BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATIONS ENGINEERING (ETE)

A Compact and Efficient mmWave Microstrip Patch Antenna for 5G Communication

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December 2022

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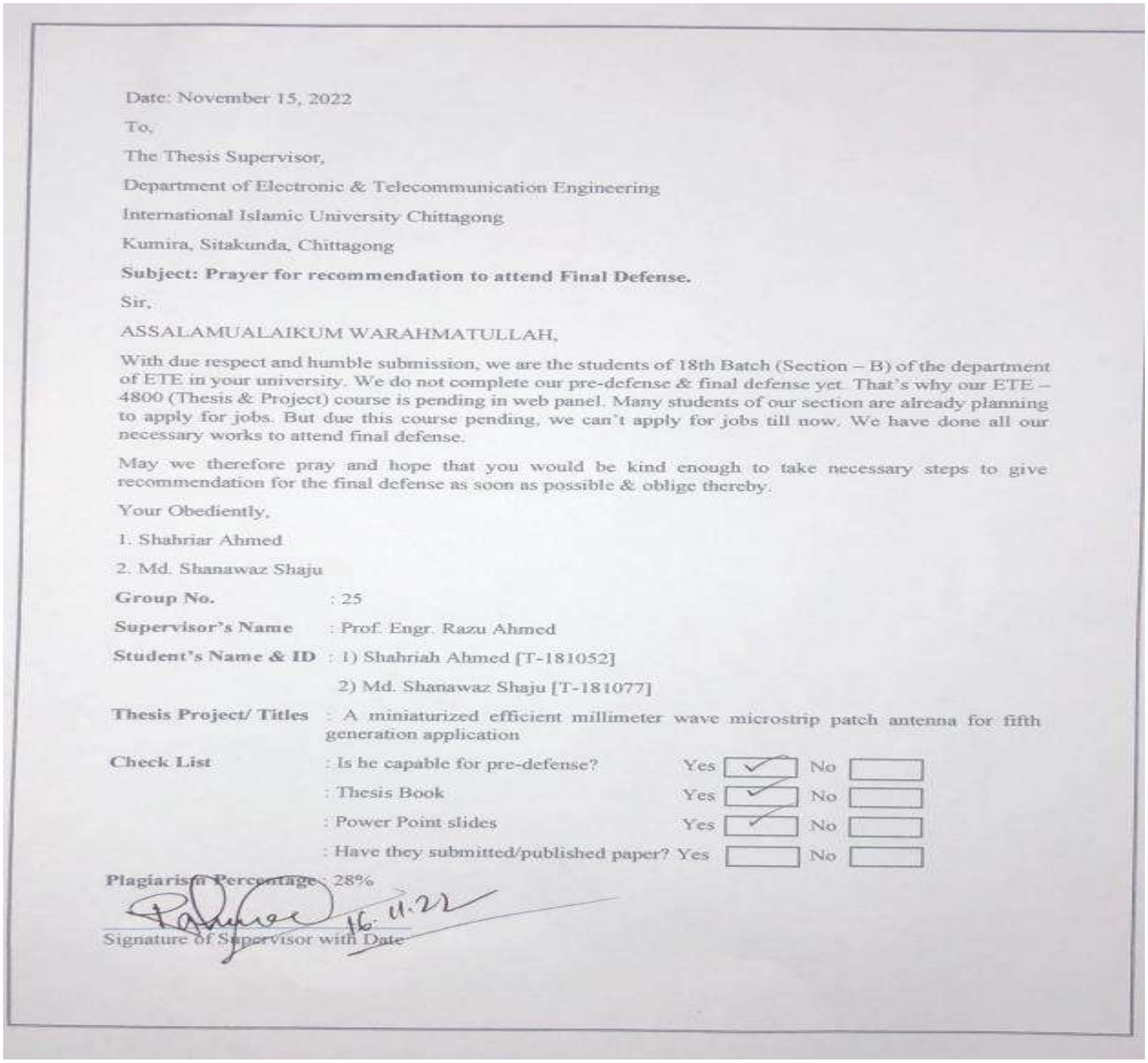
PROOF OF AUTHORIZATION



Date: November 15, 2022

To,

The Thesis Supervisor,

Department of Electronic & Telecommunication Engineering

International Islamic University Chittagong

Kumira, Sitakunda, Chittagong

Subject: Prayer for recommendation to attend Final Defense.

Sir,

ASSALAMUALAIKUM WARAHMATULLAH,

With due respect and humble submission, we are the students of 18th Batch (Section – B) of the department of ETE in your university. We do not complete our pre-defense & final defense yet. That's why our ETE – 4800 (Thesis & Project) course is pending in web panel. Many students of our section are already planning to apply for jobs. But due this course pending, we can't apply for jobs till now. We have done all our necessary works to attend final defense.

May we therefore pray and hope that you would be kind enough to take necessary steps to give recommendation for the final defense as soon as possible & oblige thereby.

Your Obediently,

1. Shahriar Ahmed

2. Md. Shanawaz Shaju

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Thesis Project/ Titles : A miniaturized efficient millimeter wave microstrip patch antenna for fifth generation application

Check List

: Is he capable for pre-defense?	Yes	✓	No	
: Thesis Book	Yes	✓	No	
: Power Point slides	Yes	✓	No	
: Have they submitted/published paper?	Yes		No	

Plagiarism Percentage : 28%

16.11.22

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DECLARATION BY CANDIDATES

We now confirm that the book serving as our thesis is entirely the product of our own effort. The thesis book has been submitted to the ETE IIUC department's thesis committee for the purpose of obtaining a B.Sc. in engineering degree. The proposition's outcome is entirely dependent on our own efforts. The work on this thesis was supervised by **Prof. Engr. Md. Razu Ahmed**, an associate professor of (ETE) and the department's chairman of (CCE) at the International Islamic University in Chittagong.

Shahriar Ahmed

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Acknowledgements

First and foremost, we would want to express our gratitude to Allah (SWT) for giving us the capacity and chance to complete this report on "A miniaturized efficient millimeter wave microstrip patch antenna for fifth generation application" and other related activities.

Any form of thesis involves collaboration from a lot of people to be completed successfully. In addition, we received assistance from a variety of sources to prepare this thesis report. We are making a small effort right now to express our sincere gratitude to those kind persons.

In particular, **Mr. Prof. Engr. Md. Razu Ahmed**, Professor & Chairman, Department of CCE. This thesis would have been a modest success without his considerate guiding and sound advice. His supervision and direction were vital in shaping this thesis to be completed flawlessly at every stage.

We thank **Mr. Engr. Syed Zahidur Rashid,** Chairman of the Electronics and Telecommunication Engineering Department at IIUC, for his timely recommendations and provision of the best departmental equipment.

Also **Mr. Engr. Abdul Gafur,** the convener of the thesis committee, is also appreciated for his commitment and effort. We are also very appreciative of our entire faculty, who have offered us nonstop help and support in every aspect.

We also appreciate the help we received from our friends in compiling the complete report. We are most appreciative of our parents' love, prayers, care, and sacrifices in raising us and educating us for the future. Our family, close friends, and well-wishers who consciously and unconsciously pray for us have our sincere gratitude.

Abstract

Several well-known advantages of microstrip patch antennas are their low profile, affordability, light weight, simplicity of manufacture, and conformance. Microstrip antennas are becoming a common fixture in the field of wireless communication because of their low cost, low profile, and ease of manufacture on circuit boards. The use of high-speed millimeter wave (mm Wave) wireless technology in high-speed and secure data transfer has become commonplace. A millimeter wave microstrip patch antenna and related array are proposed for 5G applications.

The Rogers RT-Rogers 5880 substrate, which has a relative dielectric constant ($\in r$) of 2.2, is used to make the 5G Microstrip patch. The antenna's resonance frequency is 27.38 GHz, it has a 2.4 GHz bandwidth, and a return loss of -58.84 dB. The antenna can be utilized for 5G mobile communication due to its tiny size. The proposed antenna has better gain and directivity, offers excellent VSWR and efficiency, as well as having a reasonable enough bandwidth at the resonance frequency under consideration, according to comparative research that was also carried out. The proposed antenna's efficiency is 90%.

LIST OF SYMBOLS

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

LIST OF ABBREVIATIONS

RT	Rogers 5880
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.
SDR	Software Define Ratios
GSM	Global System for Mobile communication
2D	Two Dimension
3D	Three Dimension
VSWR	Voltage Standing Wave Ratio
WCC	Wireless Communication Center
IE3D	Moment of Method of EM Simulator
HFSS	High Frequency Structure Simulator
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	Advanced Mobile Telephone System
FDMA	Frequency Division Multiple Access
TDMA	Time Division Multiple Access

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CHAPTER 1

Introduction

1.1 Evolution of Wireless Communication

The rapid growth of wireless systems and radio telecommunication systems has raised the demand for antenna designs with superior characteristics, such as antenna size, bandwidth, gain, power loss, traffic demand, and high data rate. Several designs have been created in order to balance design, high gain, low loss, antenna size, high bandwidth, 70%+ radiation efficiency, low cost, and high data rate.

High data speeds, wide bandwidth, and high capacities will all be included in the Fifth Generation (5G), which will be five times as powerful as the Fourth Generation (4G). The millimeter wave radio frequency has the potential to create the essential framework for the New Generation (5G). Millimeter waves can utilize the untapped spectrum to satisfy the requirements of the new generation (3GHz-300GHz). The evolution of communication is now one generation to fifth generation.

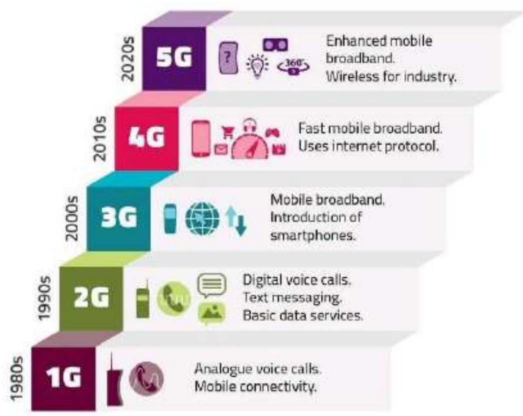

Figure 1 Evolution/Enhancement of communication

1.2 Zero Generation Wireless Technology (0G)

Zero pre-cell phone Before the invention of cell phones, some people used mobile telephony equipment like radio telephones in their cars. Only voice was available for communication. The majority of the time, these mobile phones were mounted in cars or trucks.

1.3 First Generation Wireless Technology (1G)

The first generation of mobile networks were introduced to Japan by NTT (Nippon Telephone and Telegraph Corporation) in Tokyo in 1979. Since the 1980s, it has gained popularity in the US, Finland, the UK, and Europe. This system, which used analog transmissions, had many flaws because of technological limitations.

1.4 Second Generation Wireless Technology (2G)

Finland became the first country to implement the GSM (Global System for Mobile Communication) standard in 1990. This system uses digital voice technology with FDMA implementation and TDMA with an increased speed of about 64 kbps, known as 2G. The system then employs 144 kbps data rates for GPRS, CDMA, and edge using 2 G to 2.5 G circuit switching and packet switching techniques. [6].

