BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATION ENGINEERING

Analysis the Performance of mm Wave Microstrip Patch Antenna (MPA) with Array for 5G Applications

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DEDICATION

This thesis work is dedicated to all of our honorable professors and our beloved parents for their prayers and encouragement in helping us reach our goals.

CERTIFICATE OF APPROVAL

The project entitled **as "Analysis the Performance of mm Wave Microstrip Patch Antenna (MPA) with Array for 5G Applications"** submitted by Md.Yeasin Arfath having an ID No: T-181059, to the Department of Electronic and Telecommunications Engineering (ETE) of International Islamic University Chittagong (IIUC) has been accepted as satisfactory to partially fulfill the bachelor's degree criteria in Electronic and Telecommunications Engineering and approved as to its style and contents for the examination members.

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CANDIDATES DECLARATION

It is thus declared that the work included in this thesis has not been submitted elsewhere for the award of any degree or certificate and that it contains no illegal declarations.

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In the name of Allah, the Most Gracious, the Most Generous, the Most Kindhearted, we give Allah (SWT) all the praise and glory because He has provided us with a variety of opportunities as well as mercy and guidance throughout our lives. And may the Prophet Muhammad (pbuh) receive Allah's blessings and peace, guiding and inspiring us in our lives. Our deepest appreciation goes out to our thesis supervisor **Mohammad Ariful Islam** & Co Supervisor **Abu Zafar Mohammad Imran** for their research initiative in this field, useful guidance, and encouragement during the research process. We express our appreciation **Syed Zahidur Rashid**, Chairman of the Electronics and Telecommunications Engineering Department at IIUC, for giving us the best departmental facilities and for his prompt guidance. We are also grateful to **Abdul Gafur**, our thesis' convener, for his efforts and dedication. We also want to thank all of our teachers for their dedication and hard work over the course of our academic careers. And we are grateful to our parents for their assistance throughout our life so far. Additionally, we would like to thank our friends for helping us finish this thesis, whether directly or indirectly.

Abstract

The evaluation of Microstrip antenna performance has changed from a simple free space evaluation, where things like efficiency, gain, bandwidth, and matching were looked at, to a much more complicated process that takes into account the end-user and real-world environments. This process of evaluating is still going on, and both academics and industry people are coming up with better ways to evaluate antennas. This thesis gives new ideas about how to improve antennas parameters. Microstrip antennas have become a part and parcel of today’s mobile communication world due to their low cost, low profile and ease of fabrication in the circuit boards. However, poor performance, such as low power handling efficiency, limited bandwidth, low gain, etc. The next 5th generation (5G) application’s communication will experience significant route loss since high frequency bands will be employed. So, a high gain antenna is necessary for this issue.

Since microstrip antennas are small, they are a great choice for 5G technology applications.Therefore, the primary goal of this research project is to create a high-gain & high efficient antenna using a ambient microstrip patch antenna. The antenna operates on the 28 GHz band and was built and tested using CST Microwave Studio. Laminate material is used as a surface close to 2.2 with relative permittivity. Analysis the performance by implementing the MIMO and array. The gain, bandwidth, return loss, VSWR and efficiency of the 1x4 array antenna designed is 9.32 dBi, 9.5 GHz, 34.55 dB, 1.03 and nearly 94% respectively.

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LIST OF SYMBOL

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

LIST OF ABBREVIATIONS

ETE	Electronics & Telecommunication Engineering
IIUC	International Islamic University Chittagong
IEEE	Institute of Electrical and Electronic Engineers
LTE	Long Term Evolution
1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
FCC	Federal Communication Commission
GSM	Global System for Mobile communication
SDR	Software Define Ratios
ANT	Antenna
MMW	Millimeter Wave
MPA	Microstrip Patch Antenna
3D	Three Dimension
2D	Two Dimension
VSWR	Voltage Standing Wave Ratio
HF	High Frequency
MF	Medium Frequency
LF	Low Frequency
DG	Diversity Gain
WCC	Wireless Communication Centre
IE3D	Moment of Method Based EM Simulator
HFSS	High Frequency Structure Simulator
MIMO	Multiple Input Multiple Output
ECC	Envelope Correlation Coefficient
CST	Computer Simulation Technology
PCB	Printed Circuit Board

BW	Bandwidth
RL	Return Loss
QF	Quality Factor
RF	Radio Frequency
MICs	Microwave integrated circuits
PTT	Push to Talk
IMTS	Improved Mobile Telephone System
AMTS	Advance Mobile Telephone System
FDMA	Frequency Division Multiple Access

Chapter 1

Introduction

1.1 Network Communication Evolution

“Wireless transmission is the practice of communicating without the usage of cables. It utilizes a range of frequencies and bandwidths to communicate with one another. The sender uses a free and open bandwidth to convey the message signal. The receiver tunes to that particular bandwidth in order to pick up the message signal. In mobile wireless communication, the mobile service provider selects a particular frequency from a range of frequencies to allocate to each mobile station. This frequency is now being used by mobile station users to transmit and receive message signals. Motorola unveiled the first transportable cell phone in 1973. The primary commercially available mechanised cellular link in Japan was introduced by NTT in 1979. In 1981 by Denmark, Finland, Norway, and Sweden The Nordic Mobile Telephone (NMT) structure was introduced.’’ [1]. With the introduction of 0G, which makes use of the Push to Talk Technique, Mobile Wireless Communication entered the communication industry following the development of wireless communication. There will be 1G networks in the future that are solely for voice conversations. In addition to digital technology and message-sending capabilities, 2G was a redesign of 1G. Wide-ranging access to high-speed internet services was made possible by 3G. As a more developed variant of 3G with enhanced bandwidth and capacity as well as service quality, 4G was released (QoS). The bandwidth of 5G is two times that of 4G, allowing for real-time wireless Internet access (WWW). [2]

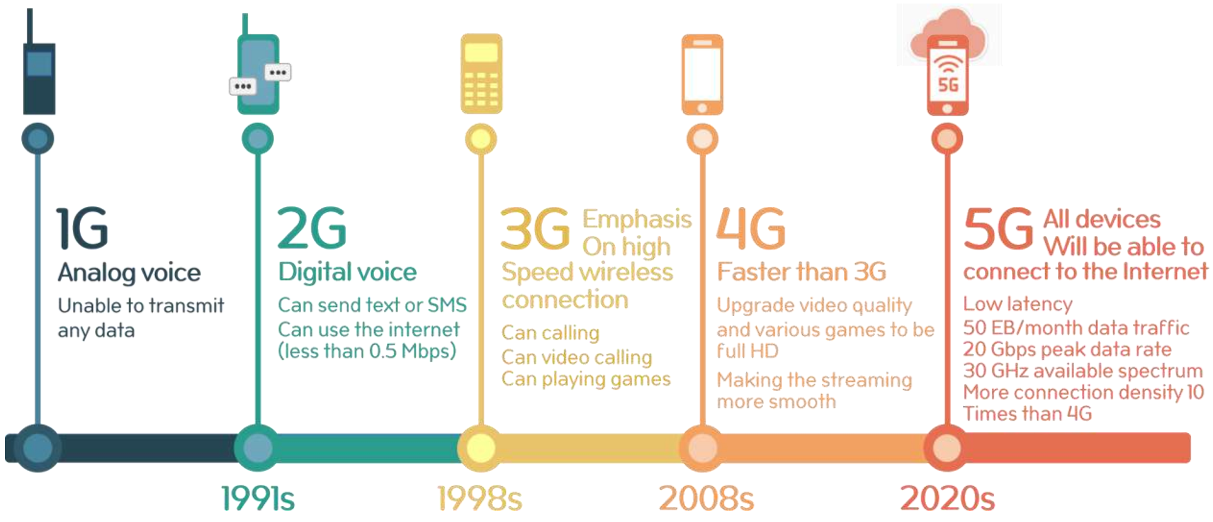


Figure 1.1: Communication Evolution of Network Technology

1.2 (0G) Network Technology

"0G" is known as Pre-cellphone mobile communications. Since they preceded the first generation of mobile phones, so These systems are referred to as 0G (zero generation) systems. Mobile phone systems were traditionally fitted on cars in the trunk or boot. The dial, display, and handset of the transceiver (transmitter receiver) were often positioned near the driver's seat and mounted in the car boot.

“In 0G systems, PTT (Push to Talk), MTS (Mobile Telephone System), IMTS (Improved Mobile Telephone Service), and AMTS (Advanced Mobile Telephone System) were used. As the ancestors of the earliest generation of cellular telephones, these structures are often retrospectively referred to as pre-cellular (or sometimes zero generation) methods. The term "Zero Generation" (or "0G") describes the period of time prior to the development of mobile telephony, which consist of radio telephones that some people used in their cars afore the enlargement of current cell phones’’.[3]

1.3 (1G) Network Technology

There was nothing known as 1G at initially. Mobile wireless communication possible by Only the improvement of 1G Technology. It was basically a voice-only network, and 1G wasn't even used until 2G was implemented. In terms of technology, 1G is dated. The technology used in mobile networks is of the first generation. For a very long period, the vast majority of individuals used the first generation of wireless telecommunications. These phones were the very first and most widely used mobile phones. NTT DoCoMo established 1G as a commercial service in Tokyo, Japan, in 1979. And it quickly expanded throughout Japan over the course of five years. Numerous Nordic nations, two years after the launch of 1G, several rich nations, including Sweden, Denmark, Norway, Switzerland, Norway, the Netherlands, Finland, Russia, and Eastern Europe, adopted NMT (Nordic Mobile Telephone) standards. Due to the fact that, 1G used an equivalent technology, phones often had deprived battery life, meagre voice class, low safety, and frequent call dropouts. The top 1G speed was 2.4 Kbps. Even though 1G technology was the first wireless telecommunications technology, it wasn't entirely digital. At radio wave frequencies of 150 MHz and above, analog data transmissions were carried out. The major problem with 1G technology was this. This made phone calls less secure. Additionally, data transmission speed was slower for 1G due to reduced frequency bandwidth.[3]

1.3.1 Basic structures of 1G

- ❖ Entrance method: Frequency Division Multiple Access (FDMA)
- ❖ Variation: Frequency Modulation (FM)
- ❖ Bandwidth: 10 MHz
- ❖ Frequency:800 MHz and 900 MHz
- ❖ Machinery: Analogue switching
- ❖ Class of service: voice only’’ [4]

1.4 (2G) Network Technology

"2G" mentions to the second generation of mobile telecommunications, which debuted towards the end of the 1980s.The Global System for Mobile Communication (GSMC), also known as 2G, Global System for Mobile Communication (GSMC), is a new digital technology developed by the that was launched in 2009. GSM created with digital signals in mind. It provides SMS and MMS delivery at a slow rate. At 30 to 200 kHz it will activates. Following 2G, 2.5G systems, packet-switched and circuit-switched domains to provide data speeds of up to 144 kbps GPRS, CDMA, and EDGE.

1.4.1 Basic features of 2G

- It can transmit data at up to 64kbps.
- It Provides SMS, MMS (Multimedia Messages), and image messaging services.
- It is incapable of handling complicated data, including movies.
- For high-quality digital signals to function 2G mobile phones necessitate.
- It is incapable of handling complex data such as movies''.[5]

1.4.2 GPRS (General Packet Radio Service) for 2.5G

For (2.5G) GPRS is a technology that is an extension of the existing GSM network. Mobile data can be sent and received more efficiently, quickly, and cheaply with this technology. Devices with GPRS are always online, which means they have a constant internet connection and are charged based on the amount of data they download or send. When the device is used, it only keeps the connection busy. As a result, capacity is more effectively utilized, and more data can be exchanged concurrently. The maximum GPRS speed is between 7 and 14 KB/s. The technology is referred to as 2.5G. This is not a Generation. It's called that because it's between 2G and 3G. M2M services continue to support 2G and 3G networks. [6]

1.5 (3G) Network Technology

3G, known as the 3rd generation of wireless mobile telecommunications technology. Then 2G, 2.5G, GPRS, and 2.75G EDGE networks, it offers faster data diffusion and better speech quality. This network ultimately gave way to 4G and then 5G. The International Telecommunication Union's International Mobile Telecommunications-2000 (IMT-2000) serve as the foundation for this network and are utilized mobile devices, mobile telecommunications services, and mobile telecommunications networks. 3G is advantageous for mobile TV, fixed wireless Internet access, mobile TV, and wireless voice communication''.[7]

1.5.1 Applications of 3G

The bandwidth and location data made accessible by 3G devices allow the creation of previously unavailable to mobile phone users apps. It became feasible to access the internet while on the move on a 3G network, as well as conduct many other things that were before sluggish and difficult on 2G. Medical gadgets, fire alarms, and ankle monitors, as well as mobile phone users, utilize this network to accomplish their assigned jobs. This network was the primary to use a cellular communications network for such a diverse set of functions, ushering in the age of ubiquitous cellular network utilization.[8]

1.5.2 Basic features of 3G

- It can go as fast as 2 Mbps.
- High bandwidth and data transmission rates are essential for web-based applications.
- It also allows for more rapid communication.
- Allow for the sending and receiving of large amounts of email.
- It has enhanced security, teleconference capabilities, and 3D gaming capabilities.

1.6 (4G) Network Technology

“The fourth generation of mobile broadband networks is known as 4G, following before 5G and after 3G. IMT Advanced capabilities essential be supported 4G system. Potential and present uses include mobile web access with modifications, video conferencing, 3D television, gaming services, high-definition mobile television, and IP telephony. The ITU changed the definition of 4G in December 2010 to include Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX), and Evolved High Speed Packet Access (HSPA+).

In 2006, South Korea was the first country to commercially deploy the WiMAX standard, and it has since extended to the rest of the globe. Following the commercial implementation of the first-generation LTE standard in 2009, it was subsequently deployed throughout the majority of the world's countries, including Oslo, Norway, Stockholm, and Sweden. However, it has been contested whether the first versions of 4G LTE should be categorized as such.The International Telecommunication Union's 4G wireless cellular standard describes the minimum requirements for the standard, including transmission methods and data speed (ITU).

The bandwidth speeds and network capacity have become faster with each iteration of wireless cellular technology. Users of 4G can imagine speeds of up to 100 Mbit/s, whereas 3G only promises a peak speed of 14 Mbit/s’

1.6.1 Basic features of 4G

- It offers high-quality video streaming at speeds ranging from 10Mbps to 1Gbps.
- It's a hybrid of Wi-Max and Wi-Fi.
- It provides an extremely high level of security.
- It uses more battery power.
- It is difficult to implement.
- It necessitates the use of sophisticated hardware.[10]

1.6.2 Extension of 4G LTE as 4.5G

The following are some characteristics of 4.5G wireless technology. It alludes to benefit that aren't a part of the typical mobile broadband network. It is a 4G LTE wing that offers download rates of up to 300 Mbps. In developing IoT commercialize, it is more crucial.

- IoT connectivity is made possible by the development of mobile broadband data rates on paired and unpaired spectrum.
- It is required for crucial public safety.
- It permits LTE broadcasting.
- Industry best practice is LTE innovative Pro 3GPP.
- Peak Downlink Data Rates: NB-IoT: 170 Kbps, LTE-M: 1 Mbps.
- Peak data rates (uplink): 250 kbps for LTE-A and 1 Mbps for LTE-M. (NB-IoT).
- NB-IoT employs 180 KHz (200 KHz carrier BW), whereas LTE-M uses 1.08 Mbps (1.4 MHz carrier BW). [11]

1.7 (5G) Network Technology

In late 2010, the Fifth Generation (sometimes referred to as 5G) started. One benefit of 5G technology is expanded coverage and concatenation. The primary focus of 5G is the wireless World Wide Web (WWWW). Due to the better technologies of 5G, customers may anticipate extremely fast internet and multimedia endorses. LTE Advanced networks give rise to supercharged 5G networks. 5G technology uses millimeter waves and an unlicensed channel for data transmission to get a greater data rate. [12]

1.7.1 5G Network Architecture

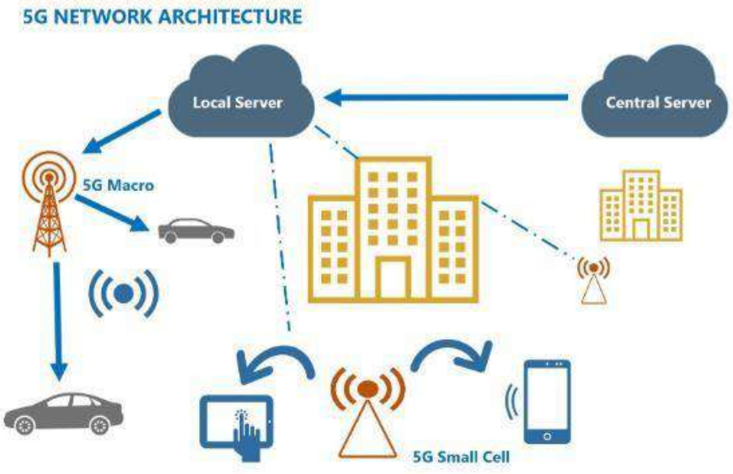


Figure 1.2: 5G Network Architecture

1.7.2 Basic features of 5G

- It fervently supports the WWW (Wireless World Wide Web).
- Both its capacity and speed are very great.
- At a rate of Gbps, it is capable of broadcasting massive volumes of data.
- offers top-notch newspapers, multi-media content, and TV show viewing in HD clarity.
- It sends data faster than the generation before it.
- Large phone memory, crystal-clear audio and video, fast calling, interactive multimedia, suffrage, and other features

- It increased the variety of multimedia services available.
- inexpensive per bit.
- The battery loses more power as a result.
- Implementing it is difficult.
- It demands the usage of sophisticated gear. [13]

Table 1.1: Comparison between different generation of technologies [14]

Introduced	**1979**	**1991**	**2001**	**2010**	**2019**
Technology	AMPS, TACS	GSM	WCDMA	WiMAX, LTE	MIMO
Frequency	800-900 MHz	1.8 GHz	2 GHz	1800 MHz	24-47 GHz
Internet Service	Normal	Narrow band	Broad band	Ultra-Broadband	Wireless World Wide Web
Net Speed	2.4 Kbps	64 Kbps	2 Mbps	1 Gbps	10 Gbps
Application	Voice call	Voice call, short message	Video call, GPS, MMS	Video call, GPS, mobile TV	HD video, robots.

