by reviewing prior studies and research. We will identify previous work to avoid duplication and properly credit other specialists. Moreover, we aim to recognize discrepancies, unresolved questions, and research gaps in previous studies. By comparing our work with that of others, we intend to improve the system's reliability and introduce innovative technological advancements. Through these comparisons, we will also identify areas of weakness in our work, enabling us to address them effectively. Ultimately, our goal is to stimulate further investigation into the subject by providing a foundation for building a functional system. After conducting the literature review, we will discuss our findings and determine the main points to be highlighted in this chapter.

2.2 Related Research Works

Here, a few research papers about 5G antennas are reviewed. Microstrip patch antennas [1] have become extensively utilized in the gigahertz range, particularly for 5G communication purposes. Their primary benefits include cost-effectiveness, ability to conform to various shapes, lightweight construction, and compatibility with both hybrid and monolithic microwave integrated circuits [2] .As per the International Mobile Telecommunications 2020 (IMT2020) standards, millimeter-wave (mm W) frequency bands ranging from 24 to 71 GHz are classified as extremely high-frequency bands [3] Due to their large bandwidth, mm Wave communication is suitable for high data rate applications such as 5G. Among these frequency bands, 28 GHz and 38 GHz are particularly favorable for deployment in next-generation cellular systems, as they experience minimal atmospheric attenuation. In this study, the design of a patch antenna is focused specifically on the 38 GHz frequency band. Several researchers have put forward proposals and designs for single-band microstrip antennas tailored for 5G applications within the millimeter-wave frequency spectrum, particularly focusing on the 38 GHz band. [4] devised a rectangular patch antenna operating at 38 GHz, employing an FR4 substrate and featuring a cylindrical notch. Their antenna exhibited a directivity of 2.37 dBi, a return loss of -24 dB, and a satisfactory bandwidth of 1.021 GHz. [5] developed a circular microstrip patch antenna optimized for operation at 38 GHz, exhibiting a return loss of -20.6 dB, a gain of 7.25 dB, and a bandwidth of 0.6391 GHz. Similarly, [6] designed a rectangular patch antenna operating at 38 GHz, incorporating two notches and forming a two-element array for 5G applications. This antenna achieved a bandwidth of 767 MHz, a gain of 7.67 dBi, and a radiation efficiency of 90%. Additionally, [7] proposed a compact 2x2 microstrip antenna array delivering high gain (14.58 dB), a return loss of -17.7 dB, and an extensive impedance bandwidth of 500 MHz [8] designed a compact antenna measuring 4.39 mm x 5.05 mm x 0.3 mm, demonstrating satisfactory performance. [9] introduced a wide bandwidth microstrip antenna employing a defected patch surface, achieving a 25% impedance bandwidth. [10] However, despite these advancements, the development of a more efficient 38 GHz microstrip patch antenna, characterized by low return loss and voltage standing wave ratio (VSWR), high gain, and wider bandwidth for 5G communication, remains an ongoing research challenge.

This paper presents the design and simulation of a single-band microstrip patch antenna resonating at a frequency of 38 GHz. The antenna is a compact rectangular slotted patch designed to meet the criteria of 5G technology, specifically with wideband characteristics. Additionally, the paper discusses the initial concepts of the rectangular patch antenna, various dimensions and structures considered for the proposed antenna, and presents miscellaneous results such as return loss, voltage standing wave ratio (VSWR), bandwidth, directivity, and current distribution obtained from the antenna simulation. Finally, the paper concludes with a summary of findings and a reference section.

2.3 Summary

Smart antenna technology is indispensable for wireless communication, driving enhancements in spectrum efficiency, data throughput, coverage, and interference reduction— all critical aspects for improving wireless communication quality. Many researchers have explored the integration of AI, ML, and deep learning technologies to extend network coverage and address challenges such as signal fading, interference, and the limited battery life of portable devices. Additionally, ongoing research in 5G communication technologies covers various applications like industry 4.0, nanosatellites, wireless power transfer, and IoT. The synergy between smart antennas and smart technologies has been extensively discussed in scholarly debates. Evaluating our work in comparison to theirs helps us identify the most effective ways to harness technology for increased productivity. Furthermore, bolstering system reliability is achieved through the integration of additional capabilities such as machine learning, deep learning, and image/video processing.

CHAPTER 3

METHODOLOGY AND METHODS

3.1 Introduction

Antenna methods encompass the techniques and principles employed in designing, analyzing, and implementing antennas, which are devices responsible for transmitting or receiving electromagnetic waves. Antennas play a pivotal role in various communication systems, including radio and television broadcasting, mobile communication, radar systems, satellite communication, among others. The effectiveness and performance of these systems heavily depend on the characteristics of the antennas utilized.

3.2 Overview of an Antenna

An antenna, stemming from advancements in electromagnetic research, originated from the discoveries of scientists like Michel Faraday in 1831 and Heinrich Hertz in 1888. [11] Hertz utilized dipole antennas to demonstrate the existence of electromagnetic waves as theorized by James Clerk Maxwell. These antennas serve the dual function of transmitting and receiving signals. When transmitting, an antenna converts electrical currents into electromagnetic waves, while during reception, it transforms electromagnetic waves into electrical impulses. In two-way communication, a single antenna can perform both functions. Antennas are indispensable in communication systems, particularly when wireless communication is necessary due to the impracticality of wired systems. They facilitate the transmission and reception of electromagnetic radiation for communication purposes.

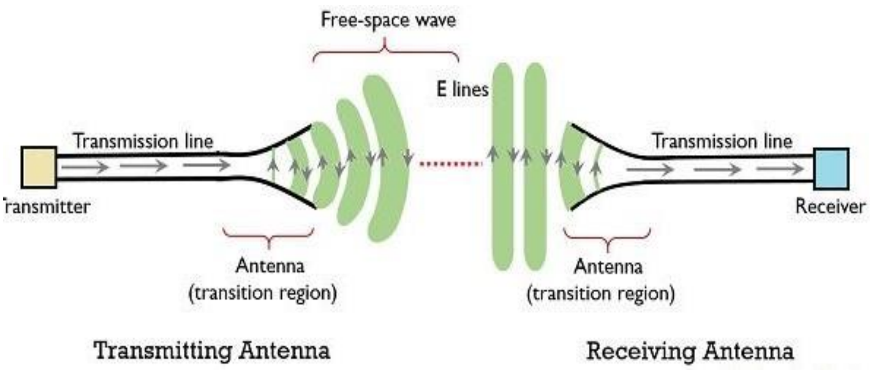


Figure 3.1 Antenna overview transition mode

The antenna stands as a pivotal element in wireless technology, enabling communication across diverse terrains such as valleys and mountains. This approach is notably more straightforward compared to the extensive installation required for a wired system, which entails navigating through challenging landscapes like valleys, mountains, rugged roads, and tunnels. The evolution of wireless technology has streamlined this process significantly. Antennas constitute one of the cornerstone components in wireless communication systems. A well-designed antenna has the potential to streamline system requirements while enhancing overall performance. In the realm of communication systems, antennas play a role analogous to that of human vision and corrective eyewear. Various types of antennas, including wire, aperture, microstrip, array, reflector, and lens antennas, are widely recognized.

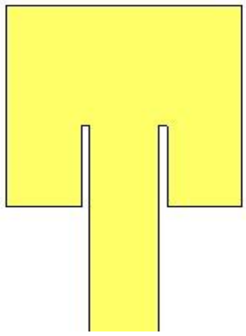
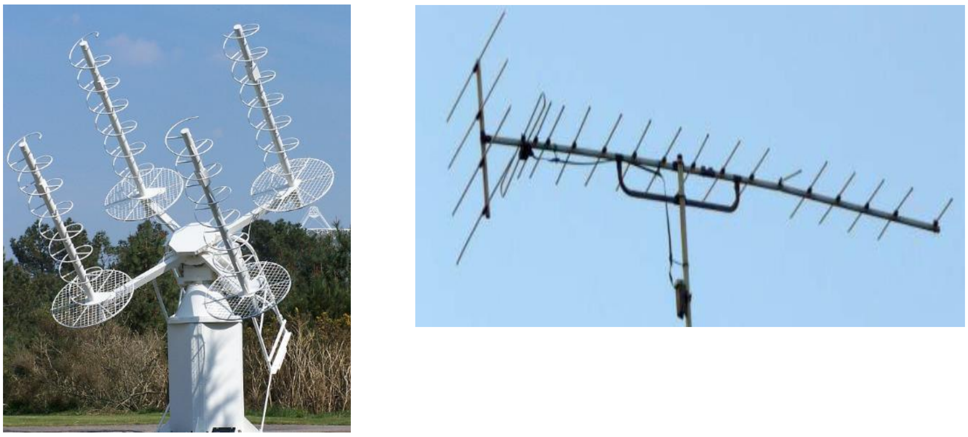


Figure 3.2 Patch antenna wireless communication

A radio antenna transforms the power supplied to it, typically in the form of an alternating current signal at radio frequency, into electromagnetic energy. This energy, in the form of an electromagnetic wave, can propagate between transmitting and receiving radio antennas. At the receiving end, the electromagnetic wave is converted back into a wireless channel that interfaces with the input of the radio receiver. Just as an electromagnetic wave would, a radio antenna can both receive power and transmit signals. Similarly, when an electromagnetic wave interacts with an antenna, it undergoes conversion into a radio frequency signal that can be transmitted to the receiving device. The fundamental theory of antenna operation can be elucidated using Maxwell's equations

3.2.1 Different Types of an Antenna

In the realm of wireless communication, the antenna stands out as the most crucial component. Its significance is underscored by the diversity of antenna types, each serving specific roles in various communication sectors. The forthcoming discussion will delve into the distinct types of antennas employed across different domains of communication.



(a) (b)

Figure 3.3 Travelling Antenna (a) Helical (b) Yagi-Uda

A helical antenna is constructed by coiling one or more conducting wires into a helix. The most common variant is the monofilar helical antenna, comprising a single helical wire. In contrast, bifilar and quadrifilar antennas utilize two and four helical wires, respectively.

The Yagi-Uda antenna, commonly referred to as a Yagi antenna, is a transceiver composed of two or more parallel resonant antenna elements arranged in an end-fire array configuration. These elements, often metal rods, serve as half-wave dipoles.

Advantages of traveling wave antennas:

- Simple and easy construction process
- Cost-effective and offers wider coverage
- High bandwidth capability
- Optimal input impedance
- Maximum directivity achieved

- Drawbacks of Travelling Wave antenna
- Generates strong minor lobes
- Requires ample space due to its size
- Length increases significantly for higher gain

Reflectors are constructions designed to deflect ultrasonic fields. In the realm of antennas, reflectors serve to redirect radio frequency radiation either independently or as integral components of antenna setups. Comprising one or multiple reflective layers along with a feed line, a reflector antenna finds extensive applications across missile systems, satellite communications, telemetry, remote sensing, and space exploration, owing to its exceptional radiation capabilities, versatility, and ease of production.