1.5 GPRS (General Packet Radio Service) 2.5G

Between the second generation, which served as its predecessor, and the third generation, which served as its successor, a mobile wireless standard known as "2.5G," which stands for "second and half generation," was developed. The term "second and half generation" is used to describe the "General Packet Radio Services." The maximum data rate that may be achieved through the use of GPRS runs anywhere from 56 to 115 kilobits per second. It offers internet capabilities such as email and access to the World Wide Web (WWW), as well as other internet protocols such as Wireless Application Protocol (WAP) and Access Multimedia Messaging Services (AMMS). GPRS often bills for data transmission in megabytes of traffic transported, whereas conventional circuit switching bills for data communication in minutes of connection time. [6]

1.6 Third Generation Wireless Technology (3G)

With an increase in transmission speed from 144 kbps to 2 mbps, 3G offers packet switching

technology. Online gaming, voice over IP (VOIP), video conferencing, video calling, access to global roaming, mobile television, and other services are all made better and more convenient by 3G technology. The 3G technology uses a wide band voice channel to provide a rapid connection. A faster Internet download service is available with 3.5G. The third generation can now assess every nation (3G). With the launch of UMTS, or Universal Mobile

Terrestrial/Telecommunication Systems, third generation mobile communication began. For the first time on mobile devices, video calling is supported by UMTS, which has a data rate of 384 kbps. Smart phones gained worldwide traction after the 3G mobile communication system was introduced. Applications specifically designed for smartphones have been created to handle social media, video calling, games, healthcare, and multimedia chat.

1.7 3.5 G to 3.75 System

Two more technological advancements are added to the network in order to increase the data rate on the current 3G networks. The 3G networks have been equipped with HSDPA, or high-speed downlink packet access, and HSUPA, or high-speed uplink packet access. The 3.5G network can support data rates of up to 2mbps. A more advanced 3G network with HSPA+ High Speed Packet Access plus is the 3.75 system. Later, this technology will develop into the more potent LTE 3.9G system (Long Term Evolution).

1.8 Fourth Generation Wireless Technology (4G)

Mobile broadband is continuously used everywhere with a new implementation. 4G communication (LTE) technology is used to deliver services. The IEEE developed 4G technologies, which offer a greater data rate and are capable of handling more sophisticated multimedia services. In 4th generation systems, LTE and LTE Advanced wireless technology are used. Additionally, it is compatible with earlier versions, facilitating LTE and LTE Advanced network setup and upgrade with the LTE system, voice and data may be transmitted simultaneously, greatly enhancing the data rate. Transmission over

IP packets is possible for all services, including phone services. Uplink and downlink Carriers' capacity is multiplied via carrier aggregation and complicated modulation methods.

1.9 Fifth Generation Wireless Technology (5G)

The 5G network makes use of cutting-edge technologies to offer users incredibly fast internet and multimedia experiences. Future LTE Advanced networks will be upgraded to become 5G networks. The fifth generation, or 5G, of wireless technology standards is anticipated to debut in the year 2020. 5G aims to streamline wireless networking by improving bandwidth, transfer speeds, and latency for a billion devices. One of the most contentious issues in IT, it seeks to democratize emerging technologies like autonomous vehicles, virtual reality (VR), and the Internet of Things (IoT). Companies in the telecommunications industry and regulatory bodies like as 3GPP, WiMAX, and the International Telecommunication Union (ITU-R) have not yet completed the technical details of 5G or produced any official paperwork to that effect.

5G is regarded as the peak of wireless communication technologies for mobile devices. Wired connectivity is practically obsolete today. Cell phones now perform a wide range of other tasks in addition to communication. The ease of sharing data and phones was made possible by prior wireless technologies, but the fifth generation of wireless technologies is taking things to a new level and making life truly mobile.

1.10 Features of 5G [1]

- Connections of 1-10Gbps to field end points provide a very big network capability.
- Data latency will be significantly reduced by 1 ms.
- 1000x bandwidth for every square inch.
- 10 to 100 times more connected devices.
- 99.999 percent availability.
- Increased data rates.
- There will be faster and more secure connectivity and 90% reduction in system energy consumption.
- Ultra-fast mobile internet up to 10Gbps.
- Additionally, subscriber supervision capabilities for quick action are provided by 5G technology.

A new 5G technological revolution is set to start because it will give conventional computers and laptops a severe competition, which will have an impact on their market value. From 1G, 2G, 3G, and 4G through 5G, there have been numerous advancements in the telecommunications industry. The market offers the new, upcoming 5G technology at reasonable prices, with higher peak futures and greater reliability than its predecessors.

Table 1 **Generation of Communications**

Generation	Starts from	Data capacity	Technology	Stander	Multiplexing	Switching	Service	Main network	Hand off	frequency
1G	1970 -84	2kbps	Analog wireless	AMPS	FDMA	Circuit	Voice only	PSTN	Horizontal	800-900 MHz
2G	1990 – 2000	10kbps	Digital wireless	CDMA TDMA GSM	TDMA CDMA	Circuit packet	Voice data	PSTN	Horiz l	850-1900 MHz (GSM)
2.5G	2001 - 2004	200Kbps	GPRS	Supported TDMA/ GSM	TDMA CDMA	Packet switch	MMS internet	GSM TDMA	850-1900 MHz	2.5G
3G	2004 – 2005	384Kbps	Broad band /IP technology FDD TDD	CDMA/ WCDMA/ UMTS/CDMA2000	CDMA	Packet& circuit	High speed voice/data/video	Packet network	Horizontal	1.6-2.5GHz
3.5G	2006 - 2010	2Mbps	GSM/ 3GPP	HSDPA/ HSUPA	CDMA	Packet	High speed voice/data/video	GSM TDMA	Horizontal	1.6-2.5GHz
4G	2010 - 2019	200Mbps -to- 1Gbps	LTE Wi MAX	IP-broadband LAN/WAN/PAN	MC-CDMA OFAM	Packet	Internet	Horizontal & Vertical	2-8GHz	4G
5G	2020	Higher then 1Gbps	IP v6	IP-broadband LAN/WAN/ PAN&www	CDMA	All packet	Dynamic Information access, wearable devices with AI capabilities	Internet	Horizontal& vertical	

1.11 Update on 5G spectrum globally

These bands have been designated or chosen as targets throughout the world.

Figure 2 worldwide 5G spectrum [10-12]

1.12 To enable 5G, The FCC is leading important spectrum measure

This includes mmWave in the low-band, mid-band, and high-band.

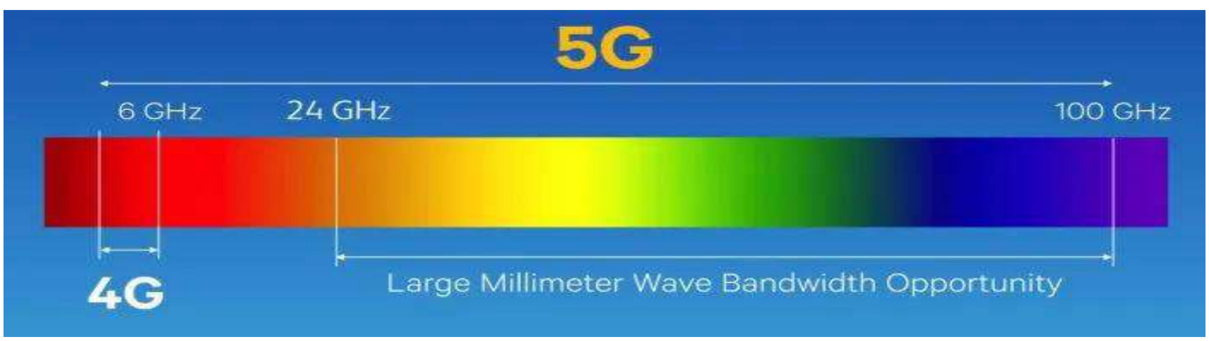

Figure 3 The 5G Spectrum [10-12]

1.13 Low- Band

Any bandwidth below 1GHz is referred to as low-band spectrum. Low band transmits at frequencies that were once utilized for analogue television broadcasts (600MHz) and early wireless networks (800MHz), offering extensive coverage over great distances with just one tower.

- Following the assignment phase, an auction for a section of the 600 MHz spectrum was successful and brought in $19.8 billion.
- 14 MHz of unlicensed spectrum and 70 MHz of licensed spectrum with 2 distinct channels each.
- Timing of spectrum availability is compatible with 5G. [10-12]

1.14 Mid- Band

As we go 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.

- Setting up the existing PAL1 and GAA2 systems to share three layers of spectrum at 3.5 GHz on 150 MHz.
- In order to make PAL guidelines suitable for 5G, the FCC developed them in 2017.
- The CBRS Alliance was established to support an LTE-based ecosystem.
- FCC alerted of inquiries on 3.7-4.2 GHz and 5.9-7.1 GHz. [10-12]

1.15 High- Band

High band millimeter wave, located at the top of the spectrum diagram, refers to frequencies over 6GHz. With peak speeds now estimated at 1-3Gbps, it provides extremely quick speeds.

- Opening up in various millimeter Wave bands around about 11 GHz.
- Unlicensed or shared music is used by 70% of recently released bands.
- Always in agreement. FCC sought observation on additional candidate spectrum with IMT-2020 branding.
- Take into consideration including 24.25-24.45, 24.75-25.25, and 42-42.5 GHz. [10-12]

1.16 Spectrum Frontiers is in charge of 5G millimeter Wave bands

The shared and unlicensed airwaves are crucial for increasing bandwidths.

Licensed Spectrum

1. Anywhere from 27.5 to 28.35 GHz
2. From 37.6 to 38.6 GHz
3. From 38.6 to 40 GHz

Unlicensed and shared spectrum

1. 37.6-37.9 GHz
2. 64-71 GHz [10-12]

1.17 5G Spectrum in Europe

Country	Frequency Band	Frequency	Auction Status

Finland	n78	3.41 - 3.8 GHz	Auctioned (October 2018)
	n258	25.1 - 27.5 GHz	Auctioned (June 2020)
France	n78	3.4 - 3.8 GHz	Auctioned (September 2020)
	n257	26.5 - 27.5 GHz	Upcoming
Germany	n1	1920 - 1980 MHz (Uplink) 2110 - 2170 (Downlink)	Auctioned (August 2019)
	n78	3.4 - 3.7 GHz	Auctioned (August 2019)
	n78	3.4 - 3.8 GHz	Upcoming (Planned)
	n258	24.25 - 27.5 GHz	Upcoming (Planned)
Ireland	n78	3.4 - 3.8 GHz	Auctioned (May 2017)
	n258	26 GHz	Upcoming
Italy	n78	3.6 - 3.8 GHz	Auctioned (October 2018)
	n258	26.5 - 27.5 GHz	Auctioned (October 2018)
	-	700 MHz	Auctioned (October 2018)
Russia	n40	2.3 - 2.4 GHz	Upcoming
	n41	2.57 - 2.62 GHz	Upcoming
	n79	4.4 - 4.99 GHz	Upcoming

	n248	24.25 - 27.5 GHz	Upcoming (Planned)
	-	694 - 790 MHz	Upcoming (Planned)
Spain	n78	3.4 - 3.6 GHz	Auctioned (July 2018)
	n78	3.6 - 3.8 GHz	Upcoming (Planned)
	-	700 MHz	Upcoming (Planned
	n258	26 GHz	Upcoming (Planned
United Kingdom	n78	3.4 - 3.6 GHz	Auctioned (April 2018)
	n78	3.6 - 3.8 GHz	Upcoming (In 2020)
	n258	24.25 - 27.5 GHz	Upcoming (Planned)

1.18 Antenna Basics

Antennas are more than just basic hardware that connects to every radio. They are the transducers that transform a transmitter's voltage into a radio signal. Additionally, they extract radio signals from the air and transform them into voltages that may be recovered by a receiver.