1.8 Important spectrum activities are being led by the FCC to enable 5G.

All frequencies, including mm Wave, in the low-band, mid-band, and high bands are covered.

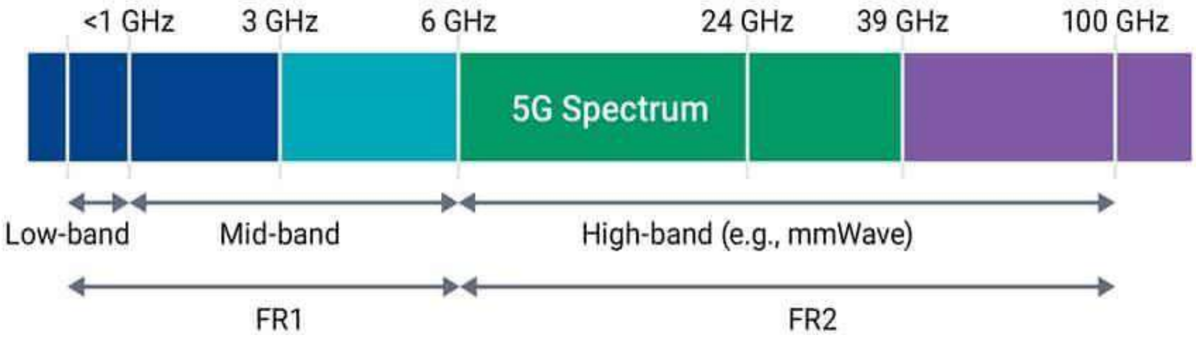


Figure 1.3: Spectrum for 5G [15]

1.8.1 Low-band

With regard to 5G, the low-band spectrum enables carriers to offer extensive coverage, even in remote areas. Additionally, the network's speed and reaction time will be far better than 4G, with peak rates encircling 300Mbps anticipated.

The low-band spectrum has the drawback that the nature of its performance will vary depending on how close you are to the cell site. You could struggle to achieve speeds faster than those offered by 4G networks if you are far from a tower.

However, because buildings may be penetrated by the 6000 MHz frequency, the the low-band spectrum, which has a 6000MHz frequency that may penetrate buildings, is an excellent place for 5G networks to start.[15]

1.8.2 Mid-band

As we proceed up to mid-band spectrum, we anticipate that the majority of carriers will choose to skip low-band 5G in favor of mid band. The spectrum in the middle is defined as 1GHz to 6GHz. Due to its ability to transmit large amounts of data over long distances, the mid-band spectrum is thought to be perfect for 5G. Data rates are anticipated to peak between 600 and 900 Mbps, which is much greater than the low-band spectrum.

While manipulators in the United States and Canada intend to use the 2.3GHz and 2.5GHz-2.6GHz frequencies for 5G, hustler in China and Japan aim to use the 4.5GHz-5GHz spectrum. Similar in terms of speed and range, only some of these radio relative frequencies will be accessible in specific nations.[15]

1.8.3 High-band

High band millimeter wave, located at the culmination of the spectrum diagram, refers to frequencies over 6GHz. With peak speeds now approximated at 1-3Gbps, it provides extremely quick speeds. Unfortunately, the millimeter wave spectrum can only go up to one mile. It is probably only going to be used in crowded areas that routinely serve a lot of people. This could include convention centers, performance halls, and sports stadiums.Compared to the sunk and mid bands, millimeter waves in the high band are more tender to interference from structures and trees. You will, however, travel at speeds you have never seen before if you are close to one of the towers.[15]

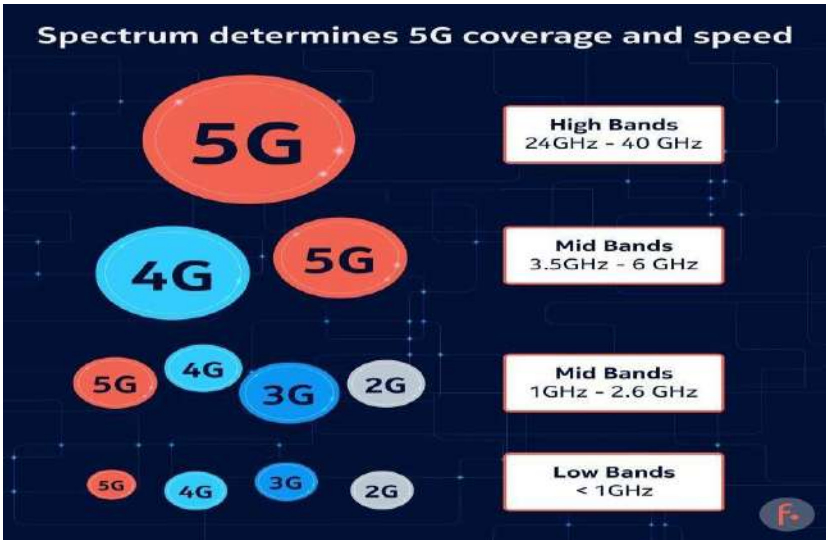


Figure 1.4: Spectrum Determines 5G coverage

1.8.4 Spectrum of Global 5G

Source: Qualcomm

Figure 1.5: Spectrum of Global 5G [10-12]

1.8.5 High-band: regulating spectrum boundaries for 5G millimeter Wave bands

Unlicensed and partial spectrum are used by more bands

Licensed Spectrum.

- A frequency band between 27.5 and 28.35 GHz.

- A range of frequencies 37.6 GHz to 38.6 GHz and 38.6 GHz to 40 GHz.

Share unlicensed spectrum

- 37 GHz–37.6 GHz frequency chain.
- 64 GHz to 71 GHz in the frequency band.[16]-[17]

1.8.6 Channels for FR1 & FR2

For 5G technology, there are two different frequency ranges, called FR1 and FR2, respectively.

The bands in spectral region 1, FR1, are expected to carry most of the typical cellular mobile communication traffic.The higher frequency bands in range FR2 are designed to give the 5G radio the ability to send and receive data at a very high rate over a short distance. Since 5G wireless technology is expected to send and receive data at much higher speeds, these higher frequency bands will be needed to provide more bandwidth.

Figure 1.6: Frequency ranges for different band

1.9 Spectrum of 5G in Asia Pacific (APAC)

From the embark of the first 3G network in Japan to the expatiate of the primary commercial 5G networks in South Korea, countries in the Asia Pacific region have been at the forefront of numerous mobile technologies. These nations have also experienced significant market transforms, as evidenced by the rapidly declining average enrichment per user (ARPU) and rising uptake in India. The historical development of fixed telecommunications networks in different nations has had some impact on the adoption of mobile; however, all nations have witnessed a massive increase in the number of supporter and the aptitude of mobile networks. Consumers in nations with less fixed breacher advantage the most from mobile broadband technologies.

The capabilities of mobile devices continue to advance, but about every 10 years a new formation of mobile technology emerges, bringing with it key advancements in mobile network capabilities and modifications to spectrum superintendence strategies.

Examining the region's present mobile employments and spectrum status is the "Roadmaps for granting 5G spectrum in the APAC region" report. It also lays out a plan to assist regional authorities in enabling 5G. [18]

1.10 Spectrum of 5G in Europe

"With the introduction of 5G, the most recent generation of mobile technology, mobile network operators (MNOs) need access to enough spectrum, particularly in the 700 MHz, 3.4-3.8 GHz, and

26 GHz frequency ranges. Nearly every European regulatory authority has purchased spectrum in at least some of these 5G frequency bands over the past four years.

We investigate the policy objectives desired by policymakers and regulators in this research to assess the results of the 5G range sales that have already occurred in Europe.

The major findings of our research include

- The 3.4-3.8 GHz spectrum has currently been allocated in the majority of European nations, while the 26 GHz range is only in a few.
- Regulators should select the auction rules that are most likely to help them reach their desired policy goals when designing spectrum auctions.
- European regulators have usually put limits on different types of spectrum to make sure that at least three MNOs have coverage in the important 3.4-3.8 GHz band and that there is enough competition in the mobile market.
- European politicians and controllers have employed a variety of strategies, such as range set-asides, rental requirements, or regional licensing, to guarantee to the 3.4-3.8 GHz band at industry access. Designing an auction with simplicity, fairness, and transparentness.
- The decreasing popularity of complex auction structures suggests that policymakers and regulators are growing more concerned about''.[19]

1.11 Antenna Basics

Any electrical system's fundamental component that uses free space as a propagation medium is an antenna. An antenna is a gadget that offers a way to send or receive radio waves. It functions as a transducer between an electromagnetic wave that is being steered and one that is moving through empty space. In a communications connection, the transmitter is linked to one antenna by a cable or waveguide; the signal is then radiated to a second antenna and transmitted to the receiver by a different cable or waveguide. Microstrip patch antennas are the most dominant form of antenna used in wireless applications. In the microwave frequency region, microstrip patch antennas are very effect.

1.11.1 Millimeter Wave

"MMWave communication has become one of the most alluring options for 5G mobile communications as a result of the enormous rise in wireless data traffic. Despite the fact that mmw communication rules have been used effectively in indoor settings, the vigilance of mobile communication systems operating in mmw bands in an outdoor environment is hampered by a number of external elements. We explore the challenges of developing an antenna array design for upcoming 5G mmw systems in which the antenna component may be positioned in non-rectangular configurations, such as a cross, circle, or hexagon. The reproduction results demonstrate that although other conventional antenna arrays usually exhibit a nontrivial gain variation, the circular antenna array exhibits a constant gain variation. Gain at various angles in the radiation pattern's principal lobe. As a result, the circular antenna vest is more resistant to the angle fluctuations that typically happen as a result of antenna vibration in an outdoor setting. Additionally, along with the design of mmw antenna equips, potential solutions like dispersed antenna methods and cooperative multi-hop relaying are examined in command to provide cogent reporting of mmw communication schemes. Additional issues, including as obstruction, communication security, hardware outgrowth, and others, are examined along with potential disruptions for the adoption of mmw cellular networks''.[20]

1.11.2 Microstrip Patch Antenna

"Over the past three decennary, the microstrip patch antenna (MPA) has been in use and the subject of intensive research. This antenna's benefits include simplicity in design and production, a low profile and planar constituency, and ease of circuit component integration. Microstrip patch antenna (MPA) made up of a metallic patch printed on a dielectric substrate above a plea plane. A typical MPA has a minimum dimension of around half a wavelength. With the introduction of new standards and small wireless devices recently, it has become necessary to scale back the extent of this kind of antenna. This paper talks about some of the main methods for shrinking an MPA that have been documented in the literature. These strategies for miniaturization include material loading, altering the antenna's shape, shorting and folding, adding slots and premise plane flaws, and using metamaterials are some examples of these techniques. This study highlights the key benefits and shortcomings of each of these strategies as well as how they affect the antenna performance parameters''.[21]

1.11.3 Frequency

The quantity of waves that pass through a certain location in a predetermined period of time is known as frequency. If a wave travels through in half a second, the frequency is thus 2 per second. The frequency is 100 times per hour if it takes 1/100 of an hour. Heinrich Rudolf Hertz, a German physicist who lived in the 19th century, gave the hertz unit its name. The quantity of waves that cross a region in a second is called frequency, and it is represented by the sign Hz.

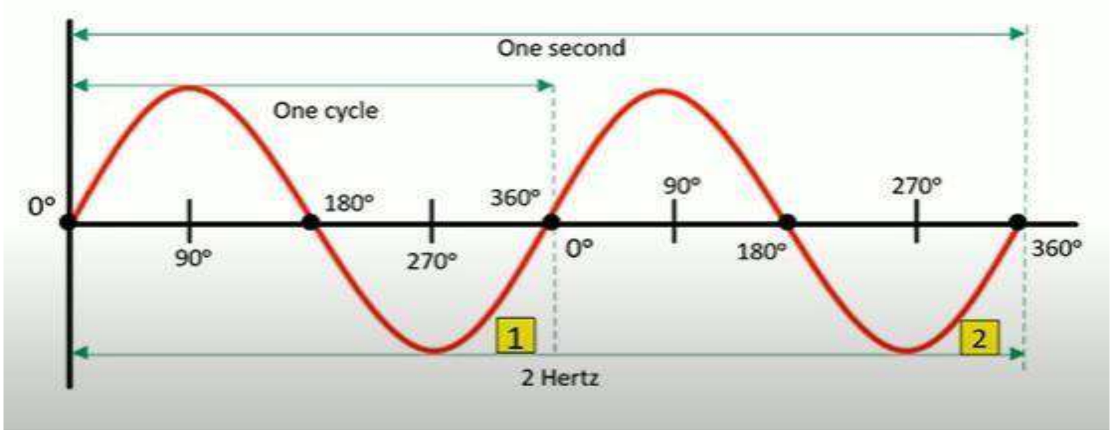


Figure 1.7: Diagram of wave frequency

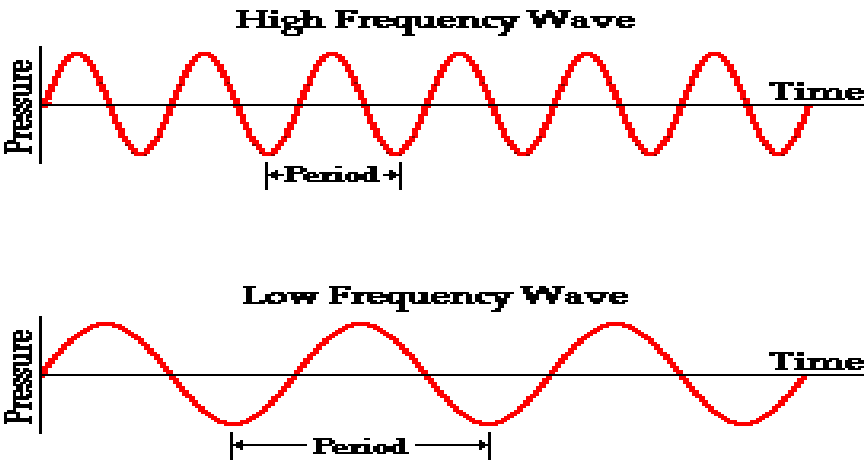


Figure 1.8: Diagram of high and low frequencies [22]

1.11.4 Bandwidth

The quantity of data that may be swiftly transferred from one point within a network to another referred to as bandwidth. Usually, the term "bandwidth" refers to the bitrate, which is measured by bits per second (bps).

The ability of a link to transmit data is referred to as "bandwidth.", and it is a main factor in defining an internet connection's dependability and speed. The measurement of bandwidth can be done in a number of methods. In addition to measuring maximum flow, usual flow, and what is deemed to be good flow, several measurements are utilized to determine the current data flow. Another important idea in many other technology disciplines is bandwidth. For instance, it is utilized in signal processing to clarify the distinction between the higher and lower frequencies of a transmission, such a radio wave, and are usually measured in hertz (Hz).

A good analogy for bandwidth is water running through a pipe. The pace at which water (or data) flows through the pipe (or link) varies depending on the situation would be the bandwidth. We could measure gallons per minute rather than bits per second. While the amount of water currently running through the pipe reflects the current bandwidth, the maximum amount of water that could conceivably pass through it indicates the maximum bandwidth.

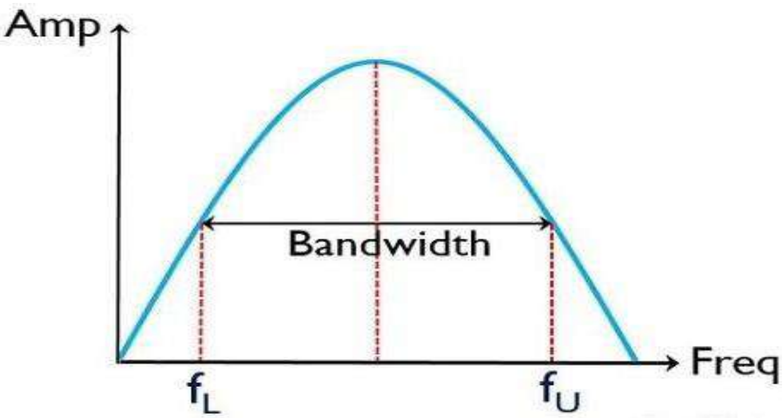


Figure 1.9: Diagram of Bandwidth

1.11.5 Input impedance

“Input impedance of an antenna is demarcated by the percentage of voltage to current at its terminals. The resonance of the antenna is expressed by this fundamental characteristic of the antenna. The two types of input impedance are real and hypothetical. impedance. The power radiated is represented by the input impedance's real component or absorbed by the antenna itself. the input impedance's fictitious component. Reflected power is the term for the power that remains in the antenna's immediate vicinity. An antenna that is in resonance has zero input resistance in both real and hypothetical directions. The antenna's input impedance is determined by its length and size. Z represents impedance, it consists of two parts: a genuine component that contains the antenna's radiation, and an actual component resistance Ohmic and Read losses Rhombic, A resonant antenna has a zero-input impedance in both the real and imaginary directions. The antenna's input impedance is determined by its length and size. Z represents impedance, it consists of two parts: a genuine component that contains the antenna's radiation, and an actual component resistance Ohmic and Read losses Rhombic and a component that is reactive and includes the radiation resistance of an antenna Ohmic and Read losses Partially rhombic X’’ [21

1.11.6 Impedance Matching

“In electronics, the act of constructing or altering an electrical device's input or output impedance to a certain value is known as "impedance matching." To improve power transmission or reduce signal reflection, the desired rate is commonly specified. For instance, impedance matching is often employed to improve power transfer from a radio transmitter via the connected transmission line to the antenna. Signals will be transmitted on the line without reflections if the termination of the transmission line has a matching impedance. Impedance matching techniques include the use of transformers, adjustable networks of lumped capacitance, inductance, and resistance, as well as transmission lines of the appropriate size. Practical impedance-matching equipment usually produces the best results across a specific frequency range. The concept of impedance matching is often used in electrical engineering, even though it is significant in many applications where energy—not usually electrical energy—is conveyed between a source and a load, such as in optics or acoustics. Impedance matching is necessary, as seen below.’’ [24]

- When the feedline's impedance matches that of the source, power from the latter will be transmitted to the former source.
- The power from the feedline will reach the antenna if the impedances of the feedline and antenna are the same.
- It is important that the input impedance of a receiver amplifier circuit match the output impedance of a receiving antenna.
- The input and output impedances of a transmitter antenna should be in perfect sync with the impedance of the transmission wire.