Figure 3.4 Reflector Antenna

- Advantages of Reflector Antenna
- Wide bandwidth coverage
- High gain
- High directivity
- Disadvantages of Reflector Antenna
- Necessity for both reflector and driving element components
- Increased cost due to the additional feeding mechanism necessity

Microstrip antennas have gained widespread adoption in the mobile phone industry [17]. Patch antennas, which are cost-effective, compact, and easy to manufacture, fall under this category. Operating primarily at microwave frequencies, microstrip antennas are characterized by narrowband wide-beam performance. They offer ease of fabrication and versatility for application on curved surfaces. Moreover, the directivity of these antennas is relatively insensitive to substrate thickness. Microstrip antenna patches can take various shapes, including rectangular, circular, or planar configurations. With the rising popularity of printed circuit boards, microstrip or patch arrays are increasingly favored as they can be directly integrated onto circuitry. These antennas are known for their low profile, with the metal patch placed on the surface of the substrate with a dielectric material in between [12]. Emitting minimal radiation, microstrip antennas are divided into three types: patch antenna, slot/traveling antenna, and printed dipole antenna. Among them, the microstrip patch antenna stands out for its ability to adopt diverse shapes.

A rectangular microstrip patch antenna is a type of antenna consisting of a rectangular patch [6] . This antenna variant is commonly observed in microstrip antenna designs, resembling a microstrip transmission line but with smaller dimensions. When air serves as the dielectric substrate, the rectangular microstrip antenna typically spans around half of a free-space wavelength. The length of the antenna with a dielectric substrate decreases as the bulk modulus constant of the substrate increases. Due to the extended "fringing fields" of electricity, the electrical frequency of the antenna slightly increases as its resonant length decreases.

Circular Polarization: In a birefringent antenna, the polarization plane rotates in a corkscrew pattern along each wavelength. A birefringent wave emits electricity in the horizontal, vertical, and intermediate planes. The circular microstrip patch antenna finds numerous applications, particularly in the pharmaceutical, military, mobile, and planetary communications sectors. The impedance of microstrip antennas varies depending on factors such as frequency, polarity, design, and the specific patch composition.

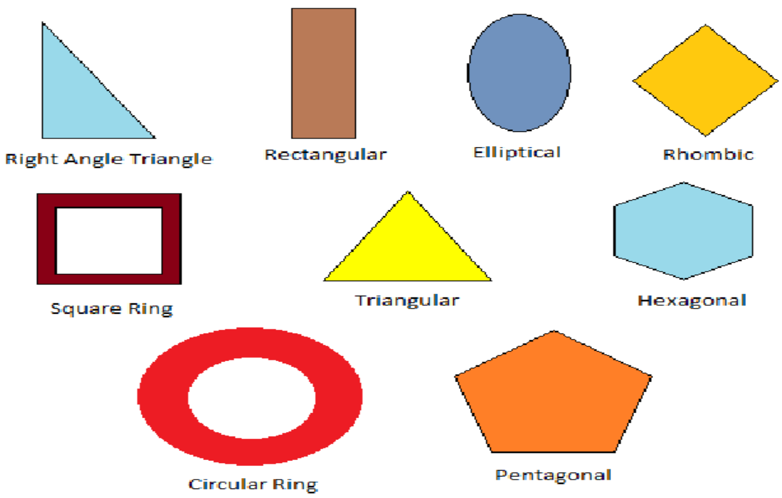


Figure 3.5 Different shape microstrips

Advantages of patch antennas (Microstrips):

- Lightweight nature
- Economical installation
- Simplicity in design
- Cost-effective fabrication, enabling mass production
- Seamless integration with radiofrequency integrated circuits
- Feasibility for operation at dual and triple frequencies

Disadvantages of antennas (Microstrip):

- Radiation inefficiency
- Inefficient radiation
- Limited frequency bandwidth
- Applications of Microstrip patches:
- Employed in spacecraft applications
- Used in aviation applications
- Applicable in compact-size antenna applications

3.2.2 Radiation Pattern

Radiation refers to how an antenna emits or receives a wavefront, along with its intensity. The radiation pattern depicts an antenna's radiation in visual form [13]. By examining an antenna's emission pattern, one can readily discern its intended function and directional attributes. An antenna's radiation pattern illustrates the energy it emits, represented graphically to show the spatial distribution of radiated energy in various directions. Radiation patterns can be categorized as field patterns or strength patterns.

• Field patterns are depicted based on the electric and magnetic fields, shown on a logarithmic scale.
• Power patterns display the square of the electric and magnetic field strengths, typically presented on a logarithmic or dB scale.

Power profile and field pattern are the predominant radiation pattern types. The power pattern displays the distribution of radiated or received power at a consistent distance and is measured as normalized power versus spherical coordinate points. Field pattern is defined as the difference between the normalized |E| or |H| and spherical coordinate location along a constant to radius. Depending on how intricate a particular antenna's radiation pattern is, we might gather the essential details using a limited set of two-dimensional radiation patterns instead of three-dimensional ones. In most scenarios, the necessary information is provided through various frequency response views for specific values of frequency, and a few characteristic views for specific values of angle.

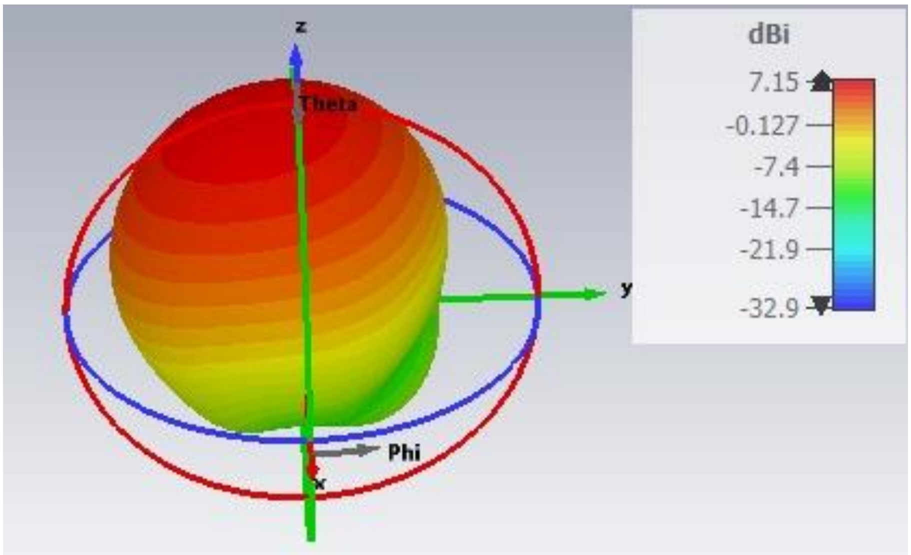


Figure 3.6 Radiation plot antenna

Lobes delineate various segments within a radiation pattern. A ray lobe denotes a section of the pattern encircled by regions of diminished radiation intensity. The primary lobe, or main lobe, encompasses a broader area and emits the highest radiation, serving as an indicator of the antenna's directivity. Side lobes, alternatively termed slight lobes, represent the remaining areas of the pattern where radiation disperses laterally, leading to energy dissipation. Another lobe, positioned in direct opposition to the primary lobe, is known as the rear lobe, albeit smaller, it still results in significant energy loss.

3.2.3 Gain of Antenna

Antenna Gain represents the ratio of power transmitted in the direction of maximum radiation to that of an isotropic source. Unlike directivity, gain is frequently utilized in antenna specification sheets as it considers actual losses. It denotes the antenna's capability to radiate more or less in any direction compared to an idealized antenna [14] . If such an antenna were to be constructed perfectly spherical, it would emit radiation evenly in all directions.

At times, gain is described as the amalgamation of an antenna's directivity and efficiency.

$$\text{Gain, } G = \epsilon R * D$$

Here,

G= Gain of Antenna

ϵR= Radiation

D= Directivity

Gain is consistently less than or equal to directivity. It is a parameter commonly employed in antenna technical specifications, surpassing directivity in frequency of use. Gain is typically measured in decibels.

$$G_{dBi} = 10.\ \log10(G)$$

A microstrip antenna boasting a 2 dB gain signifies that the power received at a distance from the antenna will be 2 dB higher (double) compared to what a flawless isotropic antenna would absorb with the same input power. A perfect antenna would yield a received signal strength of 0 dB (or 100%). Gain escalates with signal amplification. Likewise, an antenna with a 2 dB gain in a direct path would receive 2 dB more power than a lossless isotropic antenna.

In the realm of mobile cellular antennas, your smartphone's cellular antenna communicates with a singular mobile data tower. However, the cellular antenna can be oriented in any direction and situated relative to the cellular tower. Consequently, it is preferable for your smartphone to feature a low-gain antenna. While true antennas can achieve gains of up to 50 dB, this is exceedingly rare. Theoretically, gain cannot dip below 0 dB, but extremely low gain can be attained due to various losses and inefficiencies.

3.2.4 Directivity of Antenna

The directivity of an antenna is a crucial attribute that gauges the "directionality" of its radiation pattern [15] . An antenna with uniform distribution in all directions exhibits nearly zero directionality and a directivity of one (or 0 decibels). Directivity is consistently greater than one. It quantifies the ratio of an antenna's peak radiation intensity to its average radiation intensity, representing the antenna's maximum directional gain.

Here,

$$D= \frac{4\pi[E_{max}]2}{\int_0^{2\pi}\int_0^{\pi} E(\theta,\varphi)]2 \sin \ \theta \, d\theta d\varphi}\text{(Dimensionless)}$$

For beam area,

$D=\frac{4\pi}{\Omega A}$, Here ΩA= Area of beam

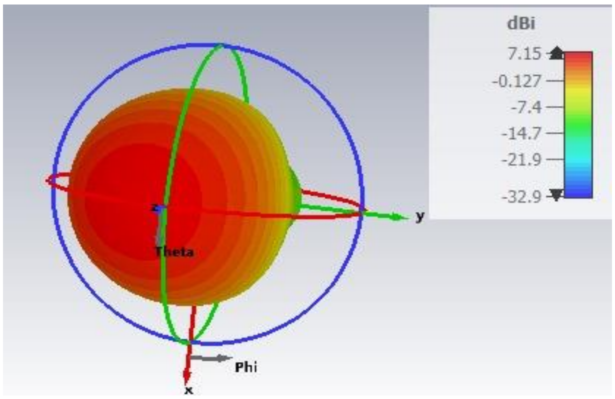


Figure 3.7 Directivity plot antenna.

Here is a listing of several antennae and their directivity:

Antenna Type	Typical Directivity	Antenna Type Typical Directivity Typical Directivity(dB)
Short Dipole Antenna	1.5	1.76
Half-Wave Dipole Antenna	1.64	2.15
Patch (Microstrip)Antenna	3.2-6.3	5.8
Horn Antenna	10-100	10-20
Dish Antenna	10-10,000	10-40

Table 3.1: Different Antennas with Directivity

Higher directivity is achieved with a narrower beam area. When an antenna radiates equally in all directions, its directionality is zero, and its directivity is one. Enhanced directivity implies that the antenna is more focused or concentrated. Due to the necessity for accessibility from various directions, mobile phones are designed with minimal directivity. Conversely, other satellite applications such as satellite telephony, satellite television, and satellite Internet typically require relatively high directivity.