Antennas are frequently overlooked and added at the very end of a design, despite their importance in establishing and sustaining a dependable radio link. Most engineers, especially EEs working with wireless applications for the first time, may find them to be mysterious and complex, not to mention that they come in an apparently limitless range of sizes and designs. A quick recap of the essentials, though, can relieve any design concerns.

1.19 Millimeter-Wave Antenna

Planning for the future was integrated into the evolution of mobile communication toward 5. For communication, picking a suitable band with low loss is essential.5G communication works best with high frequency millimeter waves, which are classified as extremely high frequencies. Millimeter-wave antennas are projected to be compact, conformal, and low-profile. The 5G communication frequency is definitely the Ka (26.5 to 40 GHz) spectrum.

1.20 Frequency

Frequency is measured by how many times something happens during a given period. Differentiating between spatial and temporal frequency is accomplished by using the phrase "temporal frequency," while normal and angular frequencies are distinguished by the terms "normal frequency" and "angular frequency," respectively. A frequency measured in hertz is equal to one "event" every second (Hz). The period is the inverse of the frequency since it quantifies the time required for a single occurrence to occur again. Taking the average heart rate of 120 beats per minute (2 hertz), the interval (or "period") T between each beat would be 0.5 seconds (60 seconds divided by 120 beats). Periodic phenomena include oscillatory and mechanical vibrations, sound transmissions, radio waves, and light, and their frequency is a crucial characteristic for describing the rate of change across time in the sciences and engineering.

1.21 Bandwidth

Outside of this range, the antenna's impedance is not a good fit for the transmission line and transmitter. An antenna's effective frequency range or bandwidth can be extraordinarily wide (as in the case of a log-periodic antenna) or extremely narrow (as in the case of a small loop antenna) (or receiver). An antenna's radiation pattern changes when it is operated outside of its intended frequency, which lowers its directional gain.

1.22 Input Impedance

Input impedance is a measure of how well an antenna accepts a signal at its terminals, and it is based on the voltage-to-current ratio. The input impedance is affected by the length and size of the antenna. The antenna's Rohmic ohmic losses and Rrad radiation resistance are accounted for in the real part of impedance Z, whereas environmental energy is accounted for in the reactive part. [11].

1.23 Impedance Matching

It is vital to match the input impedance of the antenna to 50 in order to ensure that the antenna receives the most power from the RF circuity with the least amount of reflection. Voltage standing wave ratio (VSWR), a measurement, tells how well the antenna impedance is matched to the connected Tx line impedance.

The ideal range is below 1.5. A low, flat SWR enables the transmission line to transfer its maximum amount of electricity. The reflection coefficient, which is how SWR is stated, is the power reflected from the antenna. is a function of load impedance and characteristic impedance (ZO) (ZL).

The need Matching:

A device that operates effectively in a few select limited frequency bands is said to be resonant. Resonant objects called antennas produce a better output due to their matching impedance.

- If the impedance of the feedline and the source are equal, the power from the source will be efficiently transmitted to the feedline.
- If the impedances of the feedline and antenna are compatible, the feedline's power will be effectively delivered to the antenna.
- The input impedance of the receiver amplifier circuit and the output impedance of the receiver antenna must match.

- The input impedance for a transmitter antenna should match the output impedance of the transmitter amplifier and the impedance of the transmission line. [2].

1.24 Directivity and Gain

Directivity refers to an antenna's capacity to emit energy in a certain direction when transmitting or to more effectively receive energy coming from a specific direction when receiving. Antenna gain is a measurement of the directivity and efficiency of an antenna. The difference between the radiation intensity in the direction of maximum intensity and the intensity that would be obtained if the antenna were to emit its power in an isotropic way is what is meant by this term. The former parameter considers the antenna efficiency, which is how the antenna gain differs from the directivity in comparison to a 100-watt spotlight, a 100-watt incandescent bulb will produce less light in some directions while creating lighter in others. Headlight light is thought to be more "directional" than bulb light. An accurate antenna can be compared to a headlamp.

Gain is a useful directivity indicator. Mathematically, gain is calculated by multiplying directivity by efficiency. An additional parameter (π) known as antenna efficiency is introduced by the link between gain and directivity. [12].

1.25 Radiation Pattern

An antenna's energy output is graphically represented by its radiation pattern. Diagrammatic radiation patterns depict the directional dispersal of energy in space. The radiation pattern is a three-dimensional figure and is expressed in spherical coordinates (r,,), presuming its origin is at the center of the spherical coordinate system.

An omnidirectional radiation pattern in three dimensions. This clearly illustrates the three coordinates (x, y, z). Radiation is designed in three dimensions, yet it might be challenging to see the radiation design in three dimensions in an interesting way. A two-dimensional pattern can be made by dividing a three-dimensional design into horizontal and vertical planes. The resulting patterns are, respectively, a vertical pattern and a horizontal pattern. These design estimates are available in both rectangular and polar shapes.

1.26 Voltage Standing Wave Ratio (VSWR)

The efficiency with which radio-frequency power is delivered across a transmission line from a power source to a load is measured by the voltage standing wave ratio (VSWR) (for example, from a power amplifier through a transmission line, to an antenna).

The VSWR of an antenna is always a precise, positive value. The amount of energy received by the antenna increases with the transmission line's alignment and VSWR. The base value of the VSWR is 1. Here, the ideal antenna does not reflect any power. Voltage Standing Wave Ratio, also referred to as Standing Wave Ratio, is the acronym for this measurement (SWR). The reflection coefficient, which expresses the power reflected from the antenna, is a function of VSWR. In the event when s11, reflection coefficient, or return loss are used to supply the reflection coefficients.

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

1.27 Return Loss

The return loss of an antenna is a measure of how many radio waves arrive at the antenna input but are rejected as opposed to those that are accepted. In relation to a short circuit, the decibels (dB) are provided (100 percent rejection).

The antenna parameter that is frequently cited in practice is S11. S11 is merely the loss of return in reality (RL). Nothing radiates because the antenna reflects all forces, hence S11=0 dB indicates that. The amount of energy reflected is equal to -7 dB if the antenna is supplied with 3 dB of energy and S11 = -10 dB. If the antenna is supplied with 3 dB of energy and S11 = -10 dB, the quantity of energy reflected is equal to -7 dB. An RL or S11 of 9.5 dB or less corresponds to the allowable upper 2 VSWR. -10 dB for the RL is okay. [11].

1.28 Polarization

It is possible to ascertain the polarization of an antenna by examining the radiated fields it emanates in the distant field. Thus, the terms "Linearly Polarized" or "Right Hand Circularly Polarized Antennas" are widely used to describe antennas.

This simple concept is fundamental to antenna-to-antenna communication. An antenna that is polarized vertically and one that is polarized horizontally cannot interact with one another. According to the reciprocity theorem, antennas act the same way during transmission and reception. Thus, a vertically polarized antenna transmits and receives fields that are vertically polarized. Therefore, if a horizontally polarized antenna tries to communicate with a vertically polarized antenna, there won't be any reception. If the electric field is traced in a direct (CW) direction, it is said to have a right-hand polarization; if it is traced in the opposite direction (clockwise counter), it is said to have a left-hand polarization. This is true for both circularly polarized waves and elliptical waves. Shown in Figure 1.4.

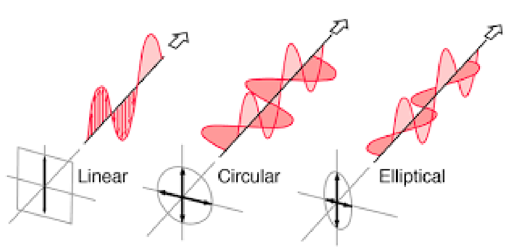

Figure 4 Different types of polarization

1.29 Linear Polarization

The time-harmonic wave is said to be linearly polarized in that region of space if the electrical field vector is always orientated in the same direction. If the electric field vector possesses the qualities listed below:

- Having just one element, or
- Two orthogonal linear components that are either 180 degrees (or multiples of 180 degrees) out of phase or in time phase.

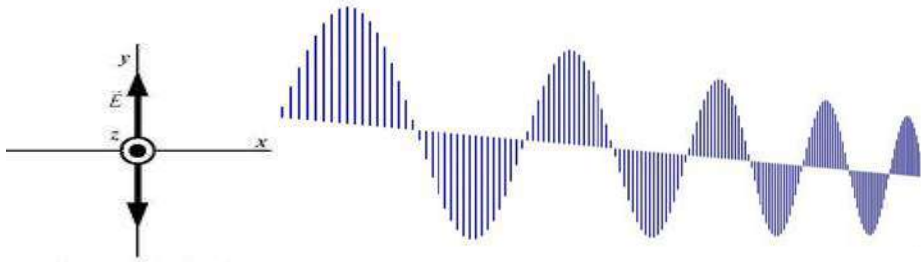

Figure 5 linear polarization

1.30 Circular Polarization

We are referring to the circular polarization of the time-harmonic wave if the electric field vector at a particular location in space follows a circle as a function of time. The requirements for doing this are if the vector of the electrical field has all the following:

- There must be two linear orthogonal elements in the field.
- Both parts must be of the same magnitude.
- The two parts must have an unusual 900 multiple time-phase difference.

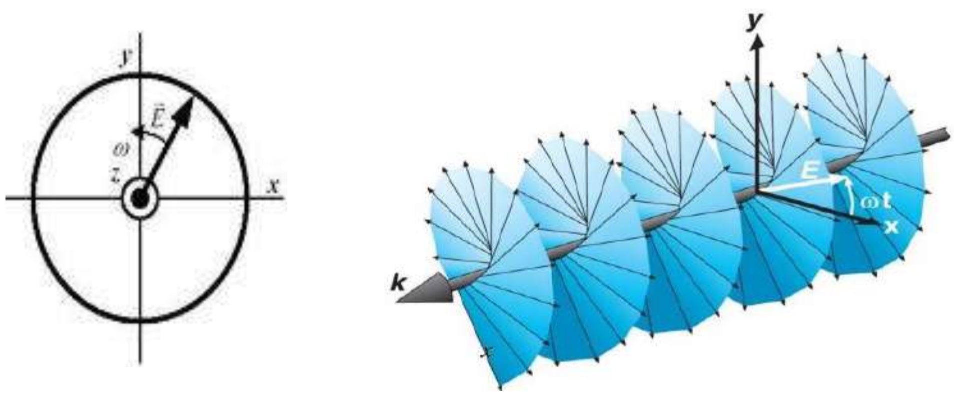

Figure 6 Circular polarization

Circularly polarized light is defined as light that consists of two plane waves with the same amplitude but a 90° phase difference. The electric field vector's peak will appear to move in a circle as it gets closer if you can see it. Right circularly polarized light is defined as having an electrical vector that, when viewed from the source, seems to revolve counterclockwise. Left circularly polarized if clockwise. The electric field vector spins entirely when light reaches a wavelength. In other words, the electrical vector will point in the direction of the fingers if the right thumb points in the direction of light propagation.