1.11.7 Directivity and Gain

The term "directivity" is used to describe the ability of a transmitting or receiving antenna to concentrate its signal in a certain direction. Gain refers to the increase in output power above that of an isotropic, lossless antenna when used in conjunction with a far-field source located along the antenna's beam axis. Gain is incompatible with both directionalities. The link between a light bulb and a spotlight may be understood by the phenomenon of greater directivity. As opposed to a 100-watt light bulb, a spotlight produces more light in one direction while less light is produced in other directions. More "directivity" is present in the spotlight than in the light bulb. A high-gain antenna and the spotlight both functions similarly. The acquisition is an important aspect of the directivity. In mathematics, directivity and efficiency are multiplied to form a reap.

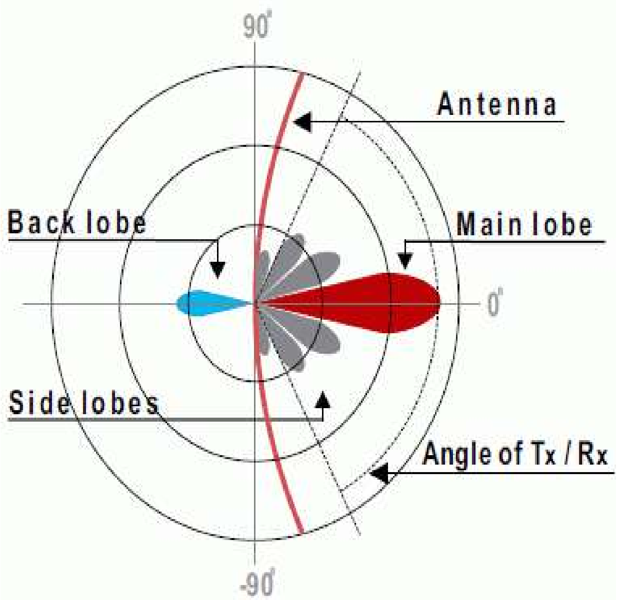


Figure 1.10: Diagram of Directivity and Gain

1.11.8 Radiation Pattern

Radiation pattern reveals antenna's power. Directional radiation shows how energy diffuses across space.

A mathematical function or graphical depiction of the far field (i.e., for r 2D2/, where D is the maximum dimension of the antenna) radiation qualities of the antenna as a function of the propagation direction of the electromagnetic (EM) wave is the definition of the term "radiation pattern." A radiation pattern may be used to represent many different kinds of data, including gain, directivity, electric field, and radiation vector, amongst others. These patterns might be described using a variety of terms, including gain pattern, electric field pattern, and radiation vector pattern, among others. Radiation patterns may exist in three dimensions, or as a function of (, r), or in two dimensions. Both are feasible. When angles are set to zero or are set to zero in the later scenario, the radiation pattern represents a cut of the three-dimensional radiation pattern.

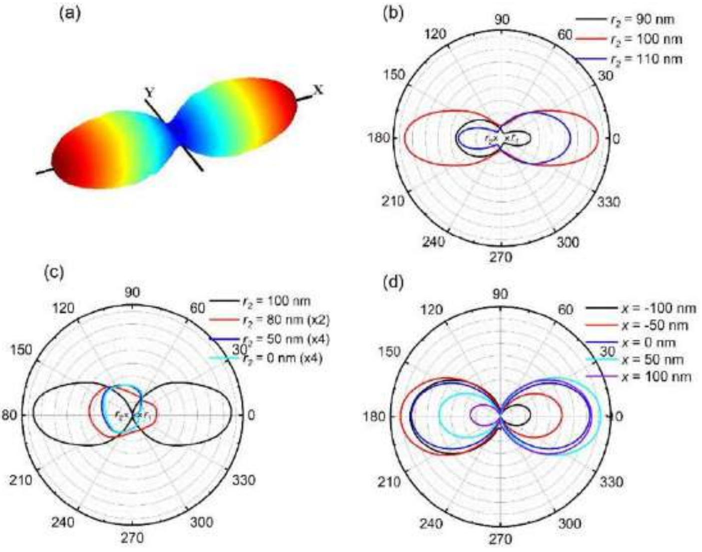


Figure 1.11: Diagram of Radiation pattern [25]

1.11.9 Voltage Standing Wave Ratio (VSWR)

“The voltage standing wave ratio (VSWR) is the ratio of transmitted voltage standing waves to reflected voltage standing waves in a radio frequency (RF) electrical transmission system. It determines how effectively radio frequency (RF) power is transferred from the power source to the load by way of the transmission line. The connection of a power amplifier to an antenna by means of a contagion line is a typical example of this phenomenon.

Therefore, the signal-to-noise ratio (SWR) is the ratio of waves that are transmitted to waves that are reflected. A high SWR indicates that the transmission lines are inefficient and that reflected radiation is present, both of which are averse to the operation of the transmitter. Standing wave ratio, or voltage standing wave ratio, is another name for SWR due to the fact that it often corresponds to the voltage ratio (VSWR)’’.[26]

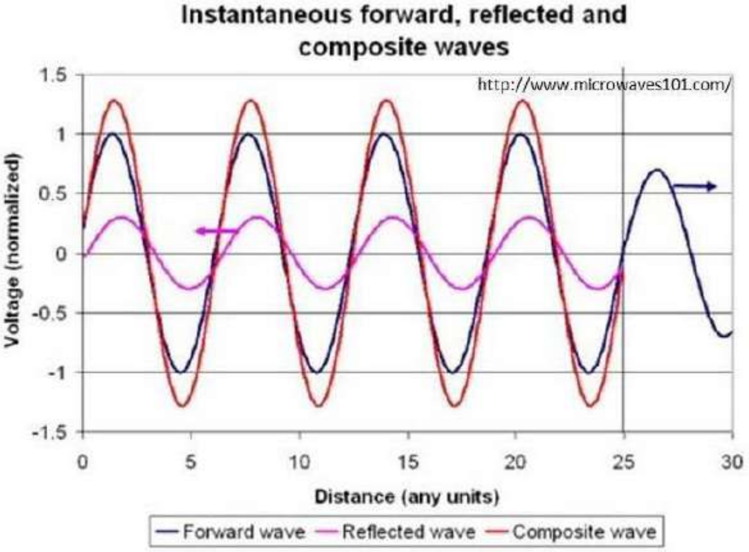


Figure 1.12: Voltage Standing Wave Ratio (VSWR)

1.11.10 Return Loss (RL)

Return loss in telecommunications refers to a measurement of the relative strength of the signal reflected by a break in a transmission line or optical fiber. The termination or load that is connected to the succession or the line's characteristic impedance may not match, which might result in this discontinuity. typically stated as a decibel (dB) ratio;

Both standing wave ratio (SWR) and reflection coefficient () impact return loss. As return loss grows, the SWR falls. Return loss measures the compatibility of devices or appearances. A contest is favorable if the return loss is substantial. It is preferable that a higher return loss results in a lower insertion loss.

1.11.11 Polarization

The polarization of the wave emitted by an antenna depends on the strength of its associated electric field. Polarization of the antenna is influenced by the strength and orientation of the electric field. An antenna has linear polarization if its electric field components have the same amplitudes and opposite phases. A circularly polarized antenna has identical signal strengths but opposite phase differences of 90 degrees. In order to have successful communication, it is necessary to properly align the projected electric fields of both of the antennas, which have linear polarization.

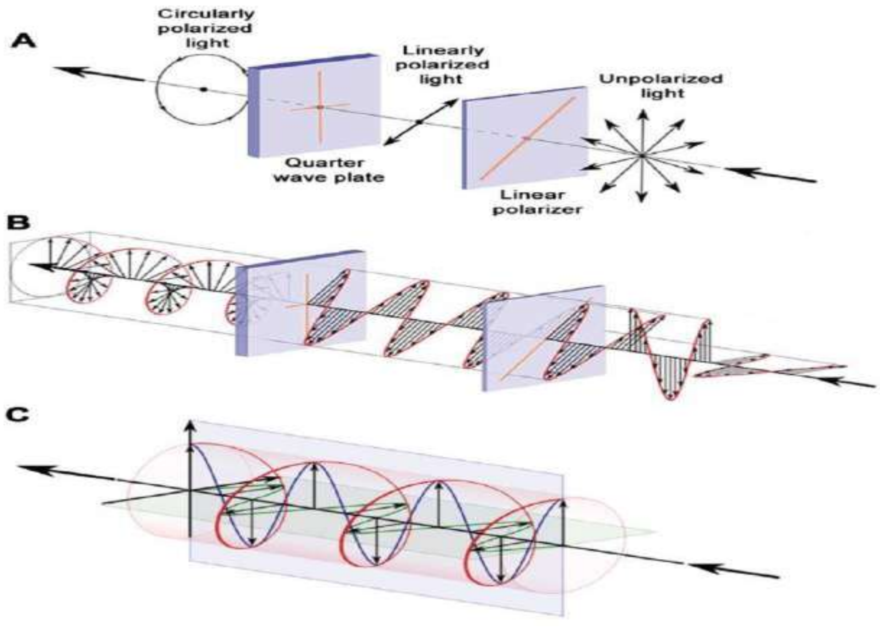


Figure 1.13: Polarization Linear, Circular, Elliptical

An antenna that is circularly polarized, on the other hand, may communicate with any other linear antenna, regardless of how it is oriented. As a result of the radiation's single-directional focus A linear antenna transmits power all at once, unlike a circular antenna, which divides energy between the dual parts. Depending on the situation, a reader antenna may be circular or linear. the tag antenna, the application, and ideally both should be circularly polarized to ensure any angle allows it to be read.

Chapter 2

Microstrip Antenna

2.1 Microstrip Patch Antenna

“A microstrip patch antenna is made by attaching a conducting patch of any shape to one side of a dielectric substrate and a premise plane to the other side (MPA). It is a well-liked printed shrill antenna for semi hemispherical coverage narrow-band microwave wireless communications. The microstrip patch antenna has drawn a lot of interest and is commonly used as a part of an array due to its flat shape and ease of integration with microstrip architecture. Up to now, many microstrip patch antennas have been researched. A complete list of the geometries and their key characteristics is available. The most staple and widely used microstrip antennas are rectangular and circular patches. These patches are utilized for the most basic and tough applications. Geometries that are rectangular are naturally separable, and their analysis is likewise straightforward. An advantage of circular patch antennas is their symmetrical radiation pattern. The diagram below depicts a microstrip patch antenna’’. [27]

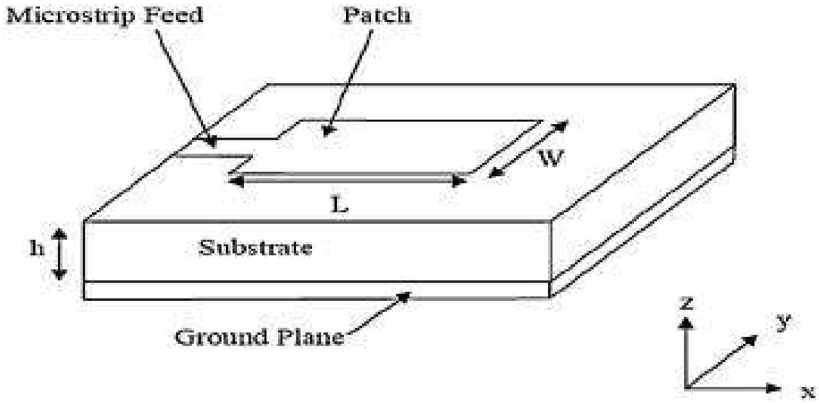


Figure 2.1: Structure of a rectangular microstrip patch antenna

But a bigger antenna is needed for such a setup. Small Microstrip patch antennas need higher dielectric constants since they are less effective and have a narrower bandwidth.

2.1.1 Microstrip antenna Feed Techniques

The following are illustrations of several microstrip antenna feed methods.

- Microstrip Line Feed
- Coaxial/probe feed
- Aperture coupled feed
- Proximity coupled feed

2.1.2 Line Feeding of Microstrip

Microstrip line feed is one of the more straightforward manufacturing methods since all that is required to connect to the patch is a conducting strip, making it feasible to extend the patch by modifying the, and because it is easy to model and match. Positioned at the rear The disadvantage of this strategy is that. The bandwidth is decreased by a specific surface wave and an increase in erroneous feed radiation in the substrate thickness.[27]

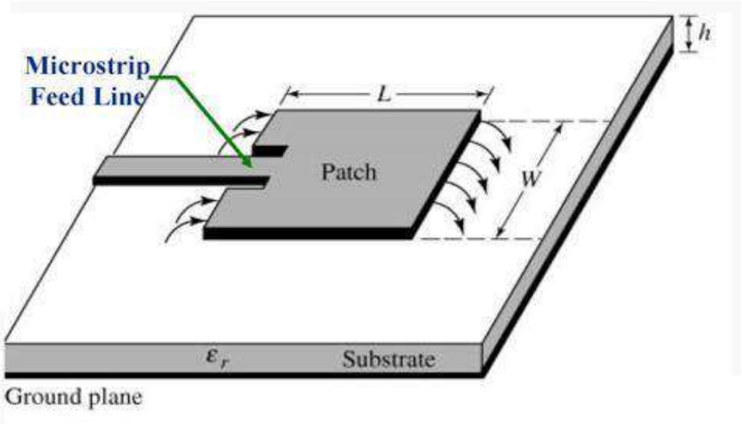


Figure 2.2: Microstrip Line Feeding Schematic

2.1.3 Coaxial or Probe feeding

“This feeding method is known as coaxial probe feeding because the interior electrode of the coaxial is linked to antenna's radiating patch and exterior conductor is attached to the plea level. Coaxial feeding has certain benefits, such simple assembly, low supposititious radiation, and easy matching, but it also has some drawbacks, including a scrutinizing bandwidth and challenging modeling, particularly for thick substrates. In the below shows a coaxial feeding system’’.[27]

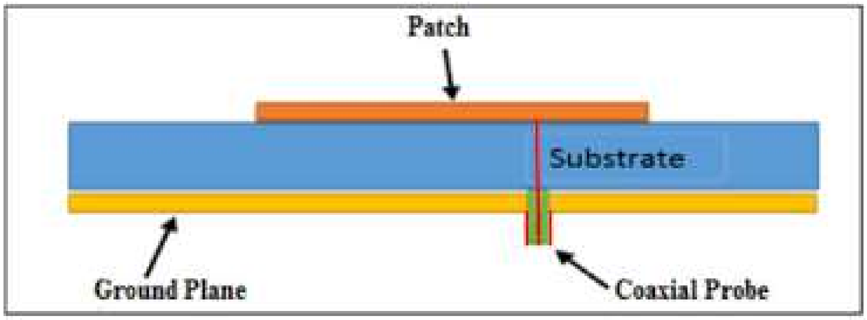


Figure 2.3: Diagram of Coaxial / Probe feeding.

2.1.4 Aperture Coupled Feed

“Aperture coupled feed composed of two different a ground plane separating two substrates. Towards the bottom It is a microstrip feed line which lower substrate is Through a slot on the patch, energy is linked. A ground plane divides two substrates. This combination allows for autonomous feed mechanism optimization as well as the radiating component. Top substrate typically makes use of while for the profuse substrate with a low dielectric continual substrate at the bottom; it has a high dielectric constant. The The feed is isolated by the ground plane, which is in the centre. radiation source and reduces interference from fake radiation for polarization and pattern formation purity. benefits is that it enables separate optimization of part of the feed mechanism''.[27]

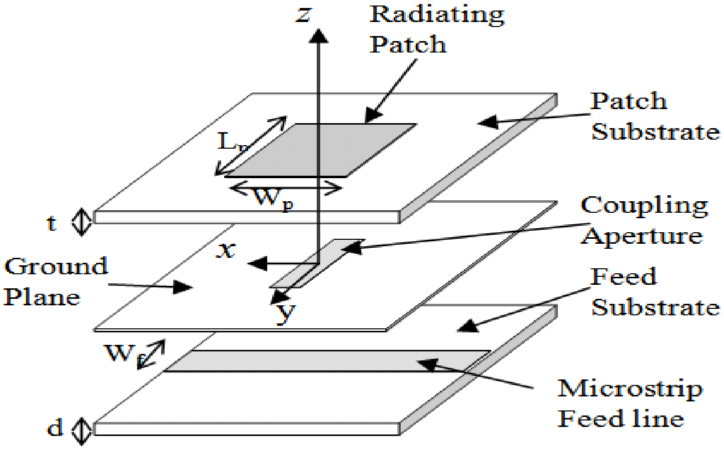


Figure 2.4: Diagram of Aperture-Coupled Feed

2.1.5 Proximity Coupled Feed

"With a little amount of spurious radiation, proximity coupling has the maximum bandwidth. But manufacturing is challenging.

The width-to-length proportion of patch and length of the feeding stub are utilized to regulate the match. Capacitive is the nature of its coupling mechanism''.[27]

It also consists of two substrates. The top substrate is where the radiating patch and microstrip are located. two substrates and a feed line in between. Figure illustrates this.