3.2.5 S- parameter for Antenna

In an electrical system, S-parameters describe the input-output relationship between ports or terminals. S21 represents the transfer of electrical power from Channel 1 to Terminal 2. In a multiport network, SNM commonly denotes the power transmitted from Point M to Port N.

S11 is the most commonly referenced parameter in antenna analysis. It quantifies the amount of power reflected by the antenna, hence termed the incident wave or return loss. If S11 equals 0 dB, it means that all power is reflected by the antenna, resulting in no radiation. For instance, if S11 is -10 dB, and 3 dB of current is supplied to the antenna, the reflected power will be -7 dB. The remaining energy is either absorbed by or transmitted through the antenna. This absorbed power is either radiated or dissipated as losses within the antenna structure. Since antennas are typically designed to minimize loss, ideally, the maximum power supplied to the antenna should be radiated. Additionally, VSWR (Voltage Standing Wave Ratio) is closely associated with S11.

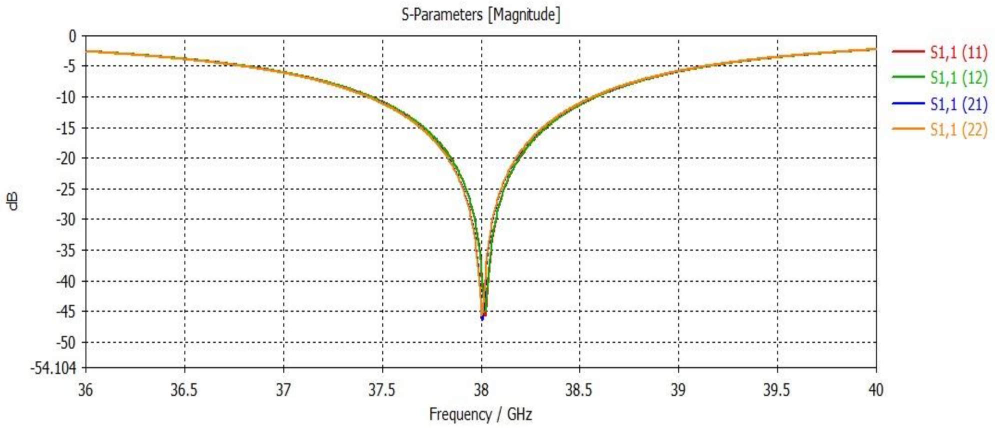


Figure 3.8 S-parameter of Antenna

S11= represents the input voltage port reflection coefficient.

S12= signifies the gain of the reverse voltage.

S21 = denotes the gain of the forward voltage.

S22 = indicates the voltage reflection coefficient at the output port.

Input return loss (RLin) is a scalar representation of how closely the actual reactance of the network matches the desired grid voltage impedances, and is provide by RLin = |20log10 |S11|| in decibels.

When S11 falls below -10dB, at least 90% of the input power is delivered to the device, while the reflected power remains below 10%. S11 represents the reflection coefficient between the port impedance and the input impedance of the network.
It measures the energy reflected back from a network's input impedance when terminated in a typical Zo (usually 50 or 75 ohms for RF networks). Calibration is performed using the amplitude of the incident (forward) signal probing the network's input. The Zo value serves as the reference impedance for both the signal source (generator) and the unidirectional coupler(s) separating incident and reflected energy.

Therefore, a reflection coefficient of zero (S11=0) would indicate an input impedance matching the measuring system's Zo. S11 is a vector with magnitude and phase properties. For passive (and the vast majority of active) circuits, S11 is less than or equal to 1. If the reflection exceeds the incoming signal, the network's input impedance is negative, implying potential instability if the input termination deviates from Zo.

3.2.6 VSWR of Antenna

VSWR, short for Voltage Standing Wave Ratio or Standing Wave Ratio (SWR), is a measure of reflected power in an antenna, influenced by thermal diffusivity [16]. When the transfer function is given by parameters like s11, radiation efficiency, or return loss, the VSWR can be calculated using a specific formula.

Vswr = Vmax/Vmin

Vswr = 1+ [Γ] / 1- [Γ]

|S11| = vswr-1 / vswr+1

VSWR is always a positive value in antenna systems. A lower VSWR indicates better compatibility between the antenna and the power system, resulting in more power being delivered to the antenna. The ideal VSWR is 1, where no power is reflected, representing optimal conditions. Lower VSWR values signify improved impedance matching between the transmitter and antenna, leading to increased power transmission and reduced reflections from the antenna.

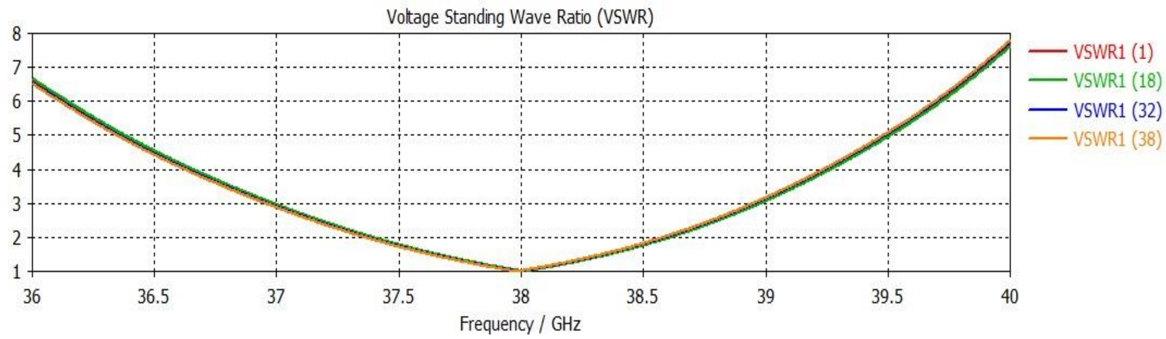


Figure 3.9 VSWR pattern of Antenna

3.2.7 Near Field & Far Field

When a transmitter sends a signal to an antenna, the antenna emits electromagnetic waves into space. These waves exhibit different properties depending on the distance from the antenna, leading to two distinct regions: the near-field and the far-field [16]

The Near Field Unit denotes the space directly surrounding an antenna describes it:

$$\text{Near Field Region} < \frac{2D^2}{\lambda}$$

Here, D = Maximum linear dimension of Antenna

Λ = Wavelength of Antenna

The near field, often referred to as the Fresnel Region, serves as the boundary between the close proximity and distant fields surrounding an antenna. It's were electromagnetic fields transition from reactive to radiative. As they're still undergoing conversion, the shape of the radiated pattern changes with distance. On the other hand, the Far Field Region corresponds to the more distant radiative near field. Here, radiating fields dominate over electromagnetic fields. The E and H fields, akin to the propagation direction of plane waves, exhibit opposite directions.

Antennas are commonly employed to transmit signals across extended distances, referred to as the far-field region. A key condition for measurements in this region is that the distance from the antenna must be notably greater than its physical size and the wavelength of the signal.

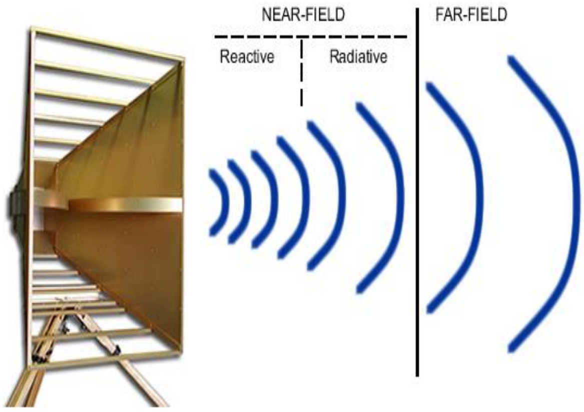


Figure 3.10 Near and Far field pattern of Antenna

3.2.8 Antenna Efficiency

Antenna Efficiency is the ratio of the power radiated (Prad) by the antenna to the power provided (P). It's often evaluated in an anechoic chamber, where the antenna is energized, and the strength of the electromagnetic field emitted in the vicinity is observed [17] . A perfect antenna achieves 100 percent efficiency, indicating it transmits all the applied power. However, in practice, a proficient antenna typically transmits around 50 to 60 percent of the available power.

Antenna Efficiency,

$$\epsilon_R = \frac{P_{radiated}}{P_{Input}}$$

Here,

P radiated = Radiated power

P input = Inputted Power

An antenna that achieves 100% efficiency is considered perfect, converting all the energy it receives. However, in reality, a good antenna typically only transmits between 50 to 60 percent of the input power, aiming to minimize losses. In an anechoic chamber, antenna performance is evaluated by supplying power to its feed and measuring the resulting electromagnetic field intensity. Efficiency is gauged by how much of the RF power provided to the antenna is emitted into the air. When faced with horizontal size constraints, antennas can be extended vertically, as seen in designs like the Yagi-Uda antenna. To optimize efficiency, substrates with low permittivity are favored, although this may increase the size of the radiating element. Advanced techniques, such as impedance matching networks and optimization algorithms, are often employed to enhance antenna efficiency in real-world applications.

3.2.9 Input Impedance of Antenna

Basically, an antenna's input impedance represents the impedance at its terminals, defined as the ratio of voltage to current at the antenna's input terminals [18]. Typically denoted as Zin, it's a common parameter used to characterize an antenna's behavior. This can be expressed using the following equation:

Antenna Impedance, $Z_A = R_A + jX_A$

Here,

R_A= Resistance at antenna terminals and

X_A= Reactance at antenna terminals.

Input impedance, often simply referred to as impedance, tends to be predominantly resistive in most amplifiers. This means that the resistive component (or real component) of the input impedance is usually much larger than the reactive component. For instance, when the input impedance is 5 k, it behaves essentially like a 5k resistor, with minimal reactive components. The real component of the antenna's impedance represents the power either radiated by or absorbed by the antenna. On the other hand, the phase difference of the impedance signifies the reactive power stored in the near field. To simplify, let's consider an antenna with an input impedance of 50 ohms. If the antenna receives a 1-volt signal, the current intensity will be 1/50 = 0.02 amperes. Because the impedance is real, the voltage and current of the antenna will be in phase. Additionally, the characteristic impedance of the antenna plays a crucial role. For instance, if an antenna with input impedance ZA is connected to a source V via a transmission line with characteristic impedance Z0, the antenna will receive power from the source.

$$P = V^2 \times \frac{ZA}{ZA = Z0}$$

If ZA differs significantly from Z0, optimal power transfer won't occur, and maximum power is only achieved when ZA equals Z0. Hence, antennas need to be tailored to match the transmission line's characteristics for efficient power transfer. Commonly, transmission lines have impedances of 50 or 75 ohms, so antennas are designed to have matching input impedances. Like in other electromagnetic circuits, the input impedance parameters of these antennas are pivotal for two main reasons:

1. Enhancing transmission efficiency: Matching the input impedance ensures efficient power transfer from the source to the antenna.
2. Minimizing signal reflection: When the input impedance matches that of the transmission line, it reduces signal reflection, optimizing performance.