1.31 Elliptical Polarization

Any fixed plane passing through this sort of polarization has an ellipse defined by the point of the electric field vector, which is normal to the direction of propagation. Two linearly polarized waves with perpendicular polarization planes can be created when an elliptically polarized wave splits. Due to the electric field's ability to rotate both clockwise and counterclockwise while propagating, elliptically polarized waves exhibit chirality.

If the electric field vector is solely to blame for this, the following conditions must be met:

1. Two orthogonal linear elements must be present in the field, and their magnitudes can be the same or different.
2. The time-phase difference between the two portions shouldn't be between 0 and 180 since otherwise there would be a linear polarization if the two parts are not the same magnitude.
3. The time-phase difference between the two portions shouldn't be odd multiples of 90 because this will be a circular polarization if the two sections have the same magnitude.

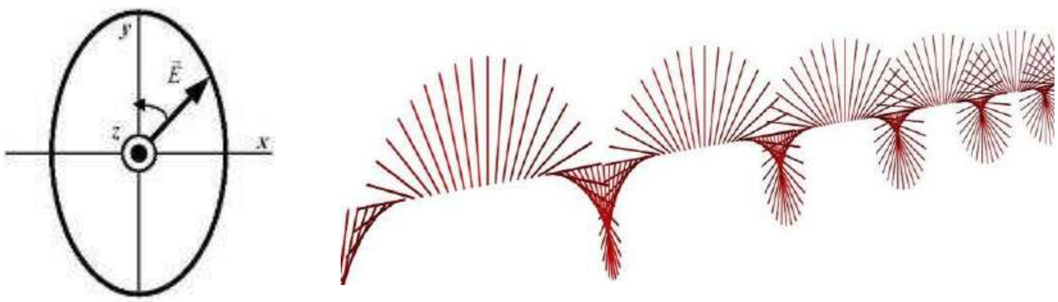

Figure 7 Elliptical polarization

1.32 Microstrip Antenna

Microstrip technology became popular because of its benefits. The technology itself has been widely used in wireless communication systems because of qualities like low profile, conformability, economical fabrication, and ease of integration into feed networks.

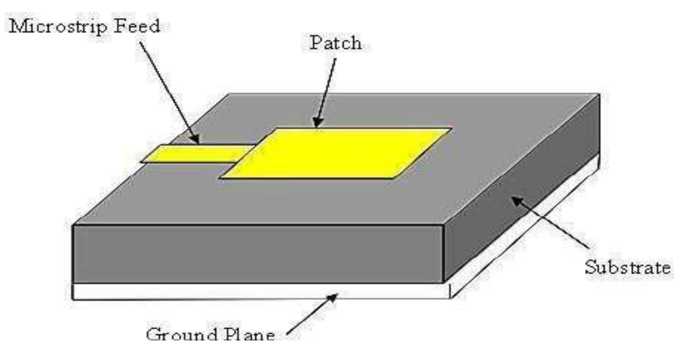

Figure 8 Microstrip Patch Antenna Structure [12]

They are the first kind of microstrip antenna, as Howell put it, where two metal sheets are welded together to form a resonant segment of a microstrip transmission line that is about one-half wavelength long. A microstrip antenna's design depends on the substrate's size, shape, and relative permittivity.

The patch is often square, rectangular, circular, triangular, or another popular shape to facilitate assessment and performance prediction. Given that 0 is the wavelength of empty space, the usual rectangular patch length (L) is 0.3333 0L 0.5 0. Because of this, the patch is made to be quite thin (where the patch thickness is tis). The dielectric substrate typically has a height of 0.003/0.05 0. Usually, the dielectric constant (r) of the substrate ranges from 2.2 to r12. Because of the bordering zones, microstrip patch antennas mostly radiate between the patch edge and the ground plane. A thick dielectric substratum with a low dielectric constant is preferred for antenna performance since it provides better efficiency, more bandwidth, and better radiation.

However, this arrangement results in a higher antenna size. Small Microstrip patch antennas need the use of higher dielectric constants, which are less effective and have a smaller bandwidth. [12].

1.33 Advantages and Disadvantages of Microstrip Patch Antenna

Microstrip patch antennas are being employed in wireless applications more and more frequently due to their low-profile design. They function effectively with portable wireless devices like cell phones and pagers since they feature integrated antennae. The telemetry and communication antennas for missiles must be compact and conformal, and they typically serve as microstrip patch antennae as well. A few advantages of the microstrip antenna are listed below:

Sl. No.	**Advantage**	**Disadvantage**
1	Light weight	Low effectiveness
2	Low profile	Low gain
3	Thin profile	Large ohmic loss in the feed structure of arrays
4	Not necessary cavity backing	little capacity for handling power
5	Circulation and linear polarization	Stimulating surface waves
6	Ability to operate on two and three frequencies	It is difficult to attain polarization purity.
7	It is possible to construct matching networks and feed lines simultaneously.	High performance arrays are required for complex feed structures.

Microstrip patch antennas are equipped with an extremely high-quality factor (Q) antenna. Large antenna-related losses are indicated by a high Q, which results in a narrow effective bandwidth. Q can be decreased by thickening the dielectric substratum. However, a growing portion of the source's total energy gets transformed into a surface wave as the thickness rises. Because the surface wave contribution eventually dissipates at the dielectric bends and weakens the antenna's properties, one could consider it an accidental energy loss. [18].

1.34 Techniques for Microstrip Antenna Feeding

Radiation can be activated by direct or indirect contact using a feedline. The four most common methods of feeding are coaxial probe feed, microstrip line, aperture coupling, and proximity coupling.

1. Microstrip Line Feed.

2. Coaxial/Positron Feed
3. Coupled Aperture Feed
4. Closely Coupled Feeding

1.35 Microstrip Line Feeding

As shown in figure 1.9, when using this style of feed approach, a conducting strip is instantly attached to the edge of the microstrip patch. This type of feed arrangement has the advantage that the feed can be etched on the same substrate to give a planar structure, even though the conducting strip is smaller than the patch.

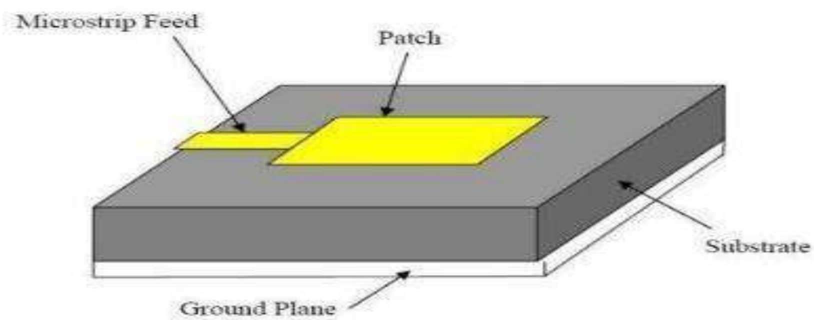

Figure 9 Microstrip Line Feeding [11]

The patch's inset cut is designed to match the impedance of the feed line to the patch without the use of additional matching components. [22]

1.36 Coaxial/Positron Feed

The co-axial feed uses z-coaxial cable to feed the patch in a non-planar manner. The inner conductor of the co-axial connection extends through the dielectric to create a metal contact with the patch, as shown in Figure 4, and the outer conductor of the cable is connected to the ground plane. The probe is placed so that it is directly in touch with the antenna and where the antenna input is 50 ohms. [22]

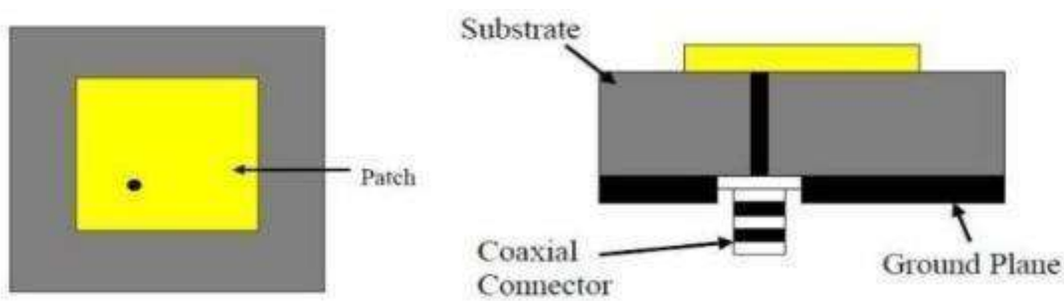

Figure 10 Coaxial / Positron feeding [11]

1.37 Coupled Aperture Feed

The two dielectric substrates employed in the aperture feed technique are the antenna dielectric substrate and the feed dielectric substrate. Both of these dielectric substrates are separated by a ground plane with a slit in the center.[22]

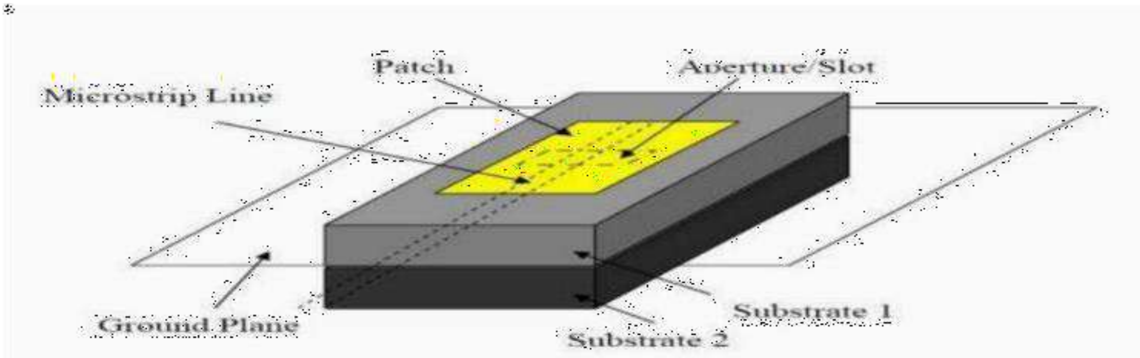

Figure 11 Coupled Aperture Feed [11]

1.38 Closely Couple Feeding

As seen in the image, this form of feed approach involves connecting a conducting strip straight to the edge of the microstrip patch. The patch has a wider width than the conducting strip. With this type of feed arrangement, a planar structure can be provided by etching the feed into the same substrate.