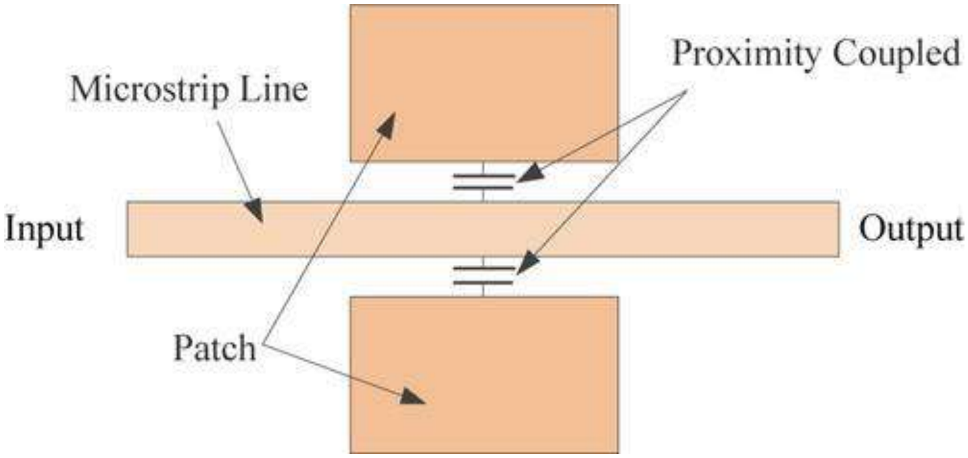


Figure 2.5: Diagram of Proximity-Coupled Feed

2.1.6 The benefits and drawbacks of a microstrip patch antenna

Microstrip patch antenna are gaining prominence in wireless applications due to their tiny profile. Consequently, integrated antennas in portable Wireless gadgets such as mobile phones and pagers function quite effectively. Due to their tiny size and conformability, microstrip patch antennas are widely utilized as telemetry and communication antennas on projectiles.

2.1.6.1 The benefits of the Microstrip Patch Antenna

The following are some of the benefits of microstrip patch antennas:

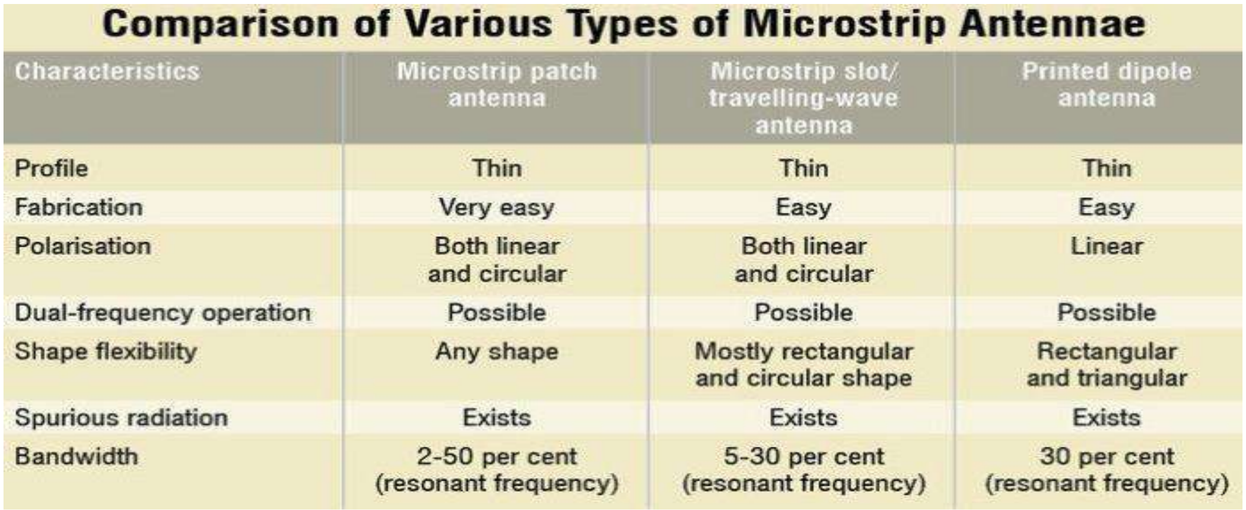
- “They operate at microwave frequencies, when ordinary antennas are ineffective.
- Because of its modest size, this antenna type will result in smaller end products.
- The patch antennas' centerline feeding decreases the activation of other undesirable modes.
- It is simple to etch microstrip patches in a variety of shapes, including rectangular, square, and triangular ones.
- They have cheaper fabrication cost and consequently they may be bulk made.
- They can accommodate numerous dual & triple frequency bands.
- It accommodate both circular and linear dual polarization.
- They have very little weigh.
- When mounted on the devices solid surfaces, they are strong.[28]

2.1.6.2 Disadvantages of the Microstrip Patch antenna

The following are some drawbacks of microstrip patch antennas:

- “The following are some drawbacks of microstrip antennas: Printed dipole antennas, microstrip patch antennas, and microstrip slot antennas all exhibit spurious radiation.
- It has a low efficiency because of conductor and dielectric losses.
- The gain of microstrip patch antenna is very lower.
- Its poorer power handling capacity and increased cross polarization radiation are disadvantages.
- It has a smaller impedance bandwidth by definition.
- The microstrip antenna's feeds and other connection points emit electromagnetic radiation’’.[28]

2.1.7 Comparison of Various type of Microstrip Antenna:



Comparison of Various Types of Microstrip Antennae

Characteristics	Microstrip patch antenna	Microstrip slot/ travelling-wave antenna	Printed dipole antenna
Profile	Thin	Thin	Thin
Fabrication	Very easy	Easy	Easy
Polarisation	Both linear and circular	Both linear and circular	Linear
Dual-frequency operation	Possible	Possible	Possible
Shape flexibility	Any shape	Mostly rectangular and circular shape	Rectangular and triangular
Spurious radiation	Exists	Exists	Exists
Bandwidth	2-50 per cent (resonant frequency)	5-30 per cent (resonant frequency)	30 per cent (resonant frequency)

Figure 2.6: Comparison of Microstrip Antenna

2.2 Antenna Array

When an antenna is used by itself, it can send out a certain amount of energy in a certain direction, which improves transmission. Imagine what would happen if a few more elements were added to make the antenna's output more efficient. Exactly because of this idea, antenna arrays were created.

An antenna array is a system for radiating that is made up of many separate radiators and elements. Each of these radiators utilizes its own induction field as it works. The elements are so close together that each one is in the induction field of the one next to it. So, the pattern of radiation they put out would be the vector sum of each individual pattern. When making these antennas, you also have to think about how far apart the elements are and how long the elements are based on the wavelength.

The antennas radiate on their own, and when they are in an array, the radiation from all of the elements adds up to make a beam of radiation that has high gain, high directivity, and better performance with fewer losses.

2.2.1 Advantages of Antenna Array

The following are the advantages of using antenna arrays:

- The signal strength increases gradually.
- High directivity is attained.
- Minor lobes are cut down a lot.
- It is possible to get a high signal-to-noise ratio.
- High gain is obtained.
- Power waste is drastically reduced.
- Better performance have been obtained.

2.2.1 Disadvantages of Antenna Array

The following are the disadvantages of using antenna arrays:

- There is a rise in resistive losses.
- Installing and maintaining them is difficult.
- Significant outdoor area is needed.

2.3 Motivation

Since its inception, wireless communication has been more and more popular due to its low cost, adaptability, portability, and other benefits. As a result, demand for mobile connections and data rates has rapidly increased. During the preceding three periods, the amount of mobile data traffic has grown tremendously. The breadth of these needs has once again expanded because to the Internet of Things (IoT). To meet this growing need, the telecoms sector has created new generations of standards almost every decade. In order to achieve the objectives of linking more than 100 billion wireless devices, millisecond latency, 10 Gbps data throughput, and the internet of things, they have led to the fifth generation (5G), which will be implemented in the matutinal 2020s [29]. Communication at high frequencies is one of the primary obstacles to the deployment of 5G, therefore we developed an antenna that can handle it.

2.4 Essence

The telecommunications sector is changing quickly. A new generation starts every ten years. The technology that came before, known as 5G, is the one that researchers are most intrigued by. The fifth generation (5G) of wireless technology has emerged as a result of the enormous growth in wireless applications (5G).

5G is the wireless communication protocol that will succeed 4G/IMT-Advanced.Compared to current 4G, 5G will be more capable and enable the Internet of Things, large-machine networking, ultra-reliable device-to-device communication, and higher wireless network densities (IoT).

Due to the fact that wireless communication is impossible without antennas, we must design 5G-compatible antennas.The microstrip patch antenna, which has unmatched qualities, is the one most frequently employed in modern wireless communication. As a result of its lower. This antenna can support end devices of lower sizes. Any PCB can easily have microstrip antennas etched into it. Microstrip patches come in a number of shapes, including rectangular, square, and triangular patches, and are simple to etch. Because of their cheaper production costs, they can be produced in large quantities. They can function in several frequency bands (dual, triple). They accept mutually polarizations—linear and circular. They don't weigh a lot. Sub-6-GHz channels are used by the existing 4G network for communication. The spectrum that is accessible in these bands, nevertheless, is not enough to meet 5G's requirements . Higher frequency ranges between 6 and 300 GHz will therefore be necessary. As a result, the Federal Communications Commission [30] has assigned the 3.4-3.6 GHz, 5-6.

Chapter 3

Literature Review

3.1 Paper Review

This section will look at other scholars' work that is relevant to this theory**, "Design of a Milimeter Wave Microstrip Patch Antenna for 5G Communication,"** which will be a crucial part of research for applications using fifth-generation (5G) the antenna we have now. Consequently, a more effective, simpler to make antenna was created. was created and modeled.

1. “A New 2x4 Array Design of Dual-Band Millimeter-Wave Antenna for 5G Applications’’ [31]

This paper correctly explains how a 2x4 dual-band mm-wave array for 5G implementation processes is put together. This arrangement of antennas makes frequency bands at 28 & 38 GHz. The increase of an antenna array with a SMA correlation, according to this antenna, is 15.5 dBi at 28 GHz & 13.9 dBi at 38 GHz. The simulation shows that an antenna assortment with SMA terminals and one with a waveguide feed have almost the same gain. Preservation between feeding venues is so much of around 28.692 dB at 28GHz and 38.779 dB at 38GHz, that is enough to meet the inhume component shelter criteria.

2. “Design and Characterization of Compact Broadband Antenna and Its MIMO Configuration for 28 GHz 5G Applications” [32]

The goal of this study was the development and evaluation of a compact MIMO antenna in 5G systems. The unit element of the suggested invention is motivated by a conventional ringed patch antenna, to wherein two rectangular apertures are added to provide a wide bandwidth. The footprint of the unit element is 10 mm x 10 mm x 1.575 mm, which equates to an electrical wavelength of 0.83 mm x 0.83 mm x 0.13 mm, which is the free-space length at 28 GHz. The single antenna component has a 3.52 GHz bandwidth across 26.16 and 29.72 GHz, 7.1 dB of gain, and a perpendicular emission pattern. The unit element was then used to construct a miniature, four-element MIMO antenna measuring 30 mm x 30 mm x 1.57 mm. The proposed MIMO antenna has outstanding efficiency characteristics, comprising a reciprocal coupling of lower than 30 dB, an ECC of lower about 0.0005, a CCL of 0.15 bits/s/Hz, a MEG of 6 dBi, and a DG of 9,999 dBi. In conclusion, a comparison is made between the proposed method and cutting-edge research with comparable applications. The comparison reveals that the proposed antenna beat prior work by delivering compact sizes and high-performance characteristics for both individual and MIMO antennas.

3. “Design a Single Band Microstrip Patch Antenna at 60 GHz Millimeter Wave for 5G Application’’ [33]

This research recommends a microstrip patch antenna with a single band slot for 5G wireless application. The suggested antenna has a simple structure, is affordable, and is small. A unique frequency band is used by the small antenna. Due to the elimination of the H and E slots, the impedance bandwidth increased. The design specifies a bandwidth of 4.02 GHz, a central frequency of 59.93 GHz, and a frequency range of 57.981 GHz to 62.009 GHz. 5.42 dB is the maximum efficiency of the 229 recommended microstrip patches antennas of millimetre wave radio applications. Return loss, VSWR, surfaces current, and three-dimensional radiative pattern simulation outcomes for the proposed single-band antenna are shown. The computed antenna's return loss at 60 GHz millimetre wave is -40.99 dB. A 5G wireless applications as an example.

4. ‘’Design of a Compact High Gain Microstrip Patch Antenna for Tri-Band 5G Wireless Communication’’ [34]

A small retargeting microstrip patch antenna of multi - band 5 G wireless communications technologies is described in this study. The proposed antenna is produced on a small Rogers RT5880 chip that dimensions 20 x 16.5 x 0.508 mm3 with a loss curve of 0.0009. To decrease return loss and boost bandwidth, the proposed antenna employs a partial surface plane approach. The proposed antenna uses three of the bands recommended by the Universal Telecommunication Organization (UTO) for 5 G cellular communications, running at 10, 28, and 38 GHz. The emitting patch has been created with two T-shaped apertures to reject undesired frequencies in order to reduce cross-band interference. The suggested configuration has efficiencies of 5.67 dB at 10 GHz, 9.33 dB at 28 GHz, and 9.57 dB at 38 GHz. The recommended antenna was created using two different 3D full-wave planning and optimisation tools, CST microwave workshop & Ansoft HFSS. S11 and VSWR prototype data coincided well with computerized models of the suggested antenna. At 10, 27.5, and 37.8 GHz, the antenna has bandwidth capacity of 101 MHz, 450 MHz, and 1.48 GHz, respectively. The suggested antenna is compatible with the upcoming 5G wireless devices. Partially grounding is used to enhance parameters like as bandwidth and return loss. The suggested antenna was developed and tested, and the measured and calculated S11 and VSWR parameters agreed perfectly.

5. ‘’mm Wave Novel Multiband Microstrip Patch Antenna Design for 5G Communication’’ [35]

In this article introduces a novel mm Wave multiband patches antenna configuration for usage in 5G communication. At frequencies of 37 GHz and 54 GHz, the 5G mm Wave antenna achieves high bandwidth capacity of 5.5 GHz & 8.67 GHz, respectively. The microstrip innovation 5G mm Wave multi - band antenna provides the advantages of low cost, low visibility, high profit, and efficiency. It is also compact and efficient. The 5G antenna is built using CST MWS modelling software. It features a small form factor of 7.2x5.0x0.787 mm3. 5 dBi and 6 dBi of observed benefit are both enough for the 5G multi - band antenna. It is easy to use for 5G connections and can be easily incorporated into smart devices. The projected antenna resonates in the 37 GHz and 54 GHz bands, respectively, with overall efficiencies of 65% and 75%. The antenna's impedance is properly matched to both resonating bands. The results show that the wide, effective, and small form element mm Wave multiband patches antenna is a recently created antenna. The antenna which was developed is ideal for 5G communication.

6. ‘’Design of Efficient 37 GHz Millimeter Wave Microstrip Patch Antenna for 5G Mobile Application’’ [36]

For cellular transmissions at 37 GHz, an optimised solitary microstrip patch antenna has been developed and tested. The return loss, gains, impedance bandwidth, voltage standing wave ratio (VSWR), and radiation pattern of the antenna have all been calculated and evaluated in both the E and H planes. Efficiency and impedance bandwidth have been enhanced by using a hybrid of a H slots and an inverse T slot in the antenna's design. The size of the two gaps was also studied. For a resonance frequency of 37 GHz, the simulated values for impedance bandwidth, insertion loss, and return loss are 16.22%, 8.245 dB, and 43.05 dB, respectively. The suggested microstrip patch antenna is well-suited to the upcoming version of cellular technology, 5G.

7. ‘’mm Wave Four-Element MIMO Antenna for Future 5G Systems’’ [37]

This research presented a unique S-shaped MIMO antenna with enhanced isolation. With the help of an isolator, the 15 dB isolation achieved by a multiple MIMO antenna arrangement was enhanced to 26 dB. The antenna is constructed on a 0.254 mm-thick, 2.3-relative-permittivity RO5880 ultra-thin substrate. The proposed antenna featured a bandwidth of 25 to 40 GHz, a peak gain of 7 dB, and a size of only 24 24 mm. The ECC value for any two radiating components is less than 0.05, and the efficiency is more than 85% throughout the whole operating bandwidth. There was very good agreement between the simulated version and the produced prototype. The suggested antenna is well suited for mm wave spectrum phones of the future and 5G devices with high data rates.

8. ‘’A Single-Band 28.5GHz Rectangular Microstrip Patch Antenna for 5G Communications Technology’’ [38]

The utilization of 5G communication technology is increasing in popularity, need, and value. To accommodate the higher gain and efficiency needs of impending 5G communication systems, a rectangle microstrip patched antenna has also constructed in this research. Both the efficiency and the return loss of the proposed model are improved. This case uses 28.5 GHz (Ka-band), one of the most important frequency channels for 5G connectivity. The suggested model has a Patch with architectural dimensions of 7.885 mm * 8.935 mm * 0.5 mm, and it has a return loss of -48.309 dB, a gain of 7.425 dB, a VSWR of 1.007129, and a directivity of 8.141 dBi. In addition, the efficiency was 91.16%, the bandwidth was 1.2 GHz, and the surface current was 760.4 A/m. With the faster speeds of 5G connection, this is also helpful. When these considerations are used, the constructed antenna may soon be suitable for 5G communication technologies.

9. ‘’A Dual Band Antenna Design for Future Millimeter Wave Wireless Communication at 24.25 GHz and 38 GHz’’ [39]

This research shows a 5G wireless communication antenna with two bands. Due to the 5G applicants’ band, the simulation results can work at both 24.25 GHz and 38 GHz, which are the two bands needed (20 Ghz to 50 GHz). To get the best simulation results, especially in definitions of frequency drop, achieve, and antenna efficiency, the antenna size was changed and the results were compared. At every frequency, the antenna has a respectable return loss of -35.518 dB and -13.625 dB and a highest gain achieve of 5.541 dB and 4.527 dB.