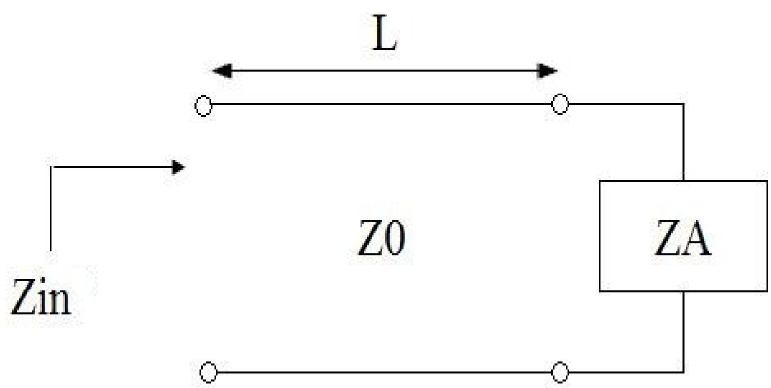


Figure 3.11 Impedance of an Antenna

3.2.10 Bandwidth of Antenna

Bandwidth is a crucial antenna attribute, denoting the frequency range within which it operates effectively. Typically, an antenna's bandwidth is determined using a return loss threshold of -10dB or -15dB. The center frequency signifies the antenna's operating frequency, while the signal's bandwidth refers to the difference between its highest and lowest frequencies. Essentially, bandwidth represents the frequency range over which an antenna can efficiently transmit and receive energy. The impedance bandwidth is calculated as a percentage, given by the formula:

Impedance Bandwidth = (Bandwidth/Center Frequency) x 100.

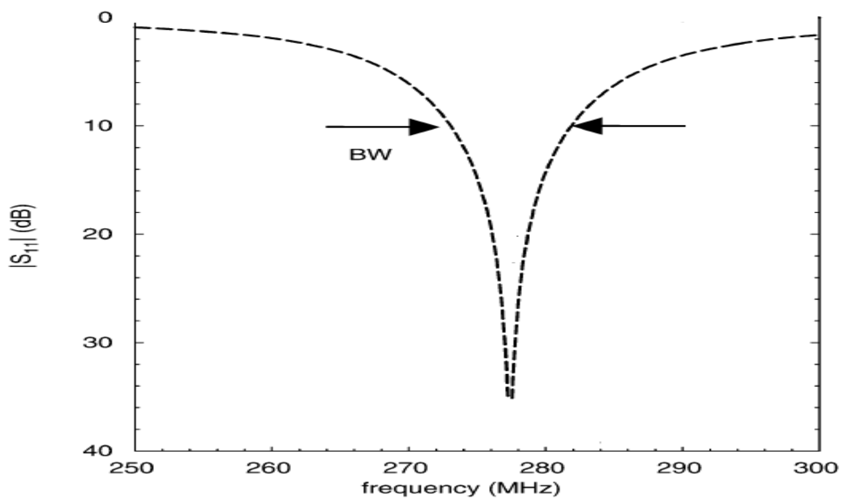


Figure 3.12 Bandwidth of Antenna

To enhance an antenna's bandwidth, several techniques can be employed, such as increasing the substrate thickness with a low dielectric constant, utilizing probe feeding, carving slots, cutting notches, and exploring alternative antenna designs. Bandwidth is a critical consideration for antennas, denoting the frequency range over which the antenna satisfies specified performance criteria. These criteria often include characteristics like gain, radiation pattern, and VSWR (Voltage Standing Wave Ratio). VSWR is commonly selected as the bandwidth parameter, known as the impedance bandwidth.

3.3 Methods and Materials

This section addresses the methods and materials needed to continue the project. Methodology refers to a systematic and theoretical examination of the procedures employed in a particular field of study. It involves analyzing the theoretical models, stages, and research methods associated with the field. It encompasses both quantitative and qualitative research approaches. An effective project management approach is crucial to prevent failure and minimize risks, as it is a key determinant of success, along with essential managerial skills [19]. Methodology consists of a set of practices or procedures, which can pertain to commonly used approaches in a business or scientific field, or the specific methods employed in a particular research study. Unlike techniques, which aim to provide answers, methodology is primarily concerned with the theoretical task of assessing whether a technique or combination of procedures can be realistically applied to a given situation.

3.3.1 Research Design

The research design is the methodology employed to address research questions. It encompasses the various components of a research project, including the research topic, dependent and independent variables, study designs, and, if applicable, data collection techniques and analytic strategies. The research design serves as a blueprint for conducting the study and provides a framework for gathering and analyzing data to answer the research questions effectively.

For this study, the following research design:

• Exploration of fifth-generation (5G) wireless communication systems.

• Identify challenges.

• Analyzing antennas for 5G communication systems involves several tasks: picking an antenna band, crafting a new model, and devising an antenna for that model. It's crucial to gather images and videos for analysis and prepare the dataset according to the established procedure.

3.3.2 Pilot Study

A pilot study, often referred to as a "feasibility" study, is a preliminary investigation conducted to assess the viability and potential of a larger-scale research project. Its primary purpose is to determine whether the proposed research is feasible and if it should proceed, as well as how it should be conducted [19]. Pilot studies are crucial in the research process as they assist in identifying any design-related problems and evaluating factors such as feasibility, practicality, required resources, time, and cost before undertaking a significant research endeavor. These studies play a vital role in providing valuable insights and guidance, ensuring that the subsequent larger-scale research study is well-planned and executed effectively. The Importance of pilot study:

• Assess research methodologies and/or procedures.

• Categorize variables of interest and operationalize them.

• Create and assess research instruments and methodologies.

• Evaluate statistical considerations for upcoming research.

3.3.3 Software for research

In our research, we require specialized software for data analysis and result simulation. We have selected CST (Computer Simulation Technology) as our research-based software. CST is specifically designed for the design, analysis, and optimization of electromagnetic (EM) components and systems. The CST STUDIO SUITE offers a comprehensive system building and modeling architecture, which allows us to develop complete systems using schematic and three-dimensional approaches. This includes designing antennas, arrays, matching or feed systems, and accounting for their surroundings [20] For data assignment and visualization, we utilize SIGMA PLOT, a unique scientific visualization and data analysis software. SIGMA PLOT is compatible with Microsoft Windows and can read various file formats, including Microsoft Excel files. It enables us to perform mathematical transformations and statistical analyses on the data [21]. In our research involving antenna beamforming and CNN (Convolutional Neural Network), we employ MATLAB, which is a proprietary scripting language and numerical computing environment developed by MathWorks. MATLAB offers a versatile platform for matrix manipulations, graphing functions and data, implementing algorithms, building user interfaces, and interacting with programs written in other languages. It provides the necessary programming structures for introductory programming courses [22].

3.4 Design Specifications. Standards and Constraints

3.4.1 Project Design

For a particular project, we must develop a schematic diagram illustrating our workflow, enabling us to monitor project advancement efficiently. Additionally, we establish a model that serves as our guide throughout the project. Subsequently, we proceed methodically, completing each step of the project sequentially.

The project layout is provided below:

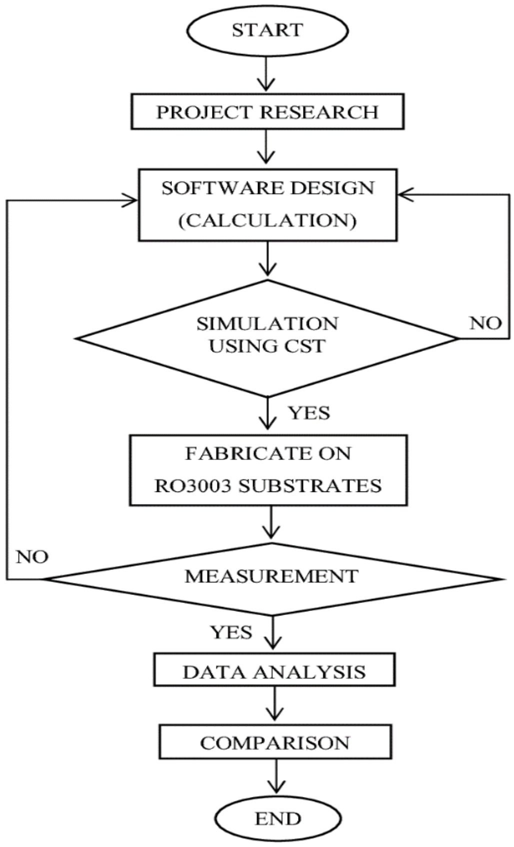


Figure: 3.13 Flow chart of the project design

Having put forward this design, we commenced our efforts and assessed the outcomes of the remaining sections.

3.4.2 Antenna Design

In our study, the task at hand involves the creation of an antenna tailored to our system. We leverage CST software for the seamless design and analysis of our antennas. Specifically, our focus has been on developing a 4x4 MIMO 5G antenna operating at a frequency of 38GHz. Our envisioned antenna is adaptable, allowing the 38GHz configuration to operate across multiple frequencies simultaneously through the integration of varactor diodes, a topic we will delve into further in the design analysis section. The schematic of the proposed antenna is provided below.

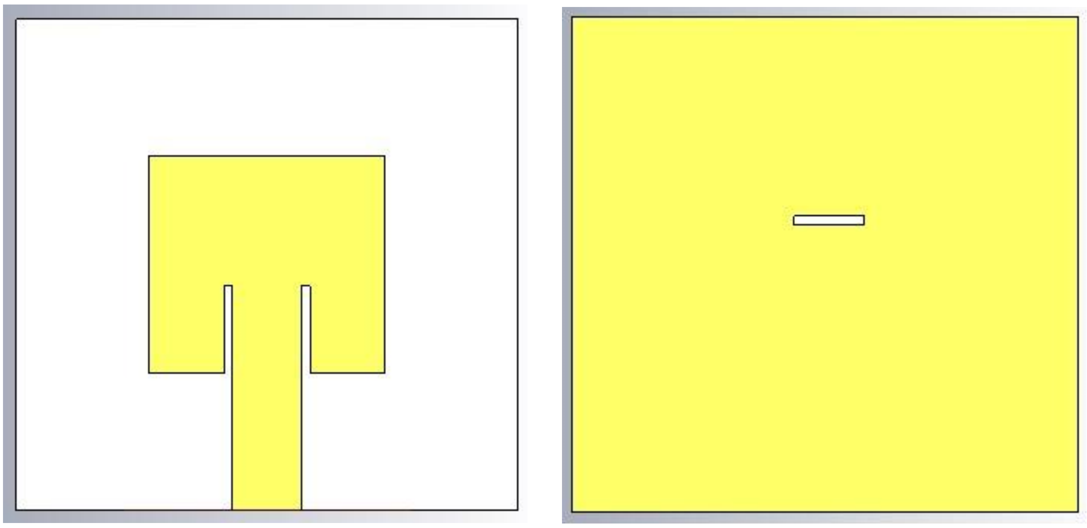


Figure: 3.14 Single Microstrip Patch Antenna

3.4.3 Constraints

Project constraints encompass time, budget, and potential hazards, all of which significantly influence project performance. Similarly, our project's system is not without its limitations. We are encountering simulation challenges during antenna design due to computational limitations, hindering accurate simulation results for large antenna arrays. Moreover, the analysis of existing designs is time-intensive, taking more than 6/7 hours to complete. Additionally, the fabrication process for our antenna design requires sending it abroad, leading to prolonged timelines and pricing concerns. Furthermore, certain components essential for our automation process are unavailable locally, necessitating sourcing from overseas, resulting in shipping delays and added expenses. Despite these limitations, the project's outcomes hold promise for enhancing wireless communication systems in anticipation of future technologies.