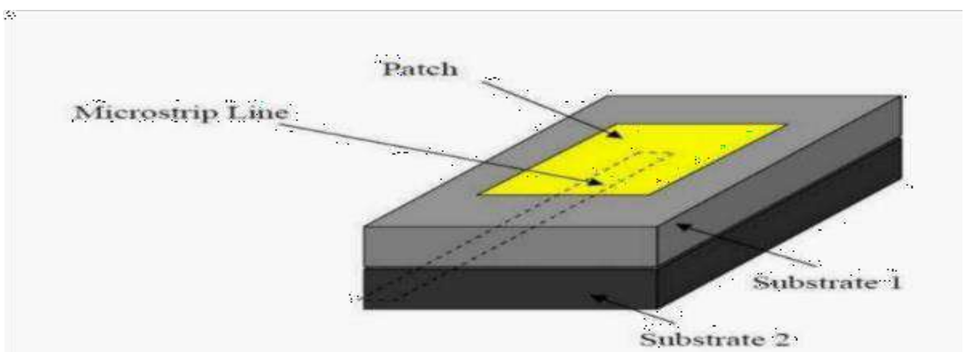

Figure 12 Closely coupled Feeding [11]

1.39 CST Microwave Studio

SIMULIA developed the CST Studio Suite electromagnetic analysis software suite to construct, analyze, and optimize electromagnetic systems. With the help of CST Studio Suite, which combines a number of different solvers into a single user interface, we can simulate the performance of a variety of electromagnetic systems for both low-frequency and high-frequency applications. To assist us in the antenna design and optimization process, CST Studio Suite's tools are simple to use. One of the tools we commonly begin with is Antenna Magus. We have the opportunity to choose detailed design requirements that are broken down by industry and include information like frequency bands and radiation patterns using a tool called Antenna Magus. You can select the most suited method for building and optimizing equipment that operates at a wide variety of frequencies using our user-friendly

3D EM simulation program. You can select the most suited method for building and optimizing equipment that operates at a wide variety of frequencies using our user-friendly 3D EM simulation program.

1.40 Motivation

Wireless communication has grown immensely in popularity since it was first introduced, thanks to its low cost, high efficiency, flexibility, portability, and many other advantages. The need for cellular connectivity, data speeds, and mobile information traffic have quickly increased during the last three decades. The Internet of Things has given these requirements a new dimension (IoT).

The telecommunications sector has created new generations of standards virtually every century to fulfill this expanding need. More than 100 billion mobile devices are expected to have their connectivity demands met quickly by the fifth generation (5G). Internet of Things, latency, and 10 Gbit/s data rates, among other things. early 2020 deployment, High frequency path loss is one of the main obstacles to installing 5G, thus we were motivated to create antennas that can overcome this difficulty.

1.41 Essence

The communications sector is expanding quickly. Almost every ten years, a new generation is added. The previous one that researchers are particularly interested in is 5G. The transition from 4th Generation (4G) to 5th generation (5G) wireless technologies and applications has been fueled by significant growth (5G). After 4G/IMT, 5G is the following cutting-edge wireless communication standard. In comparison to current 4G, 5G will have higher capacity, enabling denser wireless network user populations, supporting extremely dependable devices and massive machine communications, as well as Internet of Things (IoT) connections employing antennas. Unattainable without. 5G compatibility has to be created. Due to their superior features, antennas with microstrip patches are now the most popular type of antenna for wireless communications. The small size of this kind of antenna allows for a terminal that is convenient.

Circuit boards can readily be etched to accommodate microstrip-based antennas. The shapes of microstrip patches include rectangle, square, triangular, and others. simple to etch the low cost of manufacture makes mass production conceivable. It is possible to handle several (dual, triple) frequency bands. They offer dual polarization in both linear and circular modes. It's easy. The current 4G networks employ the sub-6 GHz range for communication. The 5G requirements, however, cannot be supported by the available frequency resources in these bands [1]. As a result, we must switch from 6 to 300 GHz to higher frequency bands. The 3.4-3.6 GHz, 5-6 GHz, 24.25-27.5 GHz, 37-40.5 GHz, and 66-76 GHz bands have been adopted as a consequence for 5G wireless communications [2] and the FCC. For 5G, the frequency is 27.5–28.35 GHz [1]. For 5G communications, high-gain microstrip patch antennas at 28 GHz have been developed through a number of research [4–9].

Many of these antennas do not cover the entire 28 GHz band as required by the FCC, while others do not because they are too wide or massive to function with 5G mobile phones. Others are not. Consequently, it is imperative to develop an antenna that works with 5G cellphones and covers the 28GHz band.

CHAPTER 02

Literature Review

2.1 Paper Analysis

The thesis, "Design and Simulation of a High Gain Microstrip Patch Antenna for 5G Wireless Communication," will be discussed in this part along with other scientists' research that is related to it. The success of the study of the fifth-generation (5G) mobile application utilizing the present antenna depends on this part. in order to create and simulate an antenna with enhanced functionality and a straightforward design.

1. **“Design of Efficient 37 GHz Millimeter Wave Microstrip Patch Antenna for 5G Mobile.”**

An effective patch antenna for 37 GHz is suggested in this work. Investigations of the antenna's performance have been done in terms of return loss, gain, impedance bandwidth, VSWR, and radiation pattern for both the E and H axes. The length and width of these two slots have also been examined and analyzed. At the 37 GHz resonant frequency, the simulation's output displays return loss of 43.05 dB, gain of 8.245 dB, and impedance bandwidth of 16.22%. The suggested microstrip patch antenna is excellent for 5G cellular communications, which are the next generation. [13].

2. “Broadband Microstrip Antenna for 5G Wireless Systems Operating at 28.”

The development of a rectangular microstrip antenna for 5G applications comes in response to the growing need for mobile data and mobile devices. With a reflectance of -22.50 dB, this antenna's resonance frequency is 28.00 GHz. The proposed antenna's radiation efficiency is 80.18%, and its antenna gain at the resonance frequency is 5.06 dB. The results also show that its bandwidth is 5.57 GHz (relative operating band 19.89%), which is a fantastic result and far better than the values recorded. [14].

3. **“Beam Steering Antenna Arrays for 28-GHz Applications.”**

For the 28 GHz band, a beam-steering planar array architecture was created in this work. An antenna with 24 patch panels has four ports and inbuilt impedance transformers. Each port includes beam steering capabilities thanks to the phase changer. The same frequency band is intended for use with a 23-patch antenna array. Applying non-uniform amplitude excitations to the ports will produce better outcomes. In our models, a respectable beam scan can be accomplished with fewer ports and phase shifters. Additionally, by reducing patch array antenna complexity by a factor of two thirds, the cost of execution and manufacturing complexity can be reduced. Applications for the forthcoming 5 G technology might use these two ideas. [15]

4. **“mmWave Novel Multiband Microstrip Patch Antenna Design for 5G Communication.”**

A novel 5G mmWave multiband microstrip patch antenna is presented in this paper. The performance of the 5G mmWave multiband antenna is shown using the reflection coefficient, efficiency, impedance, and E-H field pattern. The constructed antenna resonates at 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. [16].

5. "Design and Implementation of Microstrip Patch Antenna for 5G applications."

This work uses FEKO software, which is more trustworthy than other antenna design software for designing and visualizing high-quality results, particularly 3D radiation patterns, to effectively design and build the suggested microstrip rectangular patch antenna at the resonance frequency of 26 GHz. According to simulation results and a comparison, the proposed Microstrip patch antenna has a better and good return loss of - 33.4 dB, voltage standing wave ratio of 1.04, and a higher antenna radiation efficiency of 99.5%. It also has a higher bandwidth of 3.49 GHz for high quality e-learning or teaching, as well as the ability to download and upload additional 4K/8K ultra-high-definition content and other 5G applications. [17].

6. "Substrate Integrated Gap Waveguide Circularly Polarized Slot Antenna."

This research proposes a substrate integrated gap waveguide (SIGW)-based broadband aperture circularly polarized antenna for 5G millimeter wave applications. The SIGW metal layer is mounted to an inclined object, and the SIGW microstrip transmission line delivers excitation. We shall soon evaluate the mechanism of circularly polarized radiation. The results of the simulation demonstrate that the bandwidth from 24.8 to 31.7 GHz and the bandwidth from 27.3 to 28.8 GHz are bounded by 10 dB and 3 dB, respectively. [18].

7. "A multi-slotted antenna for LTE/5G Sub-6 GHz wireless communication applications."

For LTE and sub-6 GHz 5G applications, a low-profile multi-slotted antenna is designed, manufactured, and measured in this article. The results unambiguously demonstrate that the multi-slotted patch can create a wide operating spectrum of 3.15-5.55 GHz (55.2%), which covers all sub-6 GHz 5G bands as well as Wi-Fi, WLAN, and LTE bands of 22-43. It achieved good gain and efficiency together with the already existing WiMAX, WLAN, and 4G applications and exhibits stable omnidirectional radiation patterns, making it a strong candidate for use in the recently released 5G applications. [19].

8. "Small Form Factor PIFA Antenna Design at 28 GHz for 5G Applications."

This paper details the planning and analysis that went into creating a planar inverted-F antenna that could function at 28 GHz while taking up as little space as possible. This antenna is intended for usage in upcoming 5G mobile applications. The antenna is fed with metal strips, which are also used to shorten it. The primary features of this antenna are that it has a small footprint (0.25 g), a gain of 4.5 dBi, an impedance bandwidth of 10 dB, and an efficiency of 94% in terms of radiation. The total weight of the PIFA antenna is 0.25 grams. The performance of the PIFA antenna is significantly influenced by both the dimensions of the antenna and its location on the ground plane. When positioned in close proximity to an edge or a corner, it emits an excellent radiation pattern. An FR-4 substrate with a density of 0.8 mm is used in the construction of the PIFA antenna. It may be necessary to introduce additional parasite components in order to get the desired increase in bandwidth. [20].

9. "On the Design of Millimeter-Wave Antennas for 5G."

Fifth-generation millimeter-wave antennas are the focus of this research. The first type has a slotted patch antenna that operates between 28 GHz and 38 GHz. Microstrip-fed, circular-polarized antenna. The first configuration can be used as an antenna array for high-frequency signals with a high gain in the millimeter wave band. The second idea uses a small planar inverted-F antenna (PIFA) in conjunction with a dielectric load made up of a single layer of a superstrate to increase gain and bandwidth. The third concept is a T-shaped antenna that can receive millimeter waves. Numerous frequencies are well within the antenna's capabilities (26.5 GHz-40 GHz). PET is used because of its affordable pricing, adaptability, safety for human use, and durability in the natural environment. New mm-wave antennas use two MIMO arrays, each with two antenna elements. The proximity of two MIMO systems results in polarization diversity. The antenna's peak gain is 8.2 dBi at 38.75GHz, and it maintains more than 4 dBi across its full frequency range. At 27.47 GHz and 28.45 GHz, the antenna bandwidth is 97% and 99%, with 88% and 96% efficiency. At 28 and 28.5 GHz, the highest and minimum gains are 8.8 and 8.25 dBi, respectively.