10. ‘’Millimeter Wave Antenna Design for 5G Applications’’ [40]

The proposed antennas have a modest size of 2.5x2.5mm2 & are produced on a 5mm x 5mm x 0.8mm3 RF4 substrate. Without a DGP, the early antenna design had a bandwidth of around 37.5GHz. The second type employs the faulty ground plane approach, resulting in a wide operational frequency range between 30GHz and 45GHz. In addition, a good location for an L-shaped slots was identified above the radiator to create a notched band at around 40GHz, which will aid in reducing expected entanglements between 5G devices & other applications. Finally, a bulk capacitor was installed over the L-shaped slots & its capacitance values were changed from 0.5 pf to 7 pf to calibrate the newly formed filtering band. This resulted in a downward shift of the notch while keeping the same bandwidth (30GHz – 45GHz) from 40GHz - 33GHz. In areas of return damage, power efficiency, current levels, and efficiency, the suggested antennas demonstrate promising performance, which eventually qualifies them as promising candidate solutions for future 5G wireless systems.

11. Research Paper on “Dual-band Microstrip Antenna for 5G and Short-Range Applications” [41]

In this study, dual-band rectangular ring-shaped monopole antennas were constructed. The antenna was constructed using a Rogers RT/duroid 5880 dielectric substrate. Utilizing differences in the diameter of the circular antennas and the ground, a parameter analysis is conducted. By altering the ground diameters, it was shown that single-band, dual-band, & wideband characteristics could be generated. With a base dimension of D = 38 mm, dual resonances around 3.19 GHz & 4.63 GHz were recorded with respective available bandwidth of 240 MHz & 322 MHz. Using a VNA, the resonance frequencies of 3.17 GHz and 4.67 GHz with corresponding bandwidths of 550 MHz & 190 MHz were determined. This document is designed for usage at frequencies ranging between 3.2 & 4.6 GHz. Short-distance communication devices use frequencies between 3.1 & 3.3 GHz, whilst radiolocation services utilize the same frequency range. Additionally, frequency categories 4.4 GHz to 4.5 GHz & 4.5 GHz to 4.8 GHz are the subject of investigation. potential 5G competitors.

12. Research Paper on “Broadband Microstrip Antenna for 5G Wireless Systems Operating at 28 GHz” [42]

This study presents a unique way for constructing multichannel microstrip antenna for 5G systems. The recommended antenna, which works under the LMDS (Local Multipoint Distribution Service) frequencies range, has a basic operating frequency of 28 GHz. The antenna was intended to function in the 28 GHz frequency range, which is one of the predicted frequency bands for usage in 5G networks. Additionally, the antenna design must account for a compact antenna structure and the greatest achievable bandwidth. The design approach for antennas has been improved to make them lighter and smaller, allowing their use in mobile stations and easing their incorporation into electrical equipment. Using the FEKO software, the size, properties, & optimization of the antenna was determined. Having a compact antenna footprint of 6.2 x 8.4 x 1.57 mm. To build the antenna, we used a 2.2 dielectric constant, 1.57 mm thick slab of Rogers RT Duroid 5880. The antenna discussed in this piece has a reflections coefficient of only (22.51 dB), an energy gain of (3.6 dBi), an operational bandwidth of (5.57 GHz) ((19.89 pct), and excellent energy efficiency.

13 “Research paper on “Bandwidth Enhancement of Rectangular Patch Microstrip Antenna” [43]

The bandwidth (BW) of most microstrip antennas is between 1% and 5%. To get a low Q, broadband antennas must take into account the mentioned antenna geometry factors: a thicker substrate or a lower dielectric permittivity; matching feed impedance; patch trigonometry optimization; and suppressing ground waves in a thick substrate. In this study, the third & fourth parameters are used to make bandwidth bigger. The antenna is a rectangular patch antenna on a FR-4 substrate. It is 40 mm by 40 mm by 1.57 mm3 and has a permittivity of 4.4. Instead of being square, the patch antenna seems to be in the shape of a fan. This is done to increase the BW. The simulation shows that the band width has grown in a clear way. In terms of bandwidth, the recommended antenna works better than the classic square patch. microscopic-strip antenna the results of simulations show that the proposed antenna has a much wider bandwidth than the typical rectangular patch microstrip antenna. The pattern of radiation in all directions does not change. The new antenna might be eligible to work in the C frequency band for microwaves.

14. Research Paper on “Bandwidth Enhancement in Multipatch Microstrip Antenna Array” [44]

For this project, we used a microwave-frequency microstrip patch antenna. The software was used to investigate the influence of the upper patch, specifically the fluctuation in VSWR in response to the separation of the two patches & the size of the bigger one. An array of two multipatch microstrip antennas at a 24 resonant frequency of 5.2 GHz is shown to have a return loss S11 of approximately 29 dB, a success level of around 10.683 dB, and an improvement in bandwidth of about 23.07 percent, according to numerical simulations and experimental data. Project goal is to show how bandwidth & directivity of a multilayered multipatch microstrip antenna might well well be improved. an extremely directional antenna was constructed using a microstrip antenna arrays with such a directivity of 11.4703dB and a bandwidth of.

15. Research Paper “Gain and Bandwidth Enhancement in Compact Microstrip Antenna” [45]

This study recommends a novel, compact microstrip patch antenna with a layered layout. The return loss, efficiency, and bandwidth of the antennas are measured and compared to those of a standard microstrip patch. Superstrate loading allows the suggested concept to dramatically boost gain and bandwidth when simultaneously decreasing patch area by 66.34 percent. The stackable arrangement of small microstrip antennas creates a novel antenna design for wireless local area network (WLAN) applications. The gain and bandwidth of the antenna in the desired frequency range are both improved by the stacked arrangement. Size is reduced by 53% according to the proposed design, which also boasts a gain of 4 dBi and a bandwidth of 91 MHz Using the Natural Algorithm optimizer included inside the IE3D Commercial simulator, the suggested antenna's performance is improved.

16. Research Paper on “A New Mm-Wave Antenna Array with Wideband Characteristics for Next Generation Communication Systems.” [46]

This study introduces a planar multi-circular loop antenna with a broad impedance bandwidth for mm-wave systems of the future. Three circular rings and a partially surface plane with a squared slit make up the proposed antenna. A RO5880 substrate that is 0.254 mm thin and has a comparative permittivity of 2.3 serves as the foundation for the resonating structure. With a peak increase of 4 dBi and a radiation efficiency of 96%, the single element of the suggested design displayed resonant responses from 26.5 to 41 GHz. A four-element array system is created using the suggested multicircular ring antenna element. A peak gain of 11 dBi is maintained with an array size of 18.25 12.5 0.254 mm3. The simulated and observed results show that the constructed t array performs in fair accord the findings of the simulation and measurement of the array were shown to be in great agreement. The suggested antenna can support future 5G technology based on performance comparisons with the reported literature.

17. Research Paper on "Design of a wideband microstrip antenna" [47]

In this work, the creation of a single-layer wideband microstrip antenna is covered. A parasitic patched gap-coupled microstrip makes up the antenna. Without a doubt, gap-coupled, wideband microstrip antennas. In the current gap-coupled antenna configuration, the radiating patch has a parasitic component. The size of the parasite patch, the width of the feed strip, the separation between the feed strip & the radiating patch, and the separation between the radiating patch & the parasitic patch are all precisely measured.At its 8.2 GHz center frequency, this antenna's design produced an impedance bandwidth of 44 percent 1:2 VSWR. Between findings from simulation and measurements, there are clear relationships. With the help of this antenna, one may communicate with UWB radios. UWB-based systems Impulse radio transfers data with extraordinarily high data rates by using energy pulses as opposed to a narrow-band frequency carrier. The 6.4 GHz to 10 GHz frequency range saw the achievement of a 3.6 GHz bandwidth, or 44% of the center frequency.

18.. Research Paper on "Design of a Millimeter Wave Microstrip Patch Antenna and Its Array for 5G Applications." [48]

Future applications for 5G are suggested for a low-profile, small millimeter wave microstrip patch antenna. The array of the antenna contains 4 frequency bands that occur at (23, 27.09, 31 and 42.5) GHz, although the antenna only resonates at a single band frequency of 24.8 GHz. The 5G Microstrip patch is created on a Rogers RT Duroid 5880 surface with a standard thickness of 0.787 mm, a relative dielectric constant (r) of 2.2, and a tan value of 0.0013. The antenna has a return loss of -19.5 dB, a bandwidth of 1.318 GHz, and resonates at a frequency of 24.85 GHz. The proposed antenna has a tapered line feeding and a 1x4 element array. The antenna array has four distinct resonance frequencies, namely 23.2 GHz, 27.09 GHz, 31 GHz, and 42.5 GHz. An observable increase in gain is seen with the array of antennas. Because of how small it is, the antenna and its array are appropriate for 5G mobile communication. Due to its compactness and small size, the 5G antenna & its array can be utilized for upcoming 5G mobile communications.

19. Research Paper on "E-Shaped H-Slotted Dual Band Mm Wave Antenna for 5G Technology" [49]

For 5G technology, a dual band mm wave MIMO antenna configuration is suggested in this research. With resonances at 28 GHz and 38 GHz, this system comprises of four radiating components. With average efficiency, the envelope correlation coefficient (ECC) of the method is determined to be 70% and 0.0005 correspondingly, with the mean measured gain being 7.1 dBi at 28 GHz and 7.9 dBi at 38 GHz. The suggested system is planned, modelled, and manufactured using an LPKF D104 milling machine, & evaluated using an R&SZNA67 vector network analyzer. All of these processes are carried out using full-wave electromagnetic wave software (CST). It is expected that this technology will find use in next 5G systems because to qualities like low cost, simplicity in fabrication, and dual-band.

20. Research Paper on “A Novel Design for Millimeter Wave Microstrip Antenna with Bandwidth Enhancement” [50]

In order to expand bandwidth, a novel microstrip antenna with two rectangular slots was developed. To increase the bandwidth of two rectangular slots, we introduce additional resonances very near to the fundamental frequency. Imperial competition may also increase the patch characteristics that determine bandwidth (ICA). The final bandwidth of the proposed antenna is 2.26GHz (27.48GHz to 29.74GHz), which is 1.46GHz wider than the original proposal based on simulation results. The suggested antenna has a constant gain achieve of 7.1–7.65dBi over the usable frequency range. Locations are selected over the 27.5-29.5GHz band at uniform intervals, where N is the number of sites selected. The antenna bandwidth has been expanded to 2GHz when the S11 at these N sites is less than -10dB.

21. Research Paper on “An Integrated Antenna System for 4G and Millimeter Wave 5G Future Handheld Devices “[51]

In this research, we take a look at a combined antenna system for mobile devices and millimeter-wave fourth-generation (4G) and fifth-generation (5G) wireless applications using a Defected Ground Structure (DGS). The proposed layout is predicated on a Rogers RT/Duroid 5880 substrate that is 110 mm x 75 mm x 0.508 mm in total. Efforts to create 5G wireless networks, which would allow for mobile and wide-band wireless communication, are increasing. Millimeter-wave radios have emerged as a key component for 5G multi-Gbps low-latency wireless networks in recent years. The 4G antenna array has been tested to operate throughout a frequency range of 160 MHz to 450 MHz, which encompasses the two sub-6 GHz frequency bands with their respective centers at 3.8 GHz and 5.5 GHz. As an alternative, the 5G antenna array may receive and transmit signals in the 4.9 GHz mm-wave spectrum. Extensive bandwidth in the GHz range.

22. Research Paper on “A Flexible Directional Antenna for 5G Millimeter -wave Applications” [52]

In this work, we suggest a revolutionary flexible antenna design. These are the technical details of the microstrip antenna used for the antenna: Thin Rogers 5880 substrate, measuring in at 12.25mm by 7.45mm by 0.07mm. The bandwidth simulation runs between 24.6 and 24.7 GHz. The antenna's maximum gain is 6.16 dBi and it features a directed pattern. The purpose of this research is to develop a flexible antenna that can operate at 24 GHz with a certain pattern of radiation efficiency. One such antenna is a 50 microstrip line-powered rectangular patch antenna with a directional design. Two methods are used to increase antenna bandwidth: a stepped feeding line and slots cut into the patch. The antenna is supported by a Rogers 5880 substrate of 70 m thickness, which has a referring dielectric constant of 2.2.

23. Research Paper on "Ultra-wideband Microstrip Array Antenna for 5G Millimeter-wave Applications" [53]

This study proposes a design for a 5G millimeter-wave ultra-wideband microstrip array antenna using a combination of a graded line cut and a U-slot. The proposed design employs a method of proximity coupling feeding to enhance bandwidth performance. The suggested antenna's bandwidth performance is compared to that of a conventional antenna array design to calculate the bandwidth enhancement. The numerical and 29 modeling results demonstrate a considerable increase in bandwidth performance when compared to older designs. The recommended antenna works at 28 GHz with a bandwidth of 4.47 GHz and a gain of 8.71 dB. These findings reveal that the proposed antenna design is suitable for 5G millimeter-wave applications. They improved the bandwidth & gain performance of a microstrip antenna for 5G millimeter-wave applications using a mix of approaches. Examples include U-slot procedures and graduated line cuts. Utilizing the stepped line cut method facilitates the production of slot antennas. For two-way radiation patterns, the slot antenna provides the benefit of a broader bandwidth. The Q factor of an antenna, which is inversely proportional to its bandwidth, may be affected by slot-induced coupling effects.

24. Research paper on "Design of a Millimeter-Wave MIMO Antenna Array for 5G Communication Terminals." [54]

The design of a multiple input multiple output (MIMO) antenna array for 5G mm-wave communication systems is discussed in this paper. Two antenna arrays are combined to form the suggested MIMO arrangement. Four components from each antenna array are positioned evenly, and two arrays are then put together with a 90-degree angle to one another. The substrate is a Rogers RT5880 that is 0.254 mm thick, with a loss tangent of 0.0009, and a dielectric constant of 2.2. The 37 GHz frequency spectrum is covered by the MIMO antenna array that is being developed. The suggested antenna element produces a gain of 6.84 dB, which is increased to 12.8 dB by using a four-element array design. Therefore, the suggested design can a prospective contender for 5G mm-wave networking.

25. "Research paper on "Highly Efficient 2x2 Antenna Array at 28 GHz and 38 GHz for 5G Applications".[55]

In this study, an effective antenna array at 28 GHz & 38 GHz is suggested in accordance with 5G standards. At frequency bands 28 GHz & 38 GHz, the antenna array's bandwidth coverage is 1.3 GHz & 2.54 GHz, respectively. At 28 GHz & 38 GHz, the antenna array's realized gain is 15.3 dB & 13.6 dB, respectively. Additionally, both antenna arrays at the frequency bands of 28 GHz and 38 GHz have an antenna effectiveness of 97.3%. The suggested 2x2 antenna array demonstrated excellent performance with The antenna has a 1.3 GHz bandwidth, 61.19 dB return loss, 15.4 dB realized gain, a VSWR of 1.001, and an efficiency of 97.97% at 28 GHz; at 38 GHz, the numbers are 2.49 GHz, 52.28 dB return loss, 13.8 dB realized gain, 1.005 VSWR, and 97.97%. once we compare the proposed antenna to It was proved that the proposed antenna better fulfilled all criteria than previous efforts. In conclusion, it can be claimed that the suggested antenna array will enable the 5G wireless devices to operate at its peak performance.

3.2 Summary

Wavelength wave a report says that microstrip patch antennas for 5G connections have been made for millimeter wave bands like 28 GHz and others. Recent research shows that for 5G wireless connectivity, the millimeter wave bands at 28 GHz are the most important and useful. In this frequency band, there is a lot of research going on. Again, the hardest part of deploying 5G is making an antenna that has a high gain, is small enough to fit in a phone, works well, and is easy to make.

3.3 Objectives

- For 5g applications, a single microstrip patch antenna was built and simulated to boost bandwidth.
- creating the optimum antenna with increased bandwidth for 5g applications by adjusting various antenna design parameters.
- Antennas for 5G applications are designed using a variety of parameters, including insertion gap, patch width, patch length, etc.
- Finally, pick the antenna with the best performance.
- To create and simulate a microstrip patch antenna with enhanced antenna properties, especially in terms of bandwidth, for use in 5G applications.
- To improve microstrip patch antenna performance.
- Compared to currently available 28 GHz microstrip patch antennas.

Chapter 04

Methodology

4.1 Methodology

A methodology is a set of steps. This phrase may be used to describe procedures employed in a specific research study, methods utilized to complete a certain job, or methods that are often used in a field of study or industry. The study of such approaches, as opposed to the techniques themselves, may sometimes be referred to as "methodology" by users.

Methodology can be considered to include multiple techniques, each applied to different facts across the entire range of methodologies. Analysis can be divided into two sections, qualitative analysis and quantitative research.

4.2 Research Design

The research design is the framework for addressing the problems raised by the study. An experimental design, a research approach, dependent and independent variables, methods for data collection, and a plan for statistical analysis are all examples of research tools that are specified in a study project model.

Research Methodology for this research:

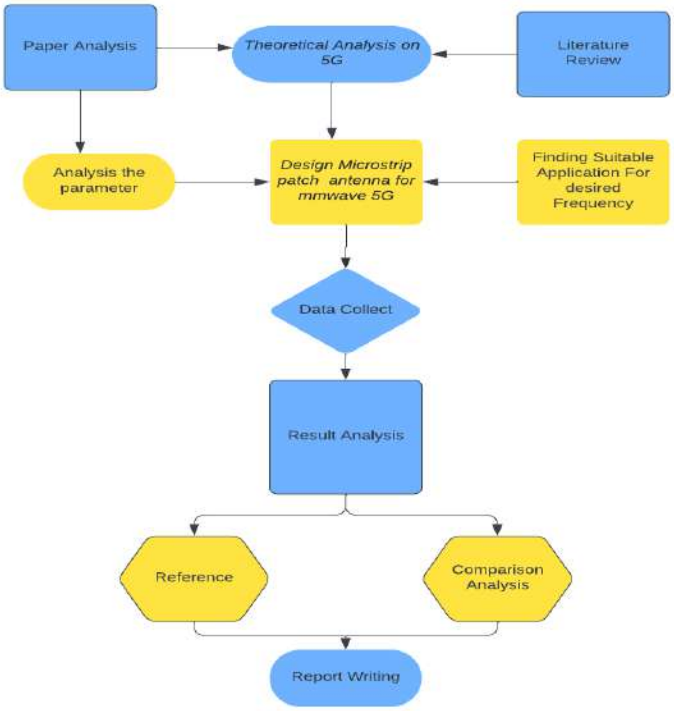


Figure 4.1: Research Methodology flowchart

4.3 Pilot Study

Before beginning a larger research effort, a pilot study, pilot project, pilot measure, or pilot experiment is conducted on a small scale to test various hypotheses. Its purpose is to determine the feasibility of the study in terms of time, money, hostile events, and study design. It is finished prior to the structuring of any research. Most of the time, pilot studies are conducted in accordance with the goals of the research. Although a pilot study greatly minimizes the number of faults that the initial study will waste time and resources on, systemic errors and unforeseen problems cannot be completely ruled out.