3.5 System Analysis

We conduct analysis on various aspects of our current system, including its model, antenna structure, array design, and automation process. The remaining content details information regarding the proposed system.

3.5.1 Antenna Substrates

A substrate, crucial for constructing a microstrip antenna, serves as its foundation or support structure. Its primary role is to provide mechanical stability to the antenna. However, as the substrate is typically made of a dielectric material, it can impact the electrical performance of the antenna, circuits, and transmission lines. Hence, selecting a suitable dielectric substrate that meets both electrical and mechanical requirements is challenging. The initial step in antenna design involves choosing an appropriate dielectric substrate with the desired thickness. Dielectric materials are employed to enhance both mechanical and electrical stability, reducing the antenna's size and aiding in the generation of displacement current. This current, as per Ampere's Law, generates a time-varying magnetic field, which in turn produces a time-varying electric field according to Faraday's law, resulting in the propagation of electromagnetic waves. Thus, a substrate plays a crucial role in improving the antenna's radiation capabilities.

Dielectric Name	Dielectric constant
FR4	4.4
RTDuroid-6002	2.94
RO4730	3
RogersRO 3200	3.02
RogersRTDuroid-5880	2.2
RogersRTDuroid-5870	2.33
Foam	1
TLC-32	4.3

Table 3.2: Different Antennas Substrates

After examining substrate characteristics, we opted for Rogers RT5880 (lossy) for our antenna design. The selection of Rogers RT5880 (lossy) substrate is pivotal due to its capability to enhance the antenna's bandwidth. The key parameters in antenna design include the substrate's composition and properties, such as the dielectric constant and the loss tangent [23].

3.5.2 Antenna Design by Equation

Throughout this period, we compute various parameters of the antenna using a specific formula. Specifically, we calculate the length and width of the microstrip patch antenna based on the operating frequency, dielectric constant, and substrate height as input variables. The dimensions of the patch antenna are determined using the following formulas.

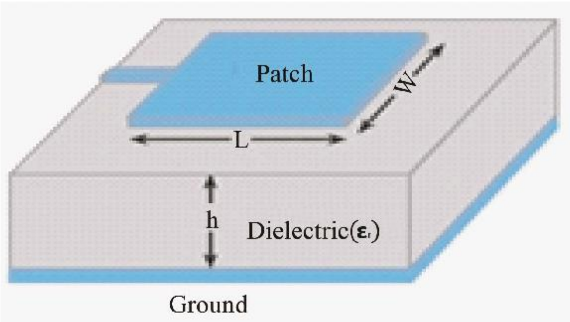


Figure: 3.15 MPA dimesons name

We have to know parameters of,

Resonant frequency, f_0

Thickness of material, h

Di electric constant for antenna, $\in_r$

Calculate the Wavelength of particular antenna $\mathbf{\Lambda} = \frac{c}{f}$

Here, c = velocity of light

f = frequency

Width of the patch, W = $\frac{c}{2f}\sqrt{\frac{2}{\in_r+1}}$.. (i)

Here,

$\in_r$=Dielectric constant of substrate

Length of the patch, L = L_{eff} - $2\Delta L$…………………………………………………… (ii)

Effective length, $L_{eff} = \frac{c}{2f\sqrt{\epsilon_{reff}}}$……………………………………………………… (iii)

Here,

ϵ_{reff}= Effective dielectric constant

Normalized extension of length,

ΔL = $0.412h\frac{(\epsilon reff+0.3)(\frac{w}{h}+0.264)}{(\epsilon reff-0.258)\left(\frac{w}{h}+0.8\right)}$………………………………… (iv)

Here,

$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}[1 + 12\frac{w}{h}]\wedge - 1^{/2}$…...……………………… (v)

Substrate length, Lg = L+6h………………………………………………………. (vi)

Substrate width, Wg = W+6h ……………………………………………………. (vii)

Here, Substrate Height, h = $\frac{0.0606\mathbf{\Lambda}}{\sqrt{\epsilon_r}}$ ………………………………………… (viii)

Feed length, Lf = $\frac{\mathbf{\Lambda}_g}{4}$ ……………………………………………………………. (ix)

Here,

$$\mathbf{\Lambda}_g = guided\ wavelength$$

$$= \frac{\mathbf{\Lambda}}{\sqrt{\epsilon_{reff}}} \text{ ……………………………………………………….. (x)}$$

Efficiency of antenna,

H= $\frac{\textbf{gain}}{directivity}100\%$ …………………………………… (xi)

By employing the nine formulas outlined above, it becomes feasible to construct a microstrip patch antenna (MPA) that precisely adheres to all 5G specifications. Subsequently, the antenna will be meticulously designed in the CST Microwave Studio, utilizing the computed parameters. We have included a proposed antenna design with dimensions determined using the aforementioned equations.

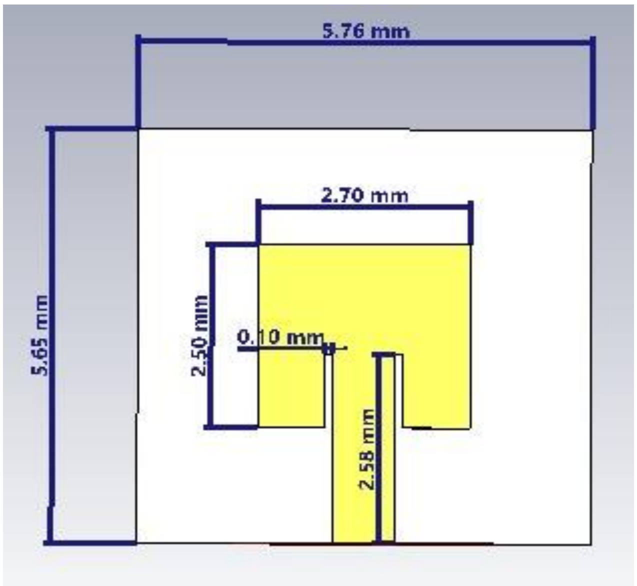


Figure: 3.16 Proposed Antenna Dimensions

Symbol	Value	Description
subl	5.65	Ground
subw	5.76	Ground
antl	2.496	Antenna length
antw	2.697	Antenna Width
subd	0.314	Substrate depth
insl	1	Inset Length
insw	0.1	Inset Width
txw	0.789	Transmission width
εr	2.2	Substrate dielectric constant

Table 3.3: Different dimensions of the proposed microstrip patch antenna

3.5.3 Antenna Reconfiguration

Antenna reconfiguration typically refers to the process of adjusting the parameters or physical structure of an antenna to optimize its performance for specific requirements or operating conditions. This can involve changing the antenna's shape, size, orientation, or electrical properties. The reconfiguration process involves adjusting a specific switching mechanism, which can be achieved using electrical, mechanical, physical, or optical switches [24].

There are several reasons why antenna reconfiguration might be necessary:

1. **Optimizing Performance**: Antennas may need to be reconfigured to achieve better performance in terms of gain, radiation pattern, bandwidth, or impedance matching.
2. **Adaptation to Changing Conditions**: Antennas used in mobile or dynamic environments may need to be reconfigured to adapt to changing environmental conditions, such as movement or interference.
3. **Frequency Agility**: Some antennas are designed to operate over a wide range of frequencies. Reconfiguring such antennas allows them to be tuned to different frequencies as needed.
4. **Multi-Functional Antennas**: In some cases, antennas need to serve multiple functions, such as communication, radar, and electronic warfare. Reconfiguration enables the antenna to switch between these functions efficiently.
5. **Space Limitations**: Antennas used in compact devices or confined spaces may need to be reconfigured to fit within the available space while maintaining acceptable performance.
6. **Fault Tolerance**: Reconfigurable antennas can be designed to have redundancy or fault tolerance, allowing them to continue operating even if part of the antenna is damaged or malfunctioning.

3.6 Summary

In this section, we will explore various antenna types, analyzing their strengths and weaknesses. Specifically, we have selected a rectangular patch antenna for our system and provided an in-depth discussion on its characteristics. Additionally, we delve into the essential antenna parameters necessary for conducting antenna simulations, including VSWR, radiation pattern, S-parameters, efficiency, and field results. Moving forward, we discuss the research materials and resources utilized, including the different types of substrates employed in antenna design. We also review the software platform utilized for designing and simulating our research. Furthermore, we outline the procedural steps employed in our research. Subsequently, we transition to the design phase, where we cover important equations essential for antenna design and visualize the systems using appropriate figures. Throughout the design phase, we also address potential limitations that may arise during the development of our research work.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Result Analysis

In this chapter, we examine the simulation results of our proposed model, focusing on observing the system's performance. Subsequently, we provide a detailed discussion of our findings in subsequent sections.

4.1.1 Antenna Simulation & Result Analysis

In Chapter 3, we introduced our suggested antenna, a 38GHz 5G microstrip patch antenna, utilizing Rogers RT5880 substrate. Following the completion of this design, we identified our most effective outcomes. The pilot signal comprises received signals that are pre-established for both the transmitter and the receiver. Utilizing the associated method and the known symbols, the receiver can predict the channel response accordingly. [25]

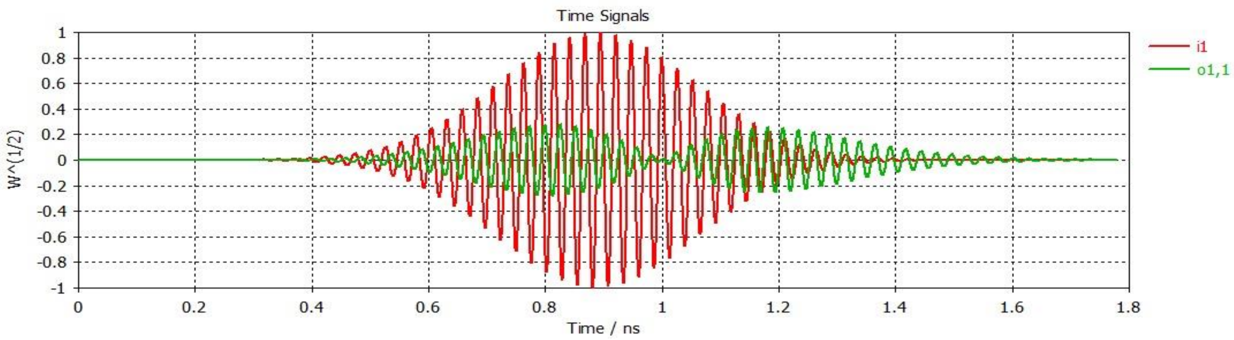


Figure: 4.1 Time Domain signal both transmitter and receiver.

S-parameters describe the relationship between input and output connections among ports or terminals. For instance, in a scenario with two ports designated as Port 1 and Port 2, S12 represents the power transferred from Port 2 to Port 1.