This article discusses designing 5G wireless systems with mm-wave antennas. We'll discuss the antenna's goals and technical specifications. Recent advancements in mm-wave antenna design and design principles have been studied. Recent sources say that four beautiful designs were chosen for the 5G requirements and application. [21].

10. "28GHz Millimeter Wave Rectangular Microstrip-Patch Antenna for 5G Communication."

A millimeter-wave rectangular microstrip patch antenna is described in this paper. the 5G antenna is a 28 GHz rectangular microstrip patch antenna. The antenna is operating at a resonant frequency of 28 GHz with a return loss of -26.40 dB. The primary motivation behind the aforementioned layout was to create an antenna with a gain of 7.4 dB and a bandwidth of 1.102 GHz. The simulated antenna also excels in terms of radiation pattern, return loss, and VSWR. This antenna design may be the best option when a large data transfer rate is essential for 5G connectivity. The final result of the recommended design is more aesthetically beautiful and suitable for 5G connectivity. [22].

11. "A 28 GHz Rectangular Microstrip Patch Antenna for 5G Applications."

With the advent of 5G, this research presents a new rectangular microstrip patch antenna operating at 28 GHz. The increasing need for mobile data and portable devices has led to the suggestion that a rectangular microstrip patch antenna be employed in 5G applications. The antenna has a return loss of -13.48 dB and a resonant frequency of 27.954 GHz. With a gain of 6.63 dB, the suggested antenna has a total radiation efficiency of 70.18%. The results also demonstrate that the suggested antenna is a feasible alternative for 5G mobile communication despite the high bandwidth needs of this technology, with a bandwidth of 847 MHz being obtained, extending on prior experiments that used inputs of 400 MHz and 582 MHz. [23].

12. "USRP-based platform for 26/28 GHz mm Wave Experimentation."

This work provided an experimental mm Wave platform based on the popular USRP SDR to aid in the study of smart spectrum utilization in mm Wave bands. The excessive computational expense associated with conventionally large bandwidths is mitigated by this system. The hardware platform has been combined with a real-time end-to-end PHY implementation that includes beam tracking, enabling the testing of beam-steering algorithms and, by extension, the reuse of space among different users. As a result, we showed that the real-time PHY works as intended with beam tracking, permitting portable data transfer at a rate of 2.9Mbits/s. Numerous extensions are planned as future work. For instance, by installing several USRPs in place of a single one and the 1 to 16 RF switch, we intend to enhance the single-user configuration with a multiple antenna system. [24].

13. "Design Properties of a 26 GHz Circularly Polarized Square Patch Antenna with Rectangular Slot."

A 26 GHz, square patch antenna with a rectangular slot is presented here. The antenna is a 50-ohm edge-fed Ka-band microstrip patch antenna with a rectangular slit for circular polarization. Increasing the slot perimeter helps to better match the patch impedance to the 50 feeds. Extending the slot's perimeter, P, does not exactly decrease AR, hence a design compromise is necessary. A compromise design case with slot length and width of 1.4 mm and 0.20 mm, respectively, may be adopted in future NN array development. [25].

14. "83 GHz Microstrip Patch Antenna for Millimeter Wave Applications."

In this research, an extremely small factor rectangular microstrip patch antenna for mm-Wave (W-band) applications is designed, analyzed, and simulated. The antenna operates at 83 GHz with a return loss of 55.7937 dB. The antenna is constructed from an RT/Duroid5880 substrate, measures 0.149 mm x 2.328 mm on the ground, and has a simplistic layout that makes it easy to manufacture. It is possible to achieve a constant radiation gain of 7.9087 dBi and a fractional bandwidth of 3.76% (S11 -10 dB) between 81.3717 GHz and 84.4912 GHz. [26].

15. "Design a Single Band Microstrip Patch Antenna at 60 GHz Millimeter Wave for 5G Application."

This paper presents a microstrip patch antenna with a single slot for usage in 5G wireless systems. The proposed antenna is simple in construction, cheap, and small in size. The small antenna controls the operation of a single frequency band. By eliminating the H and E slots, the impedance bandwidth was able to expand. The results of this design suggest a frequency of 59.93 GHz at its heart, with a corresponding bandwidth of 57.981 GHz to as high as 62.009 GHz. The recommended microstrip patch antennas for the millimeter wave wireless application have a maximum gain of 5.42 dB. [27].

16. “Multiband Microstrip Patch Antenna Operating at Five Distinct 5G mm-Wave Bands.”

The authors of this study detail the development of a compact multiband microstrip patch antenna that is capable of operating in a wide range of 5G mm-Wave frequencies. Using the multiband antenna, we were able to attain a respectable gain of 6.44882 dBi at 23.2 GHz, 7.1198 dBi at 40.3 GHz, 7.9062 dBi at 59.3 GHz, 8.1804 dBi at 86.9 GHz, and 9.8156 dBi at 104.3 GHz. The suggested antenna has a lower footprint, and its hardware is more powerful and more space-efficient than ever before. All of the planned antennas will operate in the same frequency band, between 22.6 GHz and 110.7 GHz, that is used by 5G wireless communication devices and software. [28].

17. “Parametric Analysis of mm Wave 5G Cellular Antenna.

This study presents a parametric analysis of a 5G mm-wave cellular antenna. This millimeter wave printed array antenna has excellent gain and great directivity between 28 and 30.34 GHz, making it ideal for 5G applications. The printed antenna is designed and simulated with HFSS software. The results from the simulation are satisfactory in terms of antenna gain, efficiency, and S-parameter behavior. The suggested millimeter-wave array antenna is attractive for a number of reasons and can be used in 5G telecommunications systems. [29]

18. “Compact Rectangle Patch Dual Band High Gain Antenna for mm-Wave 5G Applications.

A high-gain, dual-band, compact rectangle patch antenna is presented in this study for use in 5G networks. A simple rectangle patch is used to produce the necessary frequency of 28 GHz. By removing the slot from the patched patch, an extra 37 GHz of bandwidth is made available. At 28 GHz and 37 GHz, significant increases of 6.4 dBi and 5.4 dBi are achieved. The proposed design is one-of-a-kind since it results in a high-gain, simple antenna with a favorable current distribution characteristic and excellent directivity, and it partially or fully accommodates the n261, n260. This antenna can be used for 5G mm-wave applications. [30].

19. “Millimeter Wave Microstrip Patch Antenna for 5G Mobile Communication.

Here, a simple 4-element array and microstrip patch antenna are used to enable 5G wireless communication. The simplest microstrip patch antenna offers dual-band 5G transmission, while an array offers three. The microstrip patch antenna offers 38GHz and 54GHz, while the array offers 38.6GHz, 47.7GHz, and 54GHz; all of these bands are utilized in 5G communication. Microstrip antennas provide a gain of 6.9 dB at 38 GHz and 7.4 dB at 54 GHz. Additionally, when using a 4-element linear array, Gain is 12.2 dB at 38.6 GHz, 11.6 dB at 47.7 GHz, and 12.1 dB at 54 GHz. These results prove that by employing an array, we may get significant Gain. This antenna is well suited for 5G communications thanks to its high levels of radiation efficiency, gain, bandwidth, and directional performance. [31].

20. "A Super High Gain L-Slotted Microstrip Patch Antenna For 5G Mobile Systems Operating at 26 and28 GHz.

The suggested antenna was designed with a single patch in order to achieve simultaneous resonance in the 26 and 28GHz 5G frequency bands. The antenna's greatest gain was remarkable given that it consisted of two symmetric L-slots with a square slot in the center. The 8.63 and 11.26dBi antenna gains at the two resonance frequencies are much higher than the gains achieved in the aforementioned literature survey. The lowest reflection coefficients for the two bands under consideration were found to be -24.14 and -25.45 dB, while the corresponding directivities were 9 and 11.8 dB. [32].

21. "A low Profile Multiband Microstrip Patch Antenna For 5G Mm-Wave Wireless Applications".

Microstrip patch antennas are frequently used because to its low profile, light weight, and inexpensive cost. This paper describes a 5G-compatible multiband patch antenna with a microstrip feed line. HFSS models, designs, and evaluates the antenna. Return loss, VSWR, gain, and bandwidth simulations are verified for millimeter-wave antenna operation. The 8.6 x 9.2 * 0.6 mm3 mm-Wave antenna has a high return loss of 31.5167 dB, 30.3681 dB, 38.7860 dB, 27.9980 dB, and 13.2830 dB at 23.8 GHz, 39.4 GHz, 66.2 GHz, 81.9 GHz, and 93.9 GHz. The specified antenna gains 6.1805, 6.5250, 7.3768, 7.4845, and 7.7006 dBi. The recommended single patch multiband antenna is smaller, more hardware-compact, and performs better overall for mm-Wave 5G applications. [33].

22. "A Two-Element Microstrip Antenna 28/38 GHz for 5G Mobile Applications".

Modern communication systems need antennas with high gain, wide bandwidth, and miniaturized size to maximize efficiency across a wide variety of frequencies. It was shown that a two-element integrated antenna system is possible and will be compatible with future 5G mobile networks. Two antennas that can operate at 28/38 GHz are a part of the integrated design and are situated at the base of the mobile device. The compact two-element antenna spanned the wide frequency bands of (26.961-29.266 GHz) and (36.646-40.297 GHz). The obtained directivity, far-field gain, and efficiency at 28/38 GHz are 7.581 dBi, 7.182 dBi, and 91.24%, and at 9.716 dBi, 9.24 dBi, and 89.63%, respectively. Antenna ports have a mutual coupling of less than -30 dB to one another. Because of their simple design, planar antenna components may be easily combined with others. [34].

23. "A Single-Band 28.5GHz Rectangular Microstrip Patch Antenna for 5G Communications Technology".

In the research, a single-band 28.5GHz rectangular microstrip patch antenna is given as a concept for 5G communications technology. There has been a rapid increase in 5G communication system use, interest, and general acceptance. For the purpose of this research, a rectangular microstrip patch antenna is built to accommodate the higher gain and efficiency standards of impending 5G communication systems. The proposed model improves upon the state-of-the-art in terms of both return loss and efficiency. The 28.5 GHz operating frequency (Ka-band) was used, which is a common spectrum for 5G connection. The suggested model has a return loss of -48.309 dB, gain of 7.425 dB, VSWR of 1.007129, and directivity of 8.141 dBi, with architectural dimensions of 7.885 mm × 8.935 mm * 0.5 mm. [35]

2.2 Summary

There have been a number of reports on the topic of 5G communication using microstrip patch antennas in millimeter wave frequencies like 27 GHz. After a great deal of research, it has become clear that the 26–28 GHz millimeter wave bands are the most promising and major options for 5G wireless communication.

The most challenging aspect of deploying 5 G is the creation of a high-profit antenna that can overcome severe path-loss and is tiny enough to incorporate into a mobile phone efficiently and quickly.

2.3 Objectives

- To improve the antenna efficiency
- To reduce the antenna size
- To improve the gain
- To compare with some existing antennas.

CHAPTER 03

Methodology

3.1 Research Techniques

A technique entails a series of procedures. Methods may refer to the specific techniques utilized in a study, the general approaches used on a certain project, or the standard operating procedures followed by professionals in a particular field. The term "methodology" may be used interchangeably with "techniques" when referring to the study of such processes.