Pilot study’s importance:

- To evaluate the protocol and/or research process.
- To sort important variables into groups and decide how to use each one.
- To create or evaluate the effectiveness of analysis tools and methods.
- To figure out how to use statistics in future research.

4.4 Software

For 3D electrical stimulation of high frequency components, CST Microwave Studio (CST MWS) is a vital tool. The use of CST MWS enables a quick and accurate evaluation of HF systems, including filters, couplers, antennas, single- and multi-layer constructions, as well as SI and EMC effects.

Due to its exceptional performance, CST Microwave Studio is the top technology choice for R&D departments. CST MWS, which is incredibly user-friendly, provides a brief overview of high-frequency model EM conduct. [42].

4.5 Design procedure

Step 1: Firstly, a single rectangular microstrip patch antenna (MPA), also known as an equation-based antenna, is intended to operate in the 28 GHz band.

Step 2: Save the model, then simulate the constructed antenna.

Step 3: If the antenna satisfies the requirements, save the result.

Step 4: In order to increase effectiveness, the antenna of produced microstrip patches should be optimized.

Step 5: 1x4 Array of planar antennas designed to increase gain and direction.

Step 6: Save your structure and recreate the array antenna to be simulate.

Step 7: If the antenna fulfills the requirements, save the result.

Step 8: Connect the result with current antennas.

4.5.1 Antenna Design by Equation

The first step in developing antennas is to select a suitable dielectric substrate with a reasonable density (h). To enhance mechanical and electrical stability, dielectrics are used. By generating displacement current and aiding in the generation of time-varying magnetic fields (by Ampere's law), these are used to reduce antenna size. In addition, the time-shifting magnetic field will cause an electromagnetic field to propagate and cause time to differ from the electric field in accordance with Faraday's law.

Many common dialectical substrates with their properties are described below.

TABLE 4.1: LIST OF SUBSTRATES

Dielectric Name	Dielectric constant
Rogers RT Duroid-5880	2.2
Rogers RT Duroid-5870	2.33
RT Duroid-6002	2.94
RO4730	3
Rogers RO 3200	3.02
FR4 (Lossy)	4.4

The above table substrates have relatively high dielectric constants, which points to a significant loss in the creation of a high gain antenna.. As the purpose of this research is to design a high gain antenna, foam material with a dielectric constant close to 1 is chosen for this model. Then the microstrip line and surface material should be selected. We have three options in this case — Copper, Silver or Gold. Silver's conductivity is greater than others. But the price of copper is far more complex and cheaper than the other two. Therefore, copper is typically used. Equations (1) (5) were used to measure the length and width of the antenna [45].

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.1)$$

Where, c = Velocity of Light ($3 \times 10^8 ms^{-1}$)

Effective dielectric constant is given by,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{W}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.2)$$

Where,

ε_{eff}= Effective dielectric constant, =

Dielectric constant of substrate, h =

Height of dielectric substrate, w =

Width of the patch.

For a given resonance frequency fr, the effective length is given by,

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (3.3)$$

The actual length of the patch is given by,

$$L = L_{eff} - \nabla L \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (3.4)$$

Where,

$$\nabla L = 0.412h \frac{(\varepsilon_r + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_r - 0.258)\left(\frac{w}{h} + 0.8\right)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (3.5)$$

The basic parametric of the rectangular microstrip patch antenna are calculated using the formulas above and are shown in Table 4.2.

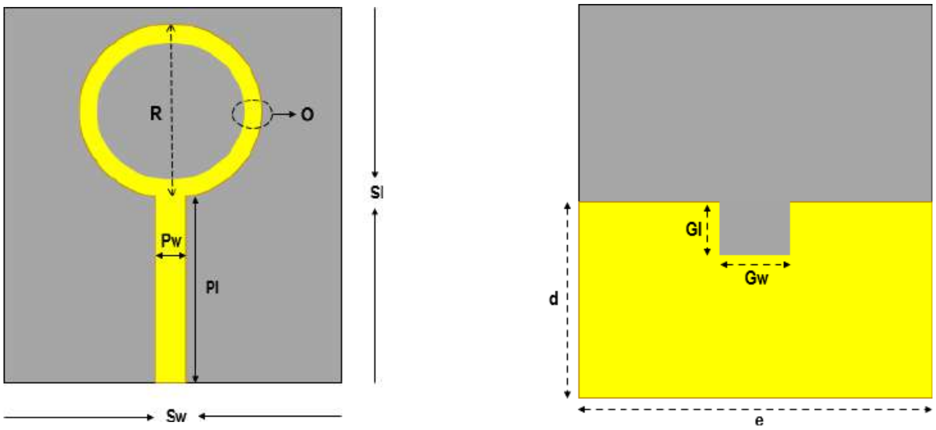


Figure 4.2: Equation based single element antenna with ground structure

TABLE 4.2: SINGLE ELEMENT ANTENNA PARAMETERS

Parameter	Value
Frequency (f_r)	28 GHz
Height of Substrate, h	0.254 mm
Dielectric Constant, €$_r$	2.2
Patch Length (SL)	5
Patch Width (SW)	4

These parameters are shown in the table below for the single element antenna design.

4.5.2 MIMO Antenna Design

In this MIMO antenna 4 element antenna was places in horizontally and vertically to form the MIMO antenna. The ground structure also placed as the patch.The dimension remain same as the single antenna.

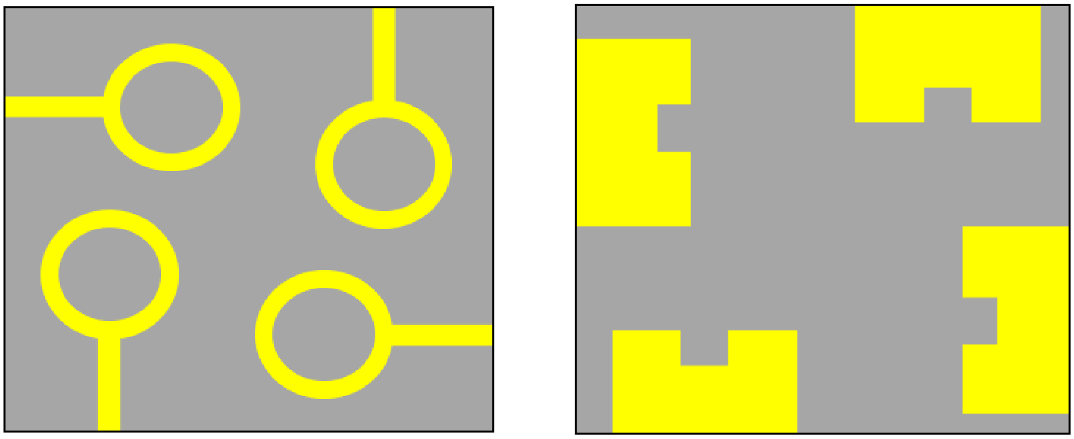


Figure 4.3: Structure of MIMO Antenna with ground structure

4.5.3 Antenna Array Design

An antenna array, also called an array antenna, is a group of antennas that work together as a single antenna to send or receive electromagnetic waves. Connecting the feedlines to the components is usually done with the feedlines that link the individual antennas, which are called components, to a single receiver or transmitter that sends energy to the components in a certain phase. During transmission, the electromagnetic waves sent out by each antenna add up and stack on top of each other. These waves can add up or interfere in a good way to increase the amount of energy sent in the right direction, or they can cancel out or interfere in a bad way to send less power in other directions. Similarly, when receiving, the signal energy gained from the necessary instructions is enhanced by the combination of electromagnetic waves from the multiple antennas in the receiver with the needed phase relationship, while the signal energy from the unnecessary instructions is cancelled. Therefore, compared to a single antenna, an array can provide more gain (directivity), resulting in a narrower electromagnetic wave beam. More antenna elements in an array means more gain and more consistent signals. In order to achieve the research goal of creating a high-gain antenna, an antenna array was developed.

The array antenna design depends heavily on the distance between two patches because it affects the antenna's overall profitability. If the patches are separated by 2, the antenna array yields the highest profit, but the array size is drastically reduced [6]. Most commonly, patch spacing values range from 0.6 to 0.9 as the starting point [15].

As was mentioned earlier, a linear array is created using a simple and direct feed structure based on the single element's reasonable performance. The feed line is made up of a 50 W transmission line that splits into 100 W parallel connections before becoming 70 W lines. For this feeding process, only three quarters of a wave transformer are needed.

TABLE 4.3: ANTENNA ARRAY PARAMETERS

Parameter	**Value**
Frequency (f_r)	28 GHz
Height of Substrate, h	0.254 mm
Dielectric Constant, $€_r$	2.2
Patch Length (SL)	8.5
Patch Width (SW)	12

This table shows the parameters that is been used for the array antenna design.

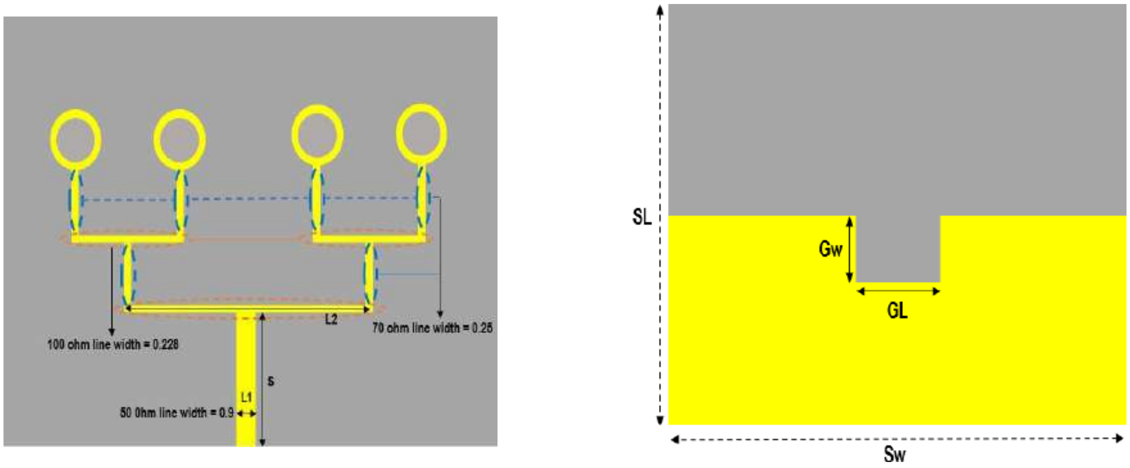


Figure 4.4: Structure of 1×4 Array Antenna with ground structure

As formerly earlier said, a linear array with a straight feed structure is developed based on the decent performance of a single element. As seen in Figure 6, the feed line is made up of a 50 W transmission line that is subdivided into a parallel connection of 100 W and then 70 W lines. The electromagnetic wave computer software CST was used in its entirety in the design of this structure.

Chapter 5

Results Analysis

This section provides and analyzes the results acquired after simulating the constructed antenna.

5.1 Results parameter

5.1.1 Return Loss Graph

The simplest parameter to test an antenna's output is the return loss, also known as the S11 parameter.The lack of return provides data on the reflected energy of an antenna. A measure of the loss of power in the signal reflected by a transmission line to a load, such as an antenna usually expressed in **decibels (dB)** as the logarithmic ratio of relative magnitudes of input power and reflected power. The operating frequency and the antenna bandwidth of the return loss vs. frequency chart can be easily determined. The parameter value of S_{11} was decreased the higher the antenna'sresonance.

5.1.2 Voltage Standing Wave Ratio (VSWR)

A voltage standing wave ratio (VSWR) is a measurement that determines how far an antenna and the feed line that is linked to it are out of phase with one another. Another name for this concept is the Standing Wave Ratio (SWR). The VSWR values might range from 1 all the way up to. It is generally accepted that a value of VSWR that is lower than 2 is acceptable for antenna applications. It is feasible to say that the antenna has a "Good Match" in its characteristics. Therefore, when someone says that an antenna has poor matching, they usually mean that the value of the VSWR for a specific frequency is more than 2.

5.1.3 Radiation Pattern

Graphical representations of an antenna's radiation characteristics are called antenna radiation patterns. The directional feature of the antenna is typically graphically represented by the antenna pattern. It displays the relative energy radiation intensity or the strength of the electric or magnetic field in relation to the antenna's direction.

5.1.4 Directivity

The conventional definition states that "the directivity is defined as the ratio of the maximum radiation power of the subject antenna to the maximum radiation level of an isotropic or reference antenna, emitting the same total power." An antenna emits power, but the direction of that power is very important. The antenna being watched is referred to as the subject antenna. While sending or receiving, its radiation strength is concentrated in that particular direction. The antenna is said to have that specific direction of directivity as a result.

- The Directivity is defined as the difference between an antenna's radiation output in one direction and its overall average radiation output.
- If that specific direction is not stated, the antenna's directivity can be assumed to be in the direction where the maximum intensity is seen.
- The directivity of a non-isotropic antenna is defined as the radiated power in a given direction divided by the radiated power from an isotropic source.

5.1.5 Antenna Efficiency

The power provided to the antenna in relation to the power emitted from the antenna determines the efficiency of the antenna. The majority of the power that is available at the antenna's input is radiated away by a high efficiency antenna. The majority of the power used by an antenna with low efficiency is lost as internal losses or is reflected away due to impedance mismatches.

5.1.6 Antenna Gain

The power that an antenna transmits in a particular direction in comparison to an isotropic antenna is measured by antenna gain. The strength of the signal that an antenna may transmit or receive in a given direction is described by this specification. A more crucial parameter than directivity is antenna gain because it accounts for all losses.

Antenna gain = Directivity x Efficiency

Technically, the result of directivity and efficiency is antenna gain. Where efficiency takes into account the losses of the antenna caused by manufacturing flaws, defects in the surface coating, dielectric, resistance, VSWR, or any other factor, and directivity measures how concentrated a radiation pattern of an antenna is in a specific direction.

5.2 Simulation Results

5.2.1 Return Loss Graph

The constructed single-element antenna's return loss plot is shown below. At 28 GHz right now, the resonance frequency is high. The optimized single-element antenna return loss value is also -29.558 dB at 28 GHz, which shows very good impedance matching.

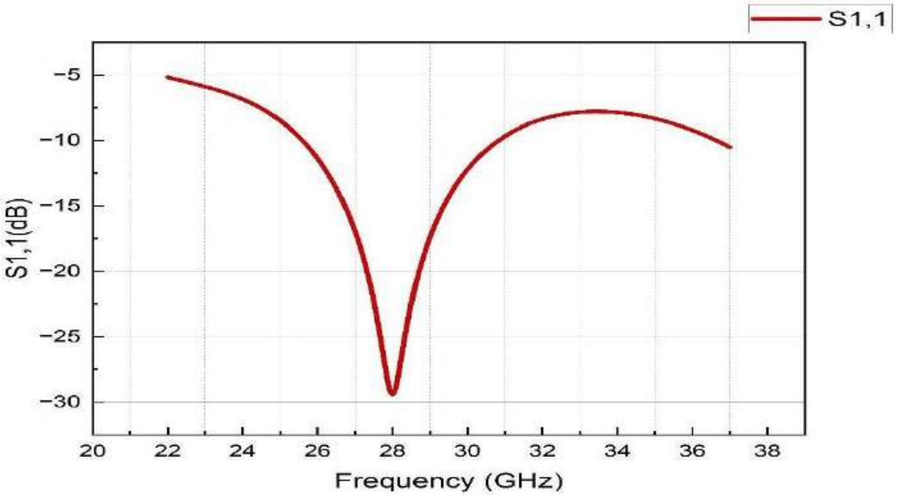


Figure 5.1: Plot of Return Loss for a Single Element Antenna

You can also calculate the bandwidth of the single component antenna from the chart above. In this case the bandwidth of 29.558 dB is on 28 GHz, which covers the entire band of 28 GHz as stated by FCC [1].

5.2.2 Voltage Standing Wave Ratio (VSWR)

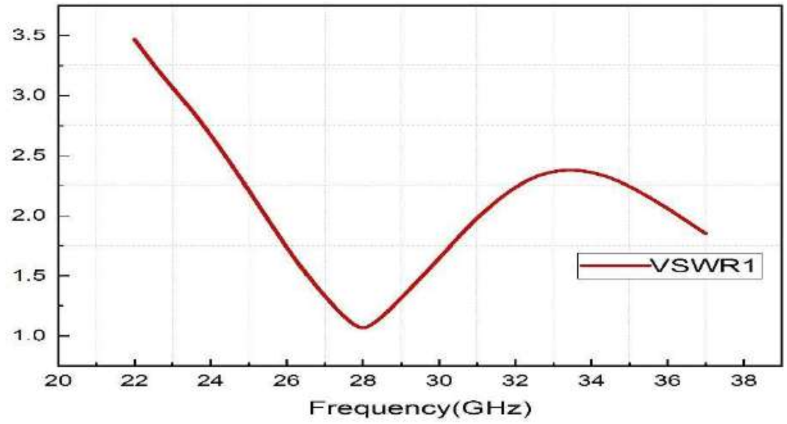


Figure 5.2: Plot of VSWR Equations Based Single Element Antenna

The VSWR of the single-element antenna is 1.068831. The VSWR value of the single-element antenna falls within the typical range of 1.0 to 1.5. Since we are taught that the antenna functions well at the frequencies if the S11 value is less than -10 dB through the frequency, the S11 value must be less than -10 dB. In addition, if the VSWR number falls within the range of 1-2, it shows that the antenna performs properly within the defined frequency range. The return loss and VSWR graphs indicate that the antenna operates well on the desired frequency band. Additionally, more than ninety percent of electrical power is used to generate electromagnetic waves.