S11 is frequently referenced in the context of antennas. It quantifies the power reflected by the antenna, making it indicative of the incident wave (also denoted as gamma or return loss).

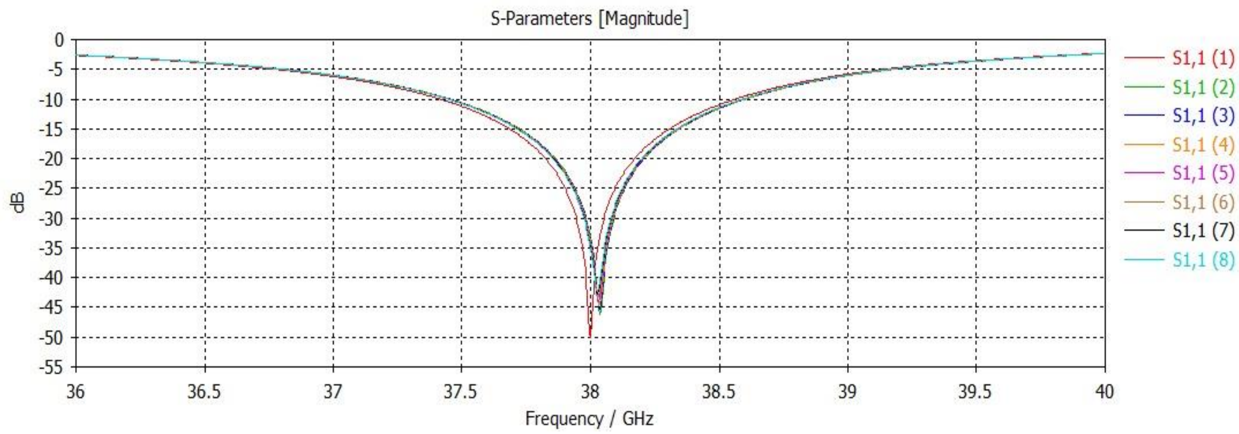


Figure: 4.2 S-parameter for proposed antenna

S11 and S21 serve as pivotal S parameters for a microstrip patch antenna. S11 evaluates reflection and signifies impedance matching, with lower values being preferable. On the other hand, S21 assesses transmission and reflects the antenna's efficiency, with higher values indicating superior performance.

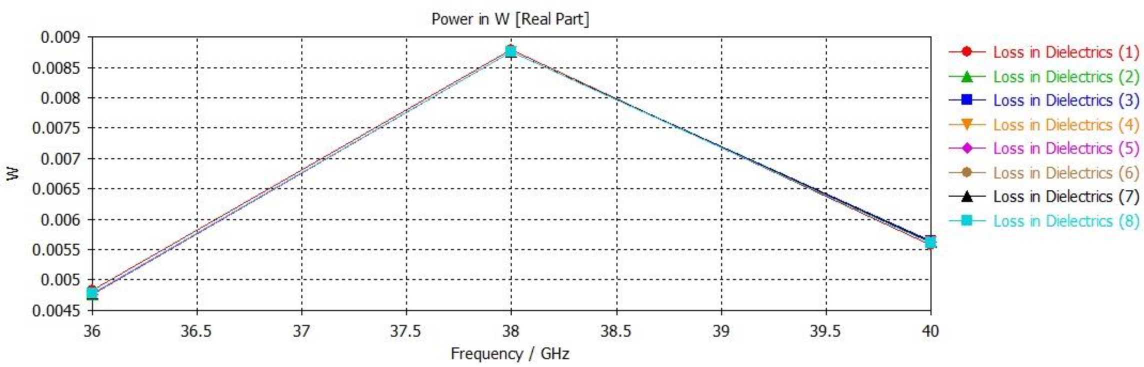


Figure: 4.3 Power loss of proposed antenna

Our simulation outcomes reveal losses within our proposed antenna design. These losses stem from various sources, including the dielectric materials utilized, the lumped elements employed for antenna reconfiguration, observed metallic losses, and inherent losses in the antenna ports. Additionally, the simulation results provide insights into the amount of power accepted and radiated by the antenna, with 0.21 watts attributed to dielectric loss.

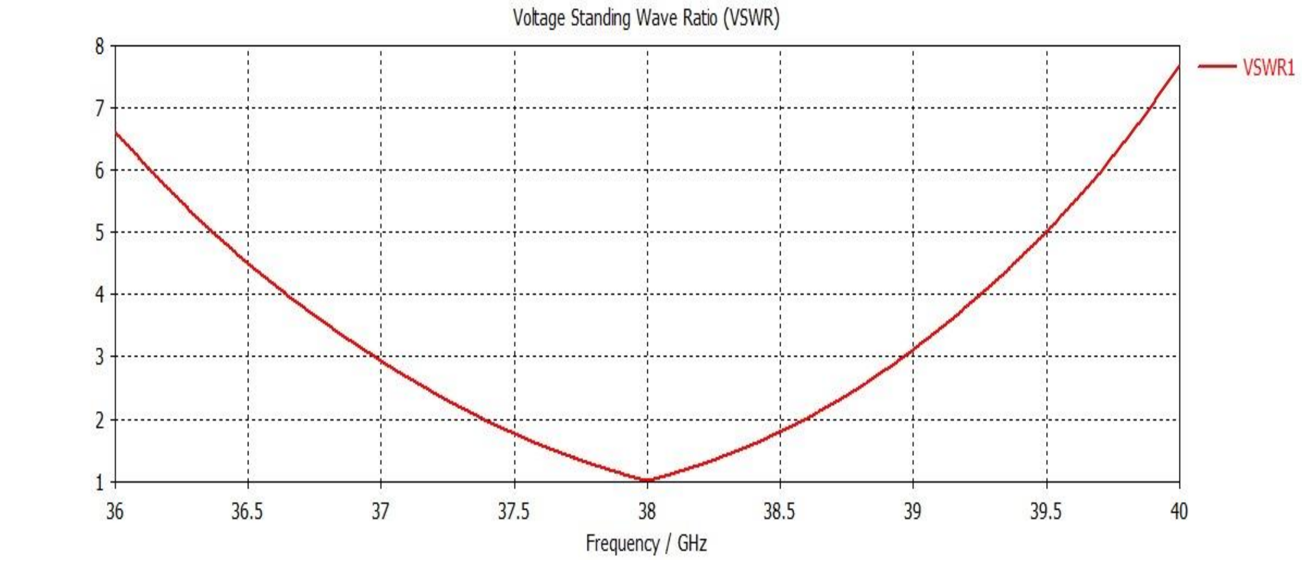


Figure: 4.4 Voltage standing wave Ratio (VSWR)

To optimize the performance of a 38 GHz microstrip patch antenna, it's ideal to target a low Voltage Standing Wave Ratio (VSWR), ideally close to 1:1. A VSWR less than 2:1 is typically considered acceptable for efficient signal transmission in applications like Wi-Fi. To achieve these goals, it's crucial to ensure proper impedance matching, utilize high-quality materials, and fabricate the antenna with precision.

The energy curve initially ascends before reaching a peak, after which energy consumption fluctuates periodically, sometimes decreasing below previous levels.

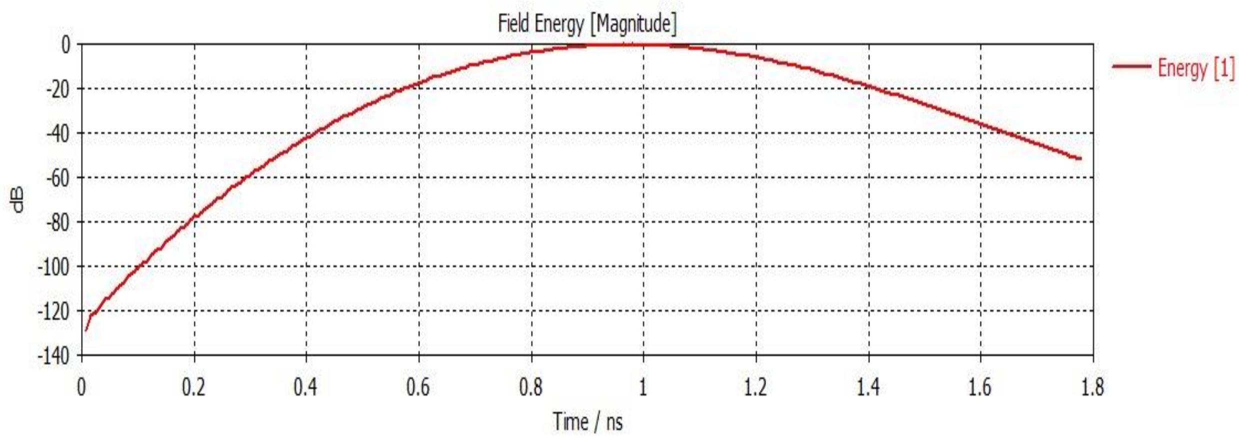


Figure: 4.5 Energy Curve

We achieved exceptional return loss, which is notably high across all measurements, reaching an impressive value of -50.2 dB.

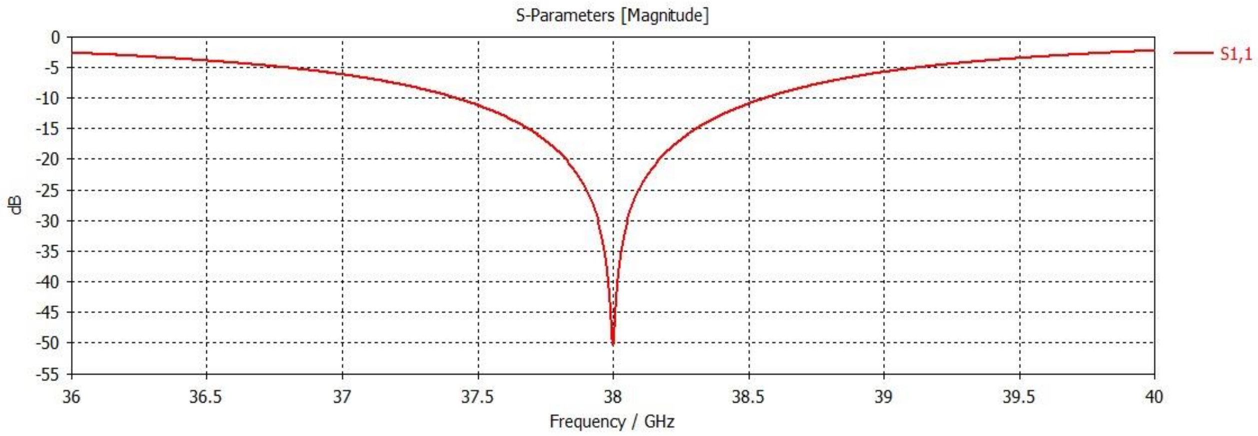


Figure:4.6 Return loss

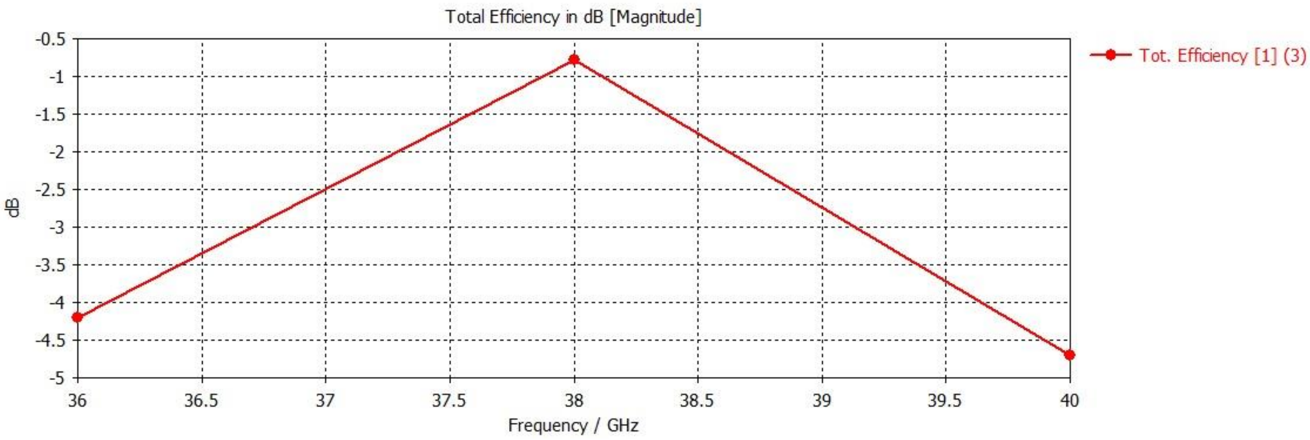


Figure: 4.7 Total Efficiency

Below are the far-field simulation results showcasing the output.