One way to define "methodological" is as a range of approaches, each of which is used to analyze a different type of data. Quantitative and qualitative approaches may be used while conducting studies.

3.2 Research Design

The term "research design" refers to the overall strategy used to answer the study's research questions. The research topic, dependent and independent variables, experimental design, data collecting methods, and statistical analysis plan are all components of a research project's design.

The steps to designing a 5G antenna are as follows:

- Research the transition to 5G;
- Research the antenna requirements for 5G;
- Choose the 5G millimeter wave band;
- Research the literature on microstrip antennas and existing 5G antennas;
- Research the design process for microstrip antennas;
- Research the design process for antennas in CST Microwave studio;
- Calculate the required parameters for

3.3 Pilot Study

A pilot study, pilot project, pilot test, or pilot experiment is conducted prior to launching a full-scale research project to assess feasibility, time, cost, unfavorable occurrences, and enhance the study's design. Preliminary work is done before the actual study begins. Typically, a research project's timeframe dictates the timing of its pilot trials. A pilot study may reduce the number of costly errors made during the first phase of an inquiry, but it can't remove the possibility of systemic errors or surprises altogether.

An advantage of doing a pilot study is that:

- To evaluate the efficacy of research instruments and protocols;
- To classify variables of concern and choose how to functionalize each;
- To test the research process and/or procedure;
- To assess statistical parameters for future studies.

3.4 Software

When it comes to electromagnetic 3D simulation of high frequency components, Microwave Studio's CST MWS is an excellent instrument. CST MWS enables rapid and accurate analysis of HF systems such as filters, couplers, antennas, single- and multi-layer designs, and the effects of SI and EMC.

CST MWS is the go-to solution for cutting-edge R&D labs because of its unparalleled productivity. The very simple CST MWS quickly summarizes the EM behavior of high-frequency systems. [37].

3.5 Design Procedure

In the first stage, using the basic equations for making an MPA (equation-based antenna), a single rectangular microstrip patch antenna (MPA) is designed to function in the 28 GHz range.

2^{nd}, step Hold still while running a simulation of the antenna that just made.

3^{rd}, step Save the findings if they meet the criteria.

4^{th}, step is to maximize the efficiency of the newly created Microstrip patch antenna.

5^{th}, step maintain the framework and test the created antenna using simulation.

6^{th}, step save the data if the antennas pass the test.

7th, step evaluate the outcome in light of already available antennas.

3.6 Antenna Design by Equation

Choosing a dielectric substrate of appropriate density is the first step in designing an antenna (h). In order to increase mechanical and electrical reliability, dielectrics are often used. They help produce displacement current, which results in a time-varying magnetic field, and so minimize the antenna's physical size (by the law of Ampere). Using the Faraday law, a time-varying magnetic field may produce a time-varying electric field, resulting in the spread of an electromagnetic field. By providing a solid base, a substratum may boost an antenna's overall output.

Here are some examples of dielectric substrates and their respective characteristics.

Table 2 Substances are listed

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

For high gain antenna designs, the substrates listed in the table above have very high dielectric constants, resulting in significant loss. Since the purpose of this study is to develop antennas with a high gain, a foam material with a dielectric constant close to 1 was selected for this design. After that, choose the microstrip line and ground material. Copper, silver, or gold are our three choices here. silver's conductivity is superior than that of the other metals. Copper, on the other hand, is harder and less expensive than the other two. copper is the material of choice because of this reason. Equations (1) through (5) have been used [38] to determine the antenna's length and breadth.

width is given by,

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

Where, c = Velocity of Light

$(3\times10^8 ms^{-1})$

Effective dielectric constant is

given by,

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

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,

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

The actual length of the patch is given by,

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

Where,

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

Basic characteristics of a rectangular microstrip patch antenna are computed using the equations above in Table no 3.2.

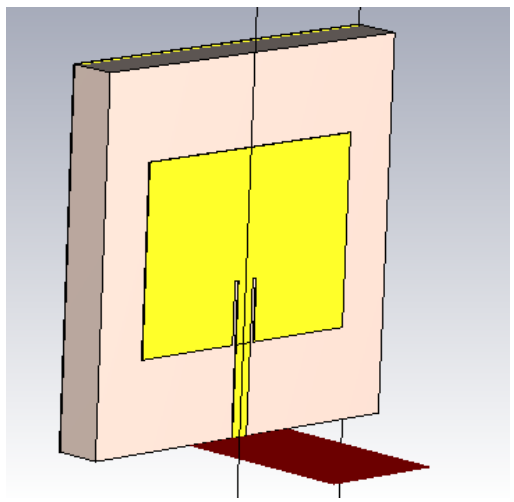

Figure 13 Equation based single element antenna

Table 3 Proposed Antenna Parameters

Parameter	**Value**
Frequency (f_r)	27 GHz
Substrate height, h	0.787 mm
Dielectric Constant, €r	2.2
Patch Length (L)	4
Patch Width (W)	3
Feedline Length (FL)	1.45
Feedline Width (WF)	0.45

3.7 Achieving Results with CST MWS

Using, the antenna's geometric design must be optimized once the approach has been used to build a single-element antenna. The optimizer accepts applications for a wide variety of algorithm types. Trust Region Framework, Genetic Algorithm, and Particle Swarm Optimization are just a few examples. In this investigation, the "Trust Region Framework" method is used because of its superior performance and quick turnaround. Multiple iterations of optimization are performed to get greater antenna gain than is possible with today's single-element antennas.

Table 4 Value of proposed antenna parameters

Parameter	Value
Frequency (f_r)	27 GHz
Substrate thickness (h)	0.787 mm
Dielectric Constant (€r)	2.2 mm
Length (L)	4.24 mm
Width (W)	3.06 mm
Feedline Length (FL)	1.46 mm
Feedline Width (WF)	0.3 mm

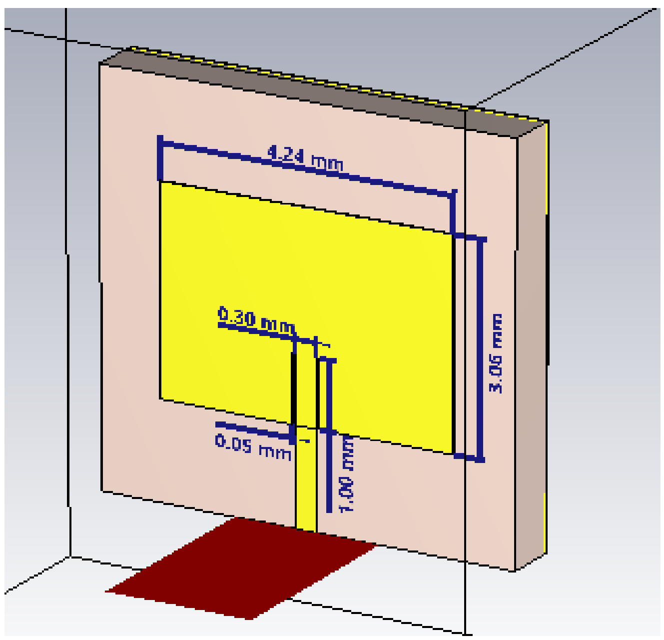

Figure 14 Proposed Microstrip Patch Antenna with dimension

CHAPTER 04

Result Analysis

The results obtained by modelling the final antenna are presented and discussed here.

4.1 Result of Single Element Antenna

4.1.1 Return Loss Graph

Parameter S11, or return loss, is the most fundamental metric for evaluating an antenna's performance. The antenna's return loss information is a measure of the energy that is reflected. The S11 is defined as the return loss of the antenna when S11 is 0 dB, then much of the power is reflected. So, it is crucial to design an antenna for better performance less than -10 dB S11. Then the antenna radiation will propagate perfectly. The operating frequency and antenna bandwidth can be quickly determined using the return loss vs. frequency plot. If S11 is lowered, the antenna will resonate more strongly. The relationship between the S11 parameter and the frequency is seen in figure 15 below. This graph shows that the resonance frequency is 27.38 GHz and the return loss value is approximately 58.83 dB .

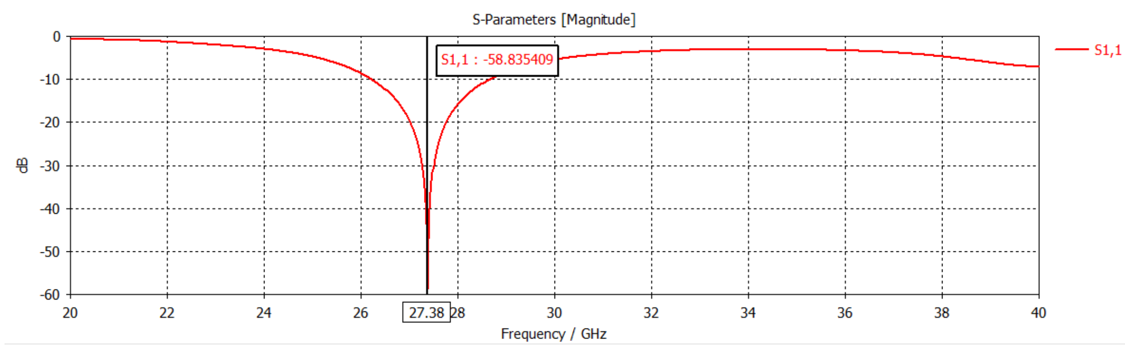

Figure 15 Return Loss Plot of Proposed Antenna

Using the data in the preceding graph, we can determine the bandwidth of the antenna with a single element. The FCC reports that the approximate 10 dB bandwidth in this case is 2.4 GHz, which encompasses the whole 28 GHz spectrum. [1].

4.1.2 An Expression of Voltage Standing Wave Ratio (VSWR)

To further evaluate the antenna's impedance match, the VSWR can be measured. It is a way to quantify the degree to which loads coincide with the transmission line's characteristic impedance. Transmission line impedance mismatch causes standing waves; standing wave ratio (SWR) is the ratio of partial standing wave amplitude to node amplitude. The VSWR is normally set between 1 and 2. The following graph shows that the measured VSWR value is well within the norm for the band of usable frequencies.