5.2.3 2D Radiation Pattern

The term "radiation profile" is used in the context of antenna design to describe the degree to which the intensity of radio waves emitted by an antenna varies with the direction in which the waves are emitted. The two-dimensional radiation pattern of a single-element antenna can be optimized by carefully controlling the beam diameter. The half-circular radiation pattern of the microstrip patch antenna allows for a directivity of 4.53 dBi at 158.0 degrees using a single patch antenna. It is also seen at an angle of 90 degrees and 270 degrees from the vertical. Because both plots are so close to a circle, From this, we can conclude that the antenna's radiation pattern is normal.

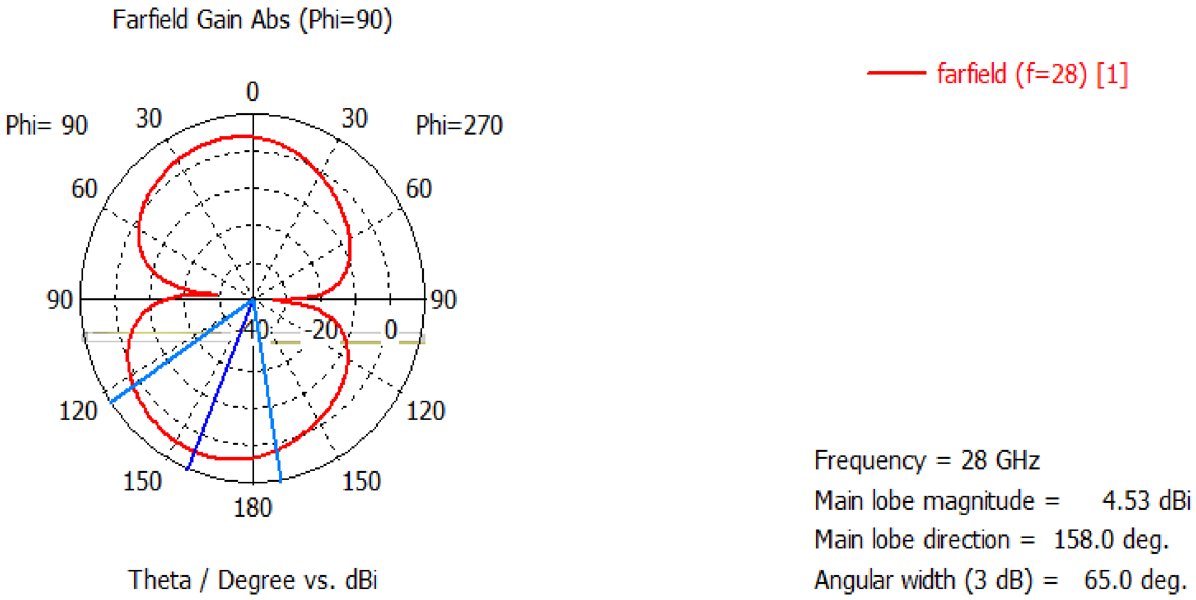


Figure 5.3: 2D Radiation Pattern of Single Element Antenna

5.2.4 3D Radiation Pattern

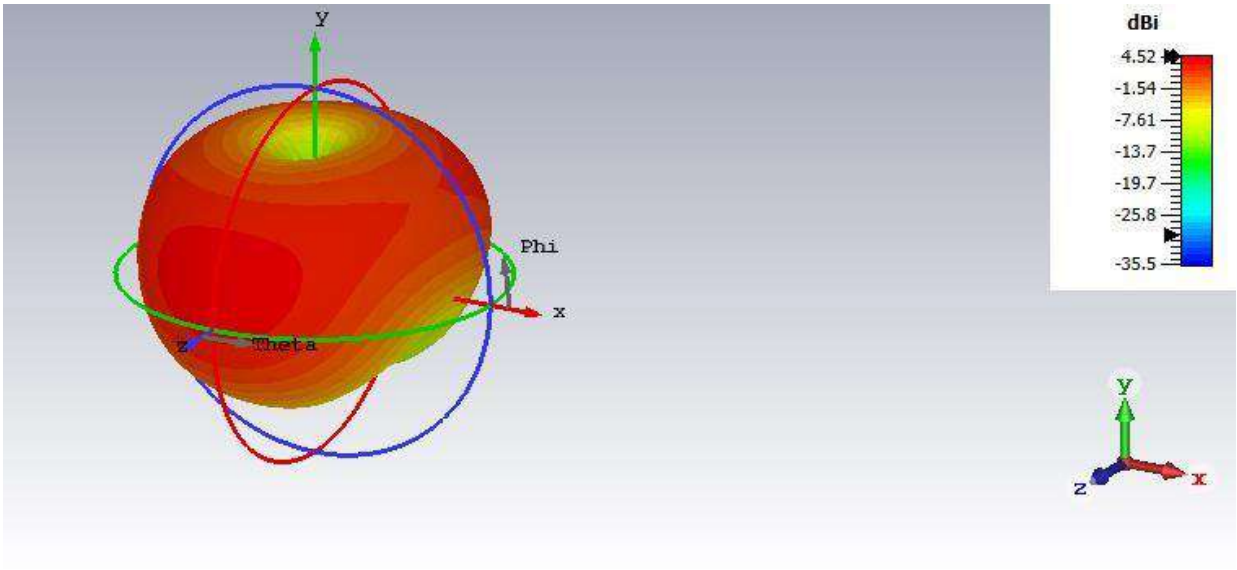


Figure 5.4: 3D Radiation Pattern of Single Element Antenna at 28 GHz

An antenna's energy radiation in the surrounding space is visible in three dimensions as a 3D radiation pattern. Typically, this pattern is measured on the far field at a sufficient distance from the known antenna. Position it only; compared to an omnidirectional antenna, it is the power radiating in all directions. A secure antenna should maintain its 3D radiation pattern throughout the service's frequency range, just like the 2D radiation pattern does. It is very tasty. It is simple to see the energy coming from a particular direction in the 3D radiation pattern. The single component antenna's 3D radiation pattern at 28 GHz is depicted above. It is possible to say that the antenna's gain4.53 dBi, which was successful.

5.2.5 Antenna Efficiency

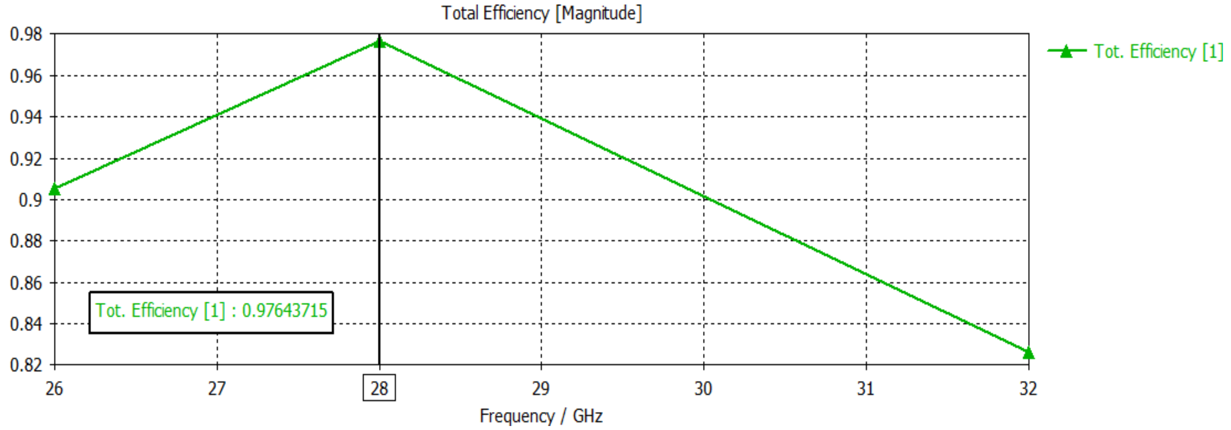


Figure 5.5: Antenna Efficiency of Single Element Antenna

The antenna's effectiveness is defined as the relationship between the effective aperture area and its actual physical area. It defines the radio frequency (RF) proportion of electricity that actually captures the region of physical aperture. The single-element antenna reached the 70 percent standard of normal antenna performance.

Figure 4.8 above demonstrates that antenna efficiency at 28 GHz is nearly 98 percent.

5.2.6 Radiation Efficiency

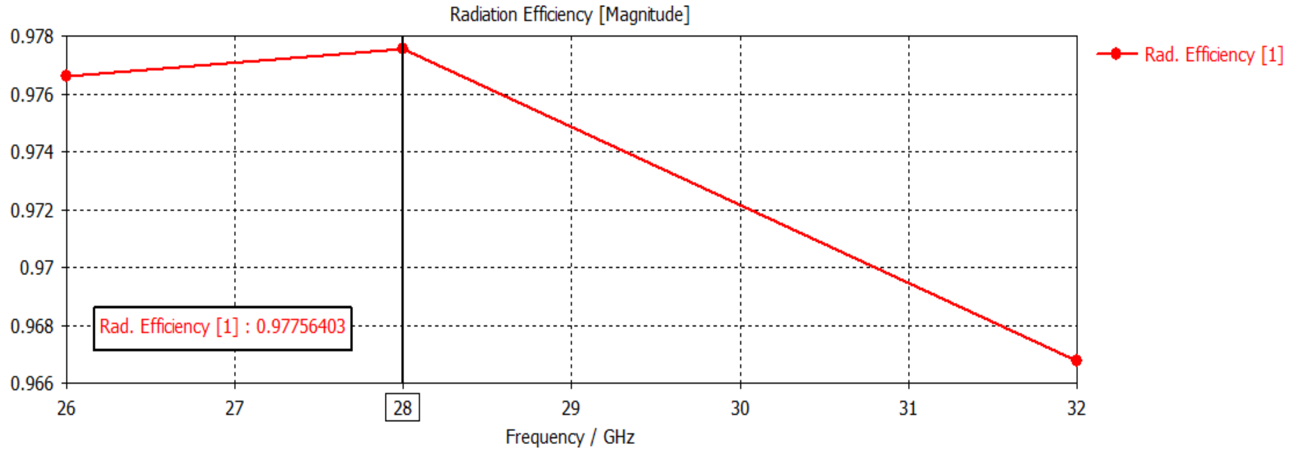


Figure 5.6: Radiation Efficiency of Single Element Antenna

The radiation efficiency of an antenna is defined as the proportion of the radiated energy of the antenna to the free space to the electrical power received by the antenna from the feedline. The standard minimum radiation efficiency is 70%. Figure 4.9 shows that radiation efficiency is approximately 98% at 28 GHz.

5.3 Results of a Single Element's Completed Design

TABLE 5.1: FINAL RESULTS OF A SINGLE ELEMENT ANTENNA'S SIMULATION

Parameters	**Value**	**Standard [10]**
Resonate Frequency	28 GHz	As per need
Bandwidth	5.25 GHz	As per need
Return loss (S_{11})	29.55 dB	less than -10 dB
VSWR	1.070	1-2
Gain	4.52 dB	6-9dBi

Directivity	4.61 dBi	5-8dBi
Antenna Efficiency	98 %	70%
Radiation Efficiency	98 %	70%

In Table 5.1, Full simulation results were displayed in tabular form after optimization of the single component antenna. This antenna shows good loss of return throughout the entire 28 GHz band. In comparison, the antenna's VSWR is less than 1.5. Compared to recent models, the single element antenna gain is quite satisfactory. Single component antenna achieves 4.52 dBi at 28 GHz. The directivity of the single-element antenna is around 4.61 dBi, which implies good omni-directional efficiency. This single component antenna has a 70% antenna efficiency and radiation efficiency across the entire band. This single component antenna has a 97% antenna efficiency and radiation efficiency across the entire band. This single component antenna has a 97% antenna efficiency and radiation efficiency across the entire band.

5.4 Comparison with the existing single element 28 GHz Antennas

TABLE 5.2: COMPARISON WITH THE EXISTING SINGLE ELEMENT ANTENNAS

Antenna ref.	Year	Return loss (dB)	Gain (dB)	Bandwidth (GHz)	Efficiency
[40]	2020	26.40	7.4	1.1	80%
[41]	2017	20	5.42	3.5	-
[42]	2018	24.35	2.37	1.021	75%
[43]	2019	52.53	5.94	4.07%	80%
[44]	2018	17.4	6.72	1.1	-
[45]	2018	16	2.28	1.2	93%
[48]	2019	30	3.76	11.3%	-
[25]	2018	46	6.61	470 MHz	79%
Proposed	**2022**	**29.6**	**4.51**	**5.237**	**98%**

In table 5.2 we compered the results of single element antennas with our proposed single element antenna, it is clear that the proposed single antenna is better compared with the existing single antennas. The purpose was to design single antenna with a high gain. The antenna efficiency is 98% and this antenna shows good loss of return throughout the entire 28 GHz band, 29.6dB. The standard value is less than 10.

5.5 Results of MIMO Antenna

5.5.1 Return Loss Plot

The return loss, or S11 parameter, is the most fundamental metric for evaluating an antenna's efficiency. Return loss gives information about how much power an antenna reflects. The bandwidth and operating frequency of an antenna can be rapidly determined by plotting the S11 parameter against frequency. The higher the performance of an antenna, the lower the S11 value should be. MIMO antennas have a return loss of 28 dB at 28 GHz, according to a plot of the data. When using a 28 GHz MIMO antenna, it is possible to determine that the bandwidth at -10 dB is roughly 6.75 GHz. The preceding analysis demonstrates that the proposed MIMO antenna has a low return loss value, making it an effective option for the 28 GHz frequency region.

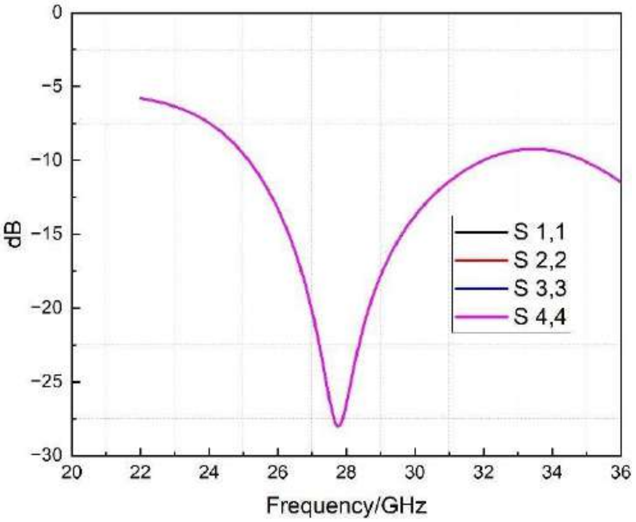


Figure 5.7: Return Loss Plot of MIMO Antenna

5.5.2 Envelope Correlation Coefficient

The Envelope Correlation Coefficient shows how independent two antennas' radiation patterns are. If one antenna is horizontally polarized and the other is vertically polarized, their correlation is zero. If one antenna merely radiated energy to the sky and the other to the earth, both would have an ECC of 0. Envelope Correlation Coefficient considers the antennas' radiation pattern form, polarization, and relative field phase. A correlation below 0.3-0.4 is "well enough" for MIMO. Our MIMO antenna's ECC value ranges from 0.0026 to 0.025, meeting the standards. This makes the MIMO antenna efficient.

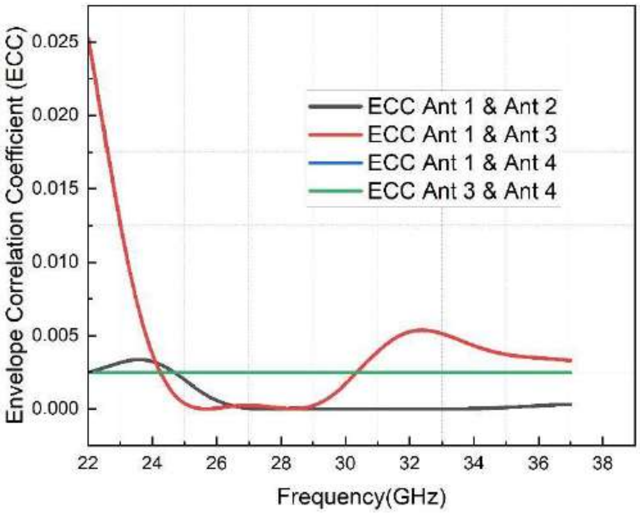


Figure 5.8: ECC Plot of MIMO Antenna

5.5.3 Diversity Gain

The diversity gain is the improvement in performance over the absence of diversity, measured by the improvement in signal-to-interference ratio achieved by a given diversity scheme or the amount by which transmission power can be decreased without degrading performance. In MIMO systems, the antenna is employed to achieve reception diversity. Because the worst ECC value of the suggested MIMO is used to compute the diversity gain (DG), we find that it is greater than 9.9 dB, indicating a significant decrease in transmission power thanks to the diversity scheme. This proves the suggested MIMO has a high diversity performance, making it ideal for high-speed data transmission. As you can see, the diversity gain for all the antennas in the below MIMO systems is very high, sitting at between 9.997 and.9.998.