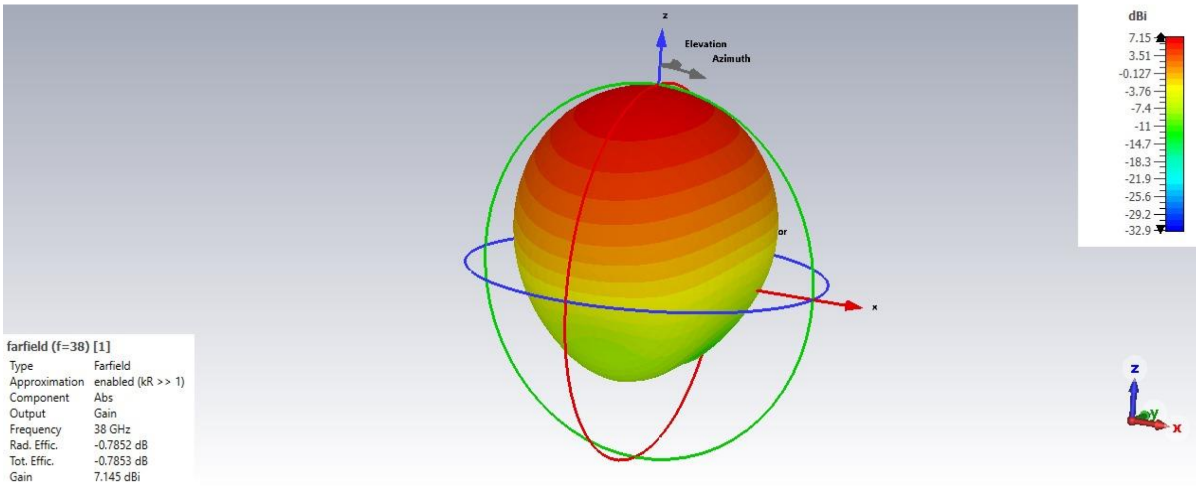


Figure: 4.8 Directivity of antenna

The directivity of the proposed antenna is 7.14 dBi.

4.1.2 Comparison with Existing Results

In this section, we will delve into a comparative analysis of our design in contrast to other relevant designs. By examining various research works, we aim to enhance our system by identifying how the performance of other designs impacts their effectiveness. The comparison will encompass antenna efficiency, S-parameters, bandwidths, return losses, and power transmission. Please refer to the attached tabular form for detailed insights and discussion on this topic.

Reference	Operating frequency	Bandwidth	Return Loss	Gain
[26]	37.96 GHz	2.14 GHz	-40.00 dB	6.85 dBi
[27]	38.50 GHz	1.02 GHz	-41.00 dB	6.33 dBi
[28]	37.40 GHz	1.40 GHz	-34.04 dB	6.80 dBi
[29]	38.00 GHz	0.90 GHz	-24.25 dB	6.98 dBi
Proposed	**38 GHz**	**1.14 GHz**	**-50.2 dB**	**7.145 dBi**

Table 4.1: Comparison of Antennas parameters

In the table provided, we observe a comparison of antenna parameters with our own work. Our antenna exhibits superior efficiency compared to others, indicating better power radiation and reduced loss in the output. Moreover, with a return loss of -50.2 dB, our proposed antenna minimizes the impact of reflected signals on the transmitted signal, which is favorable for reducing interference. These comparison results affirm the effectiveness of our research work in achieving healthier performance metrics compared to other antennas.

4.2 Discussion

The main motive of this research is to build a smart antenna system maintain the 5G future trends. Smart antenna for smart cities is mandatory. So that we chose small cell base station system that can easily implemented beside road, top of the traffic lights, street lamp. That gives the much coverage than normal base stations. Our design separated in various part antenna and other features. For antenna side, we see our antenna performance. We get highest efficiency compare to others. That's good sign to design antenna like this and that will give better result when implement it. Also, antenna that is reconfigurable. Our antenna operates at multiple frequency that means antenna can operate in multiple frequency. As we need of our system, we can switch our antenna frequency. In tech. part we added various features with our antenna. That makes our antenna smart antenna. Where we use deep learning that is trend of future technology. By processing video analysis antenna beamforming can visualize with our system. Using global system antenna coverage can also monitored. That improves the antenna performance, coverage lots of user at a time that we visualize in our system. Also, make antenna automatic movement use of robotics brain system. Antenna can radiate automatically without manual control. For smart cities it's a beneficial to having this kind of antenna. Where we find out low latency, low signal interference, high efficiency that make our system more reliable.

CHAPTER 5

PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

The primary project task has been accomplished, and each task has been followed by the completion of a milestone. Below is a tabular representation of the tasks and their respective completion statuses.

Title	Start date	End date	Duration (in days)	% Complete
Proposal of work	05/10/2023	05/15/2023	5	100
Search Relevant Literature	06/01/2023	06/06/2023	5	100
Material Available	07/15/2023	07/22/2023	7	100
Chapter 1	07/29/2023	08/18/2023	20	100
Chapter 2	08/22/2023	09/06/2023	15	100
Planning Methodology	09/08/2023	09/23/2023	15	100
Antenna Design	09/27/2023	11/03/2023	37	100
MATLAB Coding	11/10/2023	11/22/2023	12	100
Simulation Analysis & Corrections	11/29/2023	01/31/2024	63	100
Chapter 3	02/02/2024	02/20/2024	18	100
Result Analysis & Chapter 4	02/22/2024	03/10/2024	19	100
Chapter 5	03/16/2024	04/05/2024	19	100
Chapter 6 & Chapter 7	04/20/2024	04/30/2024	10	100

Table 5.1: Project task completion

Before initiating our project, we established a milestone and upon completion, we noticed minor variations. However, the project was finished ahead of the initially projected deadline. Attached below is the milestone Gantt chart, illustrating the estimated product and cost analysis. Prices may fluctuate depending on availability and transportation costs from other countries. Additionally, more products are required for lab testing before project implementation to guarantee the desired final outcomes.

5.2 Lesson Learned

The assessment of lessons learned takes place at the conclusion of a project. It involves analyzing the knowledge gained during project execution, recognizing the team's successes and failures, and striving to replicate positive aspects while avoiding mistakes. Project management encompasses learning about project planning, acquiring knowledge of new technologies, and effectively assigning tasks among team members. At the outset of any project, creating a project plan is essential, often aided by the use of a Gantt chart. This plan outlines the project's timeline, tasks, and dependencies, providing a visual representation of progress. Moreover, project milestones are established to track and assess various activities, enhancing project management. Market analysis and cost management are crucial components of project planning. Conducting market analysis helps identify target markets, understand customer needs, and evaluate competition. Cost management ensures the project's financial viability and profitability. Analyzing costs and making informed decisions contribute to a cost-effective project, attracting more users.

CHAPTER 6

IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

Economic Impact

Cost-Effective Manufacturing: Microstrip patch antennas offer a cost-effective solution compared to certain traditional antenna types. The materials involved, including dielectric substrates and conductive patches, are often relatively inexpensive, facilitating cost-effective manufacturing processes.

Integration with PCBs: Integration of these antennas into printed circuit boards (PCBs) directly eliminates the requirement for additional components, thereby reducing production costs. This streamlined integration renders them suitable for mass production across various electronic devices.

Societal Impact

Wireless Communication: Microstrip patch antennas play a crucial role in enabling wireless communication technologies like Wi-Fi, Bluetooth, satellite communication, and mobile networks. The widespread adoption of these technologies has revolutionized global communication, connectivity, and access to information, fundamentally altering the way people interact and communicate worldwide.

Miniaturization and portability: The small and flat design of microstrip patch antennas supports the downsizing of electronic devices. This innovation has led to the creation of more compact and portable communication gadgets, increasing their accessibility and usefulness for individuals.

Global Impact

Connectivity and Accessibility: Microstrip patch antennas play a pivotal role in the global communications infrastructure, facilitating long-distance communication by linking individuals worldwide through satellite links and wireless networks.

Emerging Technologies: As technology evolves, microstrip patch antennas play a crucial role in the advancement of new technologies such as the Internet of Things (IoT), 5G networks, and smart devices. These breakthroughs have the potential to revolutionize industries, boost efficiency, and enhance global connectivity.

Remote Sensing and Earth Observation: Microstrip patch antennas are essential components of satellite systems utilized for remote sensing and earth observation tasks. These antennas play a pivotal role in collecting data for diverse applications such as weather monitoring, environmental assessment, and disaster management. Consequently, they contribute significantly to global initiatives aimed at understanding and addressing critical issues.