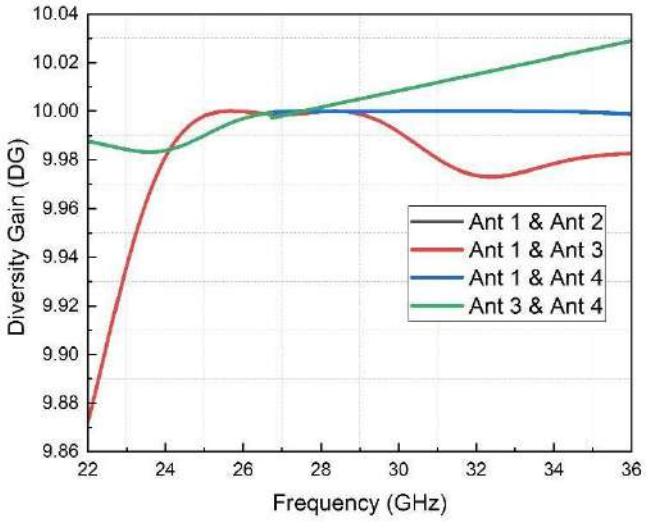


Figure 5.9: Diversity Gain of MIMO Antenna

5.6 Results of a MIMO Antenna

TABLE 5.3: FINAL RESULTS OF MIMO ANTENNA SIMULATION

Parameters	**MIMO Antenna Result**	**Standard**
Resonant Frequency	28 GHz	As per need
Bandwidth	6.74 GHz	As per need
Return loss (S_{11})	28 dB	less than -10 dB
VSWR	1.082	1 - 2
Gain	5.76 dB	6-9 dB
Directivity	6.08 dBi	5-8 dBi
Antenna Efficiency	92 %	70%
Radiation Efficiency	92 %	70%

In Table 5.4, Full simulation results were displayed in tabular form after simulation of the array antenna. This antenna shows good loss of return throughout the entire 28 GHz band. MIMO antanna achieves a gain of 5.76 dB at 28 GHz. Throughout the entire band, this antenna's antenna efficiency and radiation efficiency both reach 92%.

5.7 Results of 1×4 Antenna Array

5.7.1 Return Loss Plot

The configured 1x4 array antenna return loss plot is given below. Now the frequency of resonance is 28 GHz. The constructed 1x4 array antenna's return loss value at 28.9 GHz is also 35.55 dB which indicating excellent impedance matching.

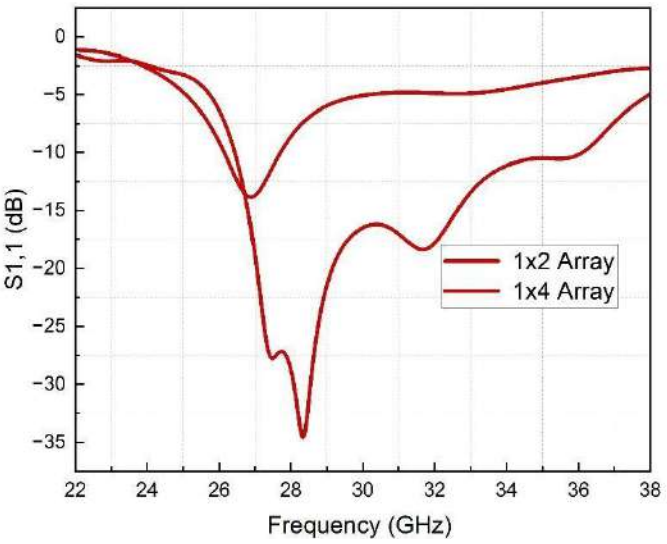


Figure 5.10: Return Loss Plot of 1x4 Array Antenna

The graph above can also be used to determine the bandwidth of a 1x4 array antenna. The 28.3 GHz band, as declared by the FCC [1], is covered by the bandwidth of 34.53 dB in this instance.

5.7.2 Voltage Standing Wave Ratio (VSWR)

The VSWR chart for the built-in array antenna is displayed above. The single component antenna's VSWR value ranges from normative 1 to 1.5, which is within the normative mark.

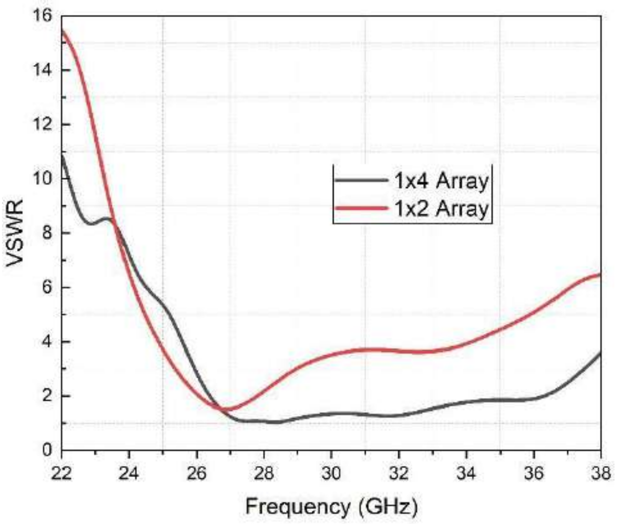


Figure 5.11: VSWR Plot of 1x4 Array Antenna

Based on the VSWR and the loss graphs As can be seen from the image above, the antenna operates effectively on the desired band and converts more than 90% of electrical current into electromagnetic waves.

5.7.3 2D Radiation Pattern

Radiation pattern, as used in the field of antenna design, describes the spatial relationship between radio wave frequency and transmission strength. With a good radiation pattern and a constrained beam diameter for the antenna being built, a 2D array antenna radiation pattern. The array antenna's directivity, which was obtained at 137.0 degrees, is 10 dBi, and the microstrip patch antenna's radiation pattern is half circular. Additionally, it is displayed at 90 and 270 degrees from the vertical. Indicating that the antenna's radiation pattern is typical, both plots are nearly circular.

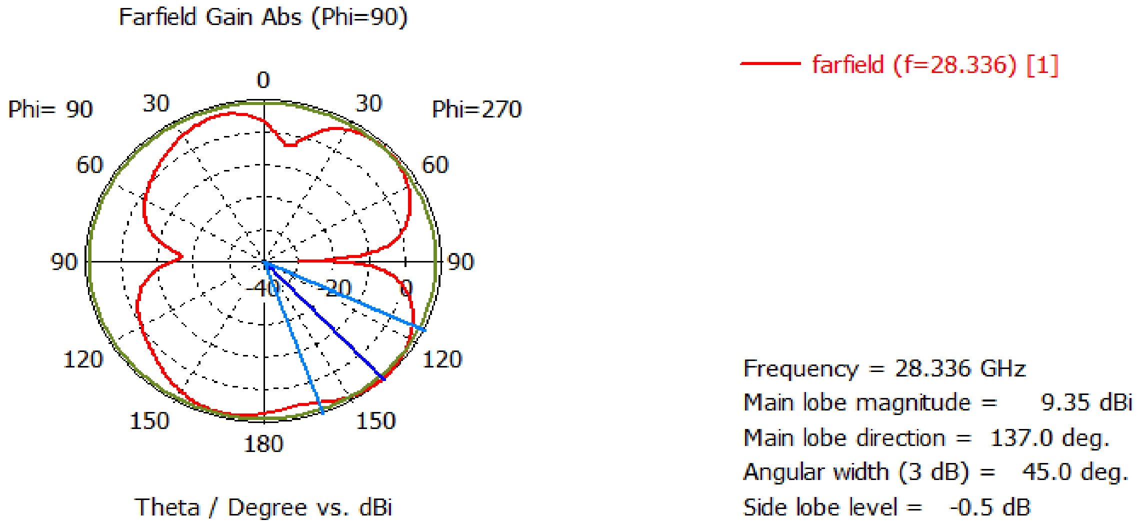


Figure 5.12: 2D Radiation Pattern of 1x4 Array Antenna at 28GHz

5.7.4 3D Radiation Pattern

A 3D view of an antenna's energy radiation in the surrounding space is called a 3D radiation pattern. Typically, this pattern is measured far enough away from the far-field antenna. If you only position it in relation to an isotropic antenna, it is the energy radiating in that direction (a theoretical antenna radiating equally in all directions). A healthy antenna should hold its 3D radiation pattern throughout the operation's frequency range, just like it does for the 2D radiation pattern.

It is very simple to see the energy that the 3D radiation pattern is supplying in a specific direction. Below is a radiation pattern for a 3D 1x4 array antenna at 28 GHz. Since the array antenna's gain was 9.32 dBi, it can be said that it satisfies the 5G gain requirement.

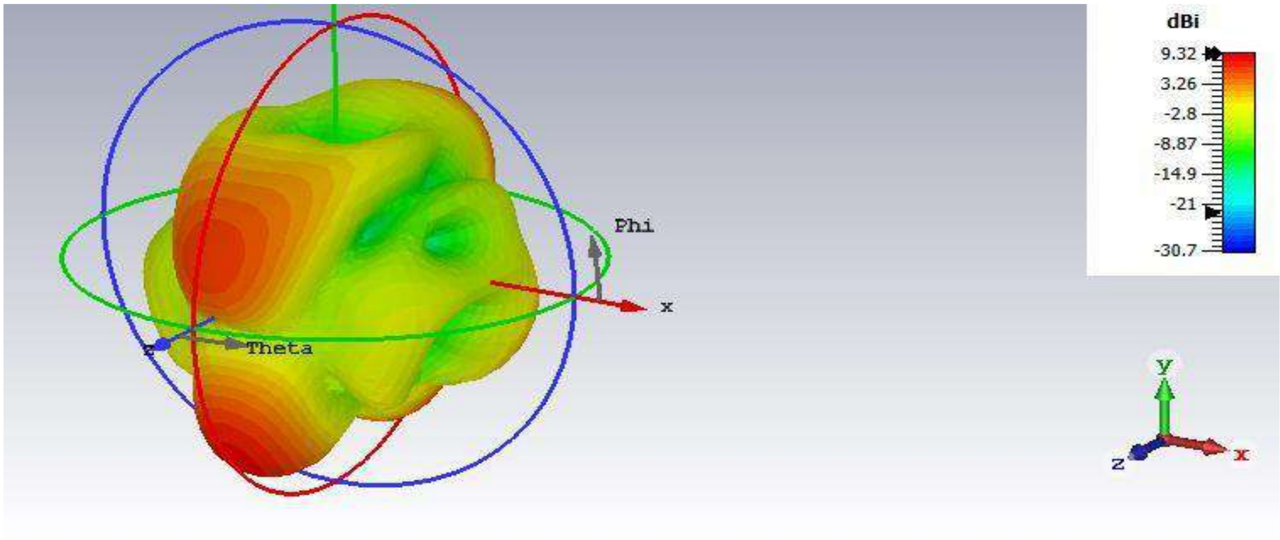


Figure 5.13: 3D Radiation Pattern of 1×4 array antenna at 28.3 GHz

5.7.5 Antenna Efficiency

The antenna's effectiveness is characterized as the relationship between the effective aperture area and its actual physical area. The efficiency diagram for the 1x4 array antenna is shown below. This determines the radio frequency (RF) proportion of electricity that actually reaches the area of physical aperture. The 4-array antenna met the antenna efficiency standards. Figure 5.11 indicates an antenna output of 94% at 28.3 GHz.

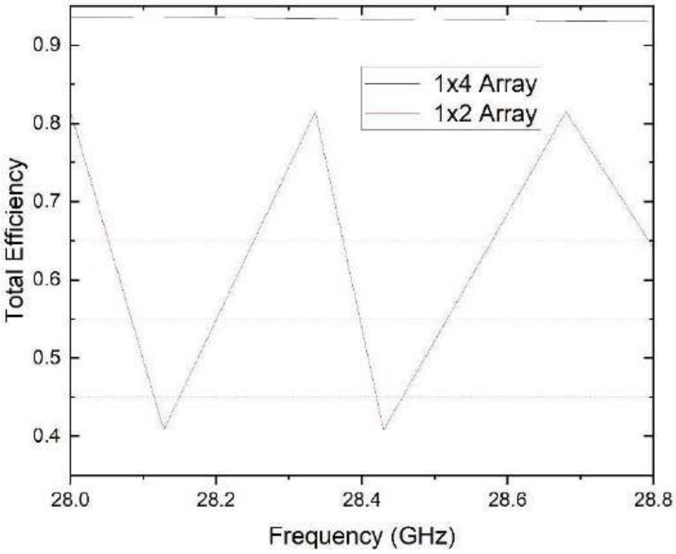


Figure 5.14: Antenna Efficiency of 1x4 Array Antenna

5.7.6 Radiation Efficiency

The radiation intensity standard was met by the 1x4 array antenna. Below figure 5.12 indicates that the efficiency of radiation is 95% at 28 GHz.

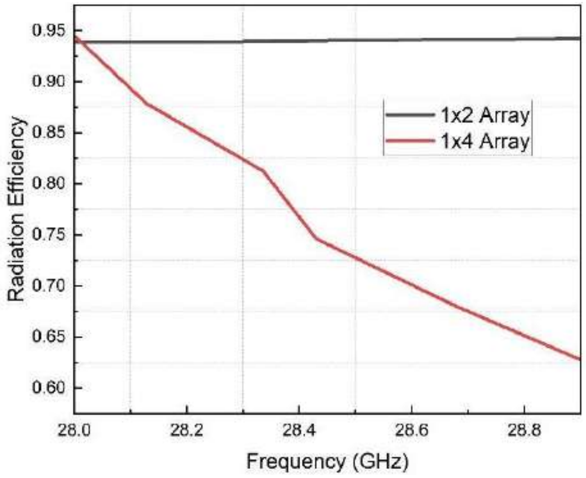


Figure 5.15: Radiation Efficiency of 1x4 Array Antenna

According to the FCC, this antenna displays excellent return loss across the entire 28 GHz band. The antenna's VSWR is under 1.5 in contrast. The 4-array antenna gain seems to be quite high compared to recent array models. At 28.3 GHz, the 1x4 array antenna achieves a gain of 9.32 dBi. The antenna's position, which is approximately 9.32 dBi, indicates a good directional output. This single component antenna's antenna efficiency and radiation effectiveness are greater than 93% over the entire operating band.

TABLE 5.4: FINAL RESULTS OF THE ARRAY ANTENNA'S SIMULATION

Parameters	**1x4 Array Antenna Value**	**1x2 Array Antenna Value**	**Standard [10]**
Resonant Frequency	28.3 GHz	26.88 GHz	As per need
Bandwidth	9.526 GHz	1.5 GHz	As per need
Return loss (S_{11})	34.53 dB	13.84 dB	less than -10 dB
VSWR	1.038	1.510	2 - 1
Gain	9.32 dBi	7 dBi	6-9dBi
Directivity	9.59 dBi	7.2 dBi	5-8dBi

Antenna Efficiency	94%	90%	70%
Radiation Efficiency	93%	89%	70%

In Table 5.3, Full simulation results were displayed in tabular form after simulation of the array antenna. This antenna shows good loss of return throughout the entire 28 GHz band. Array antenna achieves a high gain of 9.32 dBi at 28 GHz. The array antenna's directivity is approximately 9.52 dBi, which suggests good directional efficiency. Throughout the entire band, this array antenna's antenna efficiency and radiation efficiency both reach 94%.

5.8 Comparison with the existing Array Antennas at 28 GHz

A number of studies compare the performance of the proposed array antenna with recently developed array antennas in the table below.

TABLE 5.5: COMPARISON WITH THE EXISTING ARRAY ANTENNAS AT 28 GHz BAND

Antenna ref.	**Year**	**Resonance Frequency GHz**	**Return Loss (dB)**	**Gain (dBi)**	**Bandwidth (GHz)**	**Efficiency**
[46]	2021	28,38	18,20	7.1,7.9	1,1.2	85%
[24]	2020	27,39	26,30	5,5.7	0.6	98.6%
[50]	2018	28	29	12.15	9.871	85%
[27]	2017	29.5	14	7.404	4.13	-
[26]	2017	28.10, 28.0, 27.18, 26.9	30.28, 36.5,28.8, 51	5.05, 6.2, 7.45, 9.25	60, 200, 1010, 1270 MHz	-
[25]	2018	28,38	31.616, -31.064	7.18 & 10	4.127,3.152	85%
[49]	2018	28	22	9	1.3	85%
Proposed	**2022**	**28**	**34.5**	**9.32**	**9.526**	**94%**

In table 5.4 we compered the results of array antenna with our proposed antenna, it is clear that the proposed array antenna is better compared with the existing antenna. The purpose was to design array antenna with a high gain & efficiency. The antenna efficiency is 94% with a high gain 9.32(dBi), and this array antenna shows good loss of return throughout the entire 28 GHz band, 34.5. The standard value is less than 10.

Chapter 6

Conclusion

The findings of this study demonstrate that a wideband, high gain 1x4 Microstrip patch antenna (MPA) array is designed to operate at 28 GHz utilizing CST Microwave Studio. The 1x4 array is created and is intended to generate high gain using various spacing between array pieces. Results from single-element antennas and array antennas are compared to the most recent models from research that are similar to them.

6.1 Achievements

In this thesis work, a high gain 1x4 microstrip patch antenna array with 50 probe feeds is successfully designed. The suggested antenna has a return loss of less than -10 dB and works in the 28 GHz range. The standard is maintained between 1 and 2 by the simulated antenna's VSWR, which is less than 1.5 throughout the whole frequency band. According to the Federal Communications Commission (FCC), the antenna bandwidth is around 9.5 GHz, which covers the whole 28 GHz spectrum [1]. Antenna gain is more than 6 to 9 dBi, which is superior in terms of size than the current antennas discovered in the literature review. High-gain antennas are available in several current models. On the other hand, some of them are large enough to be integrated into mobile phones while some of them do not span the complete FCC frequency band. Therefore, the proposed antenna array is a strong candidate to be used as a communication device in 5G mobile phones in the future.

6.2 Limitations

The ability to change the direction of the beam would make this antenna better for use with a mobile phone, but microstrip patch antennas don't have that capacity. This is because microstrip patch antennas are not directive antennas, which means they don't focus radio waves in one direction. Instead, radio waves come out of microstrip patch antennas in all directions. So, you can't change the direction of the beam of a microstrip patch antenna.

6.3 Future Work Field

The antenna coverage angle can be increased by adding beam steering capability. In spite of the fact that mmwave communication systems have been successfully implemented in enclosed spaces, there are several obstacles to overcome when deploying mmwave-based mobile communication networks in the open. which require further investigation.

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