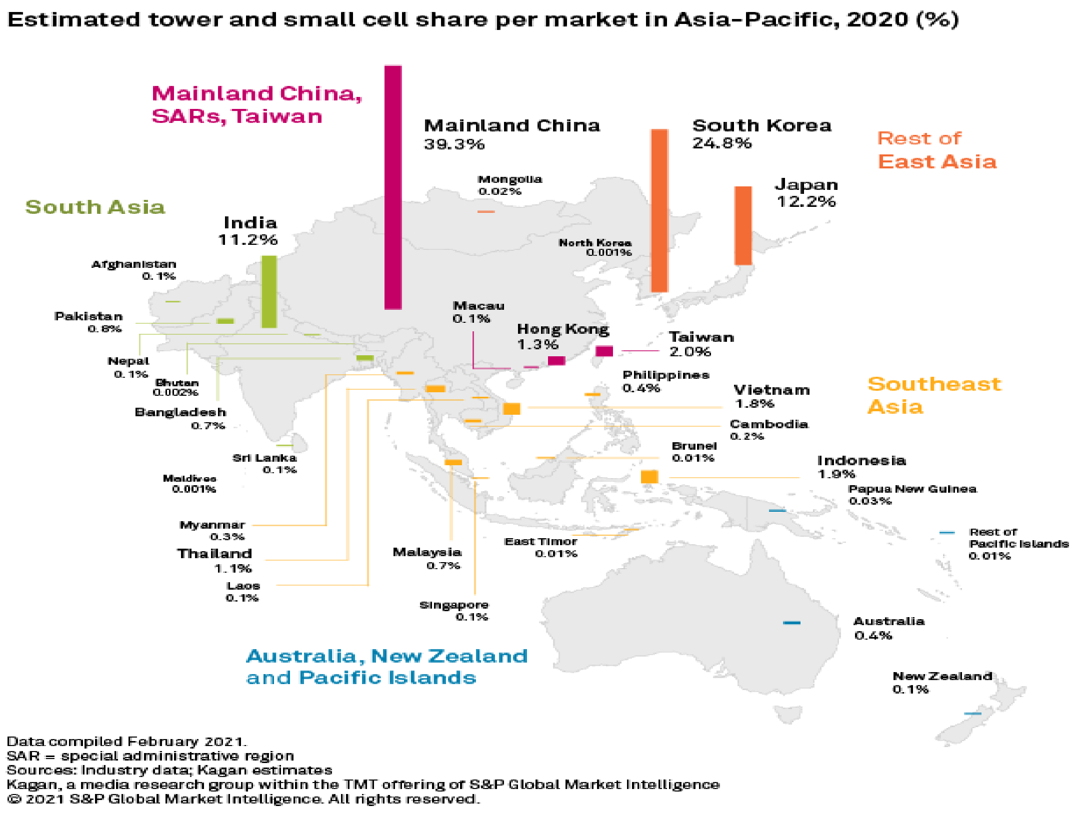


Figure 6.1 Small cell antenna market

To summarize, microstrip patch antennas offer several notable advantages. From an economic perspective, they provide cost-effective manufacturing options, making them a financially viable choice. In terms of societal impact, microstrip patch antennas enable widespread wireless communication and facilitate the miniaturization of electronic devices, which has become increasingly important in our interconnected world. On a global scale, these antennas contribute to connectivity by supporting emerging technologies and play a crucial role in remote sensing applications. Their significance extends to various domains, including telecommunications, aerospace, and scientific research, with far-reaching implications. [30]

6.2 Environmental and Ethical Issues

Electronic Waste (e-waste):

Microstrip patch antennas are prevalent features in electronic devices. However, ethical dilemmas emerge from the disposal of such devices, leading to electronic waste concerns. Ethical considerations entail designing antennas that are recyclable and promoting responsible disposal practices.

End-of-life considerations:

Making sure that antenna components can be easily separated for recycling is not only a practical consideration but also an ethical one. Designing antennas with easy disassembly in mind promotes the recycling of valuable materials and contributes to reducing the environmental impact of electronic waste. By enabling the efficient recovery of materials through recycling processes, we can minimize resource depletion, decrease landfill waste, and mitigate the harmful effects associated with the extraction and production of new materials. Emphasizing the recyclability of antenna components aligns with sustainable practices and fosters a more environmentally responsible approach to technology design and disposal. [31]

Human Rights with in the Supply Chain:

It's important to think about treating workers fairly and ethically when getting materials and parts for microstrip patch antennas. Making sure the companies we work with follow human rights rules is a big ethical concern.

Access and inclusion:

Considering technology's accessibility and inclusivity is crucial. Creating and employing antennas in a manner that guarantees equitable access to communication technologies can narrow the disparity between individuals with and without access.

Privacy concerns:

Microstrip patch antennas are frequently utilized in communication systems. Concerns regarding user privacy may arise, prompting designers to incorporate features or protocols that prioritize user privacy and data security. [32]

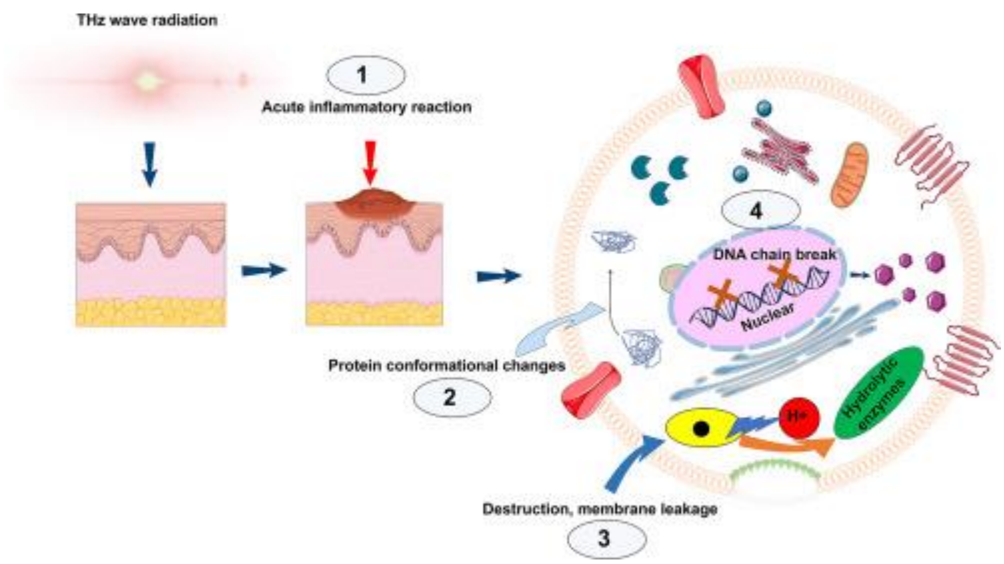


Figure 6.2 Tissue damage by radiation

In summary, adopting environmentally friendly materials, employing cleaner manufacturing processes, considering end-of-life recyclability, and addressing ethical concerns throughout the supply chain and usage collectively promote a more sustainable and responsible approach to microstrip patch antenna design and implementation.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The design and simulation of a microstrip antenna operating at 38 GHz using CST Software has been successfully accomplished. This work addresses a significant area of study within the rapidly evolving field of wireless communication, specifically focusing on the development and deployment of high-bandwidth 38 GHz microstrip patch antennas for mobile applications. The design approach adopted in this project aimed to achieve a reduction in antenna size while simultaneously increasing the overall gain by approximately 16%. The literature review conducted during the study emphasizes the diverse factors that must be considered to optimize antenna performance. These factors include patch geometry, substrate materials, feed methods, and the challenges of integrating antennas into dynamic mobile environments. The insights provided by the literature review are highly valuable for antenna designers and engineers, particularly as the demand for high-performance wireless communication continues to grow. To further advance antenna technology and facilitate seamless and effective connectivity for modern mobile applications, it is recommended that future research in this area focuses on exploring new materials, fabrication techniques, and integration strategies. By investigating and innovating in these areas, researchers can contribute to the ongoing progress of antenna technology, ultimately enabling the development of more efficient and capable antennas that meet the demands of contemporary mobile communication systems. [33]

7.2 New Skills and Experiences Learned

Throughout the process of learning and designing a 38GHz high-bandwidth patch antenna for a thesis, a broad range of knowledge and expertise was acquired. This transformative experience involved gaining technical proficiency in intricate antenna design, skillful utilization of electromagnetic simulation tools, and a comprehensive understanding of optimizing feeding mechanisms and selecting suitable substrate materials. Engaging in research also enhanced participants' ability to critically evaluate existing literature, identify gaps in understanding within the field, and position the study within the broader academic context. An important aspect of the research was establishing a correlation between simulated results and experimental measurements, highlighting the significance of translating theoretical designs into functional prototypes. The research approach incorporated parametric studies and iterative optimization, enabling the adjustment of design parameters for optimal performance. Furthermore, the experience of documenting and writing a thesis improved the ability to provide a comprehensive explanation of the research's goals, methods, and findings. The process also fostered the development of problem-solving skills, particularly in addressing challenges encountered during the antenna design and optimization stages. The cultivation of time management and project planning abilities facilitated the efficient completion of milestones and adherence to deadlines. Collaborating with advisors, colleagues, and subject matter experts contributed to the enhancement of collaboration and communication skills. Seeking input, receiving feedback, and adapting the research strategy based on constructive criticism became integral components of the research process.

Overall, this experience encompassed a wide array of skills and knowledge acquisition, ranging from technical expertise in antenna design to critical evaluation of research literature, effective communication, and project management.

7.3 Future Recommendations

Although antennas are generally considered an old technology, telecommunications companies are finding ways to innovate antennas for the next generation of electronics. Right now, product engineers use 3D printing or advanced manufacturing techniques to make antennas smaller, lighter and stronger than ever before. Cell phone companies are planning to introduce 5G technology, which will usher in an era of smaller cell towers. Despite these innovations, traditional cell phone towers and larger antennas will still play an important role in shaping the future of human communication.

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APPENDIX A

TURNITIN REPORT

Final Book 38GHz High Bandwidth and Low Return Loss Microstrip Patch Antenna Design.

ORIGINALITY REPORT

21%	17%	11%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Samrat Sadhu, Bhaskar Acharjee, Sudip Mandal. "Chapter 52 Design of Wideband Microstrip Patch Antenna at 38GHz for 5G Network", Springer Science and Business Media LLC, 2024 Publication	3%
2	dspace.daffodilvarsity.edu.bd:8080 Internet Source	2%
3	dspace.iiuc.ac.bd:8080 Internet Source	2%
4	dspace.bracu.ac.bd Internet Source	1%
5	Rafał Przesmycki, Marek Bugaj. "High Gain WAT Antenna for 38 GHz 5G Systems", Journal of Telecommunications and Information Technology, 2023 Publication	1%
6	www.researchgate.net Internet Source	1%

APPENDIX B

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
P1	Depth of knowledge required	The design necessitated a thorough understanding of Bandwidth, S-parameters, Gain, return loss, CST Studio Suite and HFSS software, requiring an extensive depth of knowledge.
P2	Range of conflicting requirements	Designing involves navigating a range of conflicting requirements. Engineers must balance factors like high data rates, low latency, and reliable connectivity with constraints such as size, power consumption, and cost.
P3	Depth of analysis required	The design necessitated thorough analysis, electromagnetic theory, antenna design principles, and signal propagation characteristics. Antenna performance considers factors like frequency response, radiation patterns, impedance matching, and environmental effects for specific applications and conditions.
P4	Familiarity of issues	Facing unique challenges in antenna design, including frequency selection, radiation pattern optimization, impedance matching, environmental effects, and manufacturability, to create effective antennas that meet performance requirements.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
A1	Range of resources	The project needed different things, showing how important it is to use resources wisely and manage them well.
A2	Level of interaction	Ranges from simple use by consumers to more involved tasks such as design, optimization, deployment, and maintenance by engineers and network operators, with ongoing exploration and development by researchers and developers.
A3	Innovation	Encouraging innovation is crucial, transforming wireless communication, with advancements in higher frequency support, beamforming, spectrum utilization, and compact design driving network efficiency and performance.