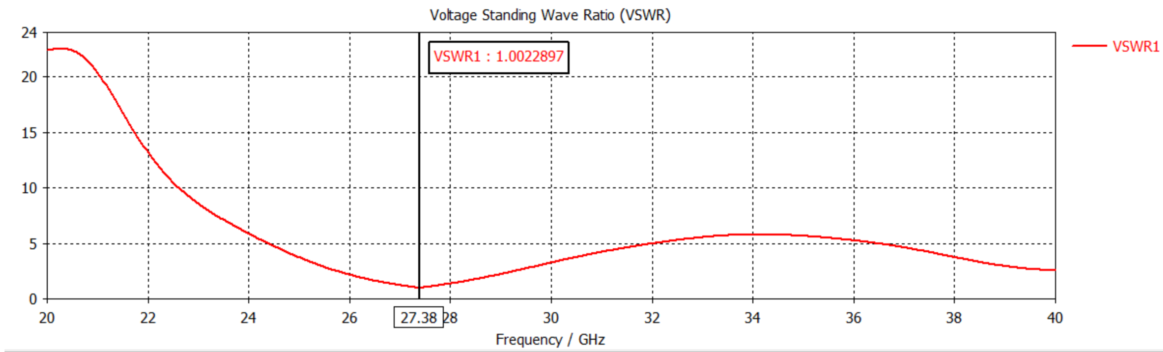

Figure 16 VSWR Plot of Single Element Proposed Antenna

Maximum efficiency is achieved with minimum VSWR by optimizing a single-element antenna, as shown in the figure. The single-element antenna has a very satisfactory VSWR of 1 to 1.5, which is well within the permitted range. If the antenna's S11 value is larger than -10 dB throughout the tested frequencies, we may be confident in the antenna's performance. If the antenna's VSWR is between 1 and 1, as it should be, then it's operating in the correct frequency range. More than 90% of the input power is being turned into useful electromagnetic radiation, as shown by the return loss and VSWR charts up top, while operating within the prescribed frequency range.

4.1.3 2D Radiation Pattern

When discussing antennas, the phrase "radiation pattern" refers to the antenna's radio waves' dependence on direction. The suggested single-element antenna has a good radiation pattern and a compact beam width in two dimensions. We can observe that our radiation pattern is an exact match for the expected half-circular pattern given by a microstrip patch antenna.

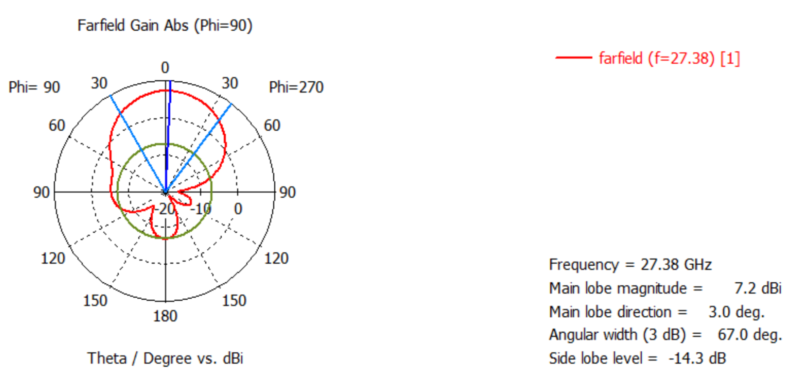

Figure 17 2D Radiation Pattern of Proposed Antenna

4.1.4 3D Radiation Pattern

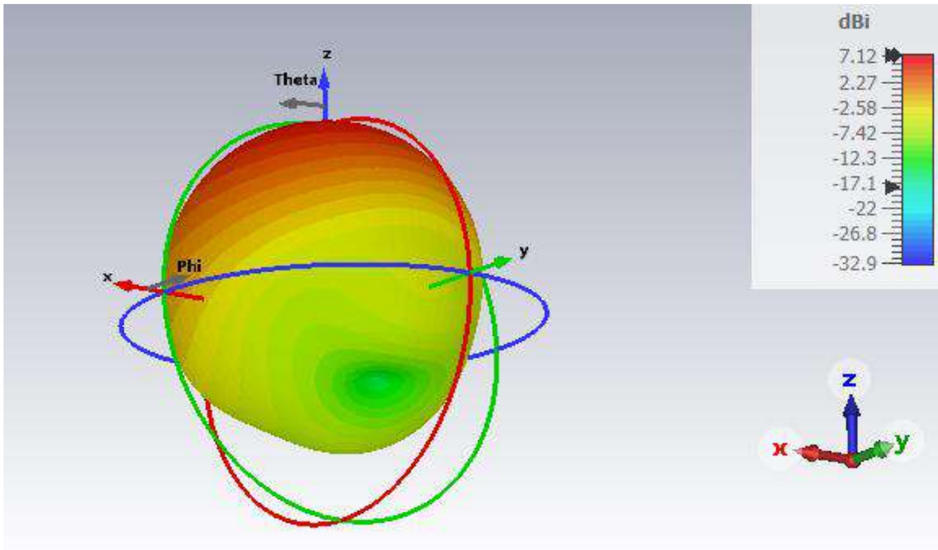

Figure 18 3D Radiation Pattern of Proposed Antenna at 27.38 GHz

The radiation pattern of an antenna is represented in three dimensions in a 3D radiation pattern. Measuring this pattern at a respectable distance from the established farfield antenna is standard practice. The energy that travels away from an isotropic antenna in a certain direction (a theoretical antenna that radiates in all directions equally). A well-functioning antenna's 3D radiation pattern, like its 2D radiation pattern, should be constant across the whole frequency range in which it operates. It is extremely clear how the 3D radiation pattern directs energy. The 3D radiation pattern at 27.38 GHz from an antenna with a single element is shown above.

4.1.5 Antenna Efficiency

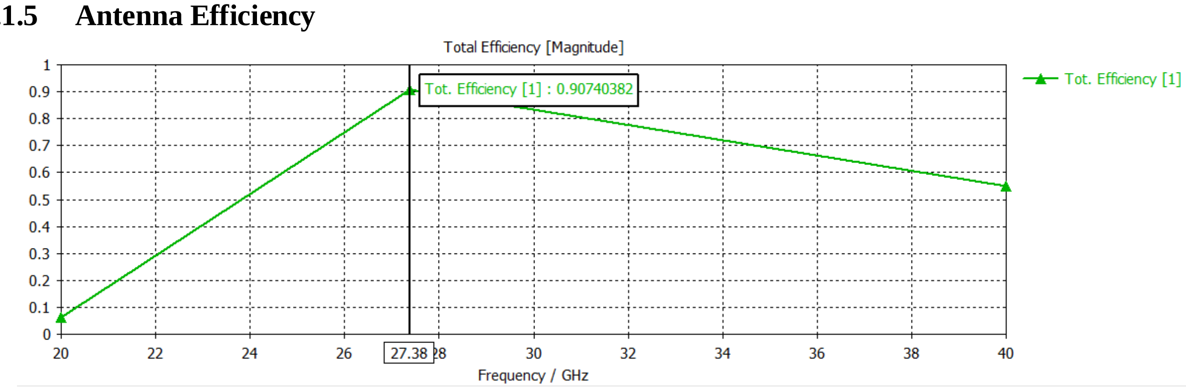

Figure 19 Antenna Efficiency of Proposed Antenna Un-Optimized and Optimized

In order to quantify how efficient an antenna is, we can compare its effective aperture area to its total surface area. It quantifies the amount of RF energy that enters the aperture in its physical form.

The typical antenna efficiency is 70%, which the single-element antenna achieved. At 27.38 GHz, as seen in the preceding figure, the antenna's efficiency is close to 90%.

4.1.6 Radiation Efficiency

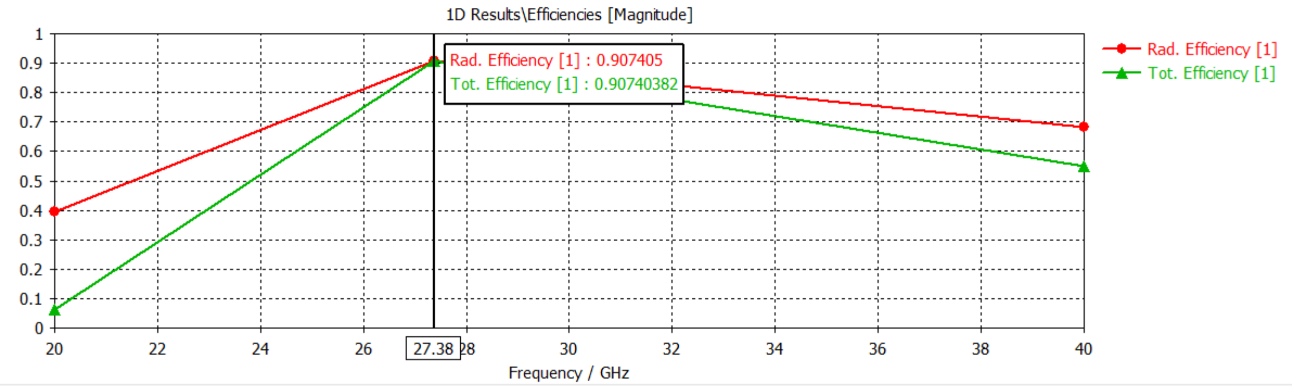

Figure 20 Radiation Efficiency of Proposed Antenna Un-Optimized and Optimized

The efficiency with which an antenna radiates energy into space is measured as a function of the ratio of the electrical power supplied by the feedline to the total power received by the antenna. The standard deviation of the lowest radiation efficiency value is 10%. Radiation is almost 90% effective at 27.38 GHz, as seen in Figure 23.

4.2 Final Design Result of Proposed Antenna

Parameters	Value	Standard [10]
Resonate Frequency	27.38 GHz	As per need
Bandwidth	2.4 GHz	As per need
Return loss (S11)	-58.84 dB	less than -10 dB
VSWR	1	2 - 1
Gain	7.193 dB	6-9dBi
Directivity	7.615 dBi	5-8dBi
Antenna Efficiency	90 %	80%
Radiation Efficiency	90 %	80%

Table 5 Total simulation Result of single element antenna

Table 4.1 displays the aggregate simulation results obtained after optimizing a single element antenna. This antenna has a low return loss across the full 28 GHz range. The antenna has a VSWR of less than 1.5 as well. The gain of the single-element antenna is quite respectable, especially when compared to more modern designs. At 27.38 GHz, a gain of 7.193 dBi is achieved with a single-element antenna. The single element antenna has a directivity of about 7.615 dBi, indicating strong directional performance. This single-element antenna has an antenna efficiency and radiation efficiency both are 90 percent over the entire frequency range.

4.3 Comparison with the existing single element 28 GHz Antennas

Table 6 In comparison to existing single-element antennas

Antenna reference	**year**	**Return loss**	**Gain (dB)**	**bandwidth**	**Efficiency**
[39]	2019	-39.37 dB	6.37	2.4 GHz	87.73%
[40]	2020	-25.44 dB	6.46	4.8 GHz	83%
[41]	2020	-54.49 dB	7.5	1.06 GHz	87%
[42]	2020	-32.86 dB	7.2	1.6 GHz	87%
[43]	2018	-32 dB	8.05	600 MHz	85%
[44]	2018	-16 dB	2.28	1.2 GHz	83.43%
[45]	2018	-18.25 dB	6.72	1.1 GHz	85.5%
[46]	2021	-25.24 dB	6.61	2.3 GHz	79%
Proposed	2022	-58.84 dB	7.193	2.4 GHz	90%

4.4 Size Comparison with the existing single element 28 GHz Antennas

Table 7 Size comparison to existing single-element antennas

Reference	Antenna dimension, mm (Wg × Lg)	Frequency, GHz	Reflection coefficient, S11	Gain, dB
[47]	7 × 7	28	-39.37	6.37
[48]	10 × 10	28	-35.73	5.54
[49]	5.5 × 4.35	28	-42.25	5.61
[50]	19 × 19	28	-24.5	8.03
[51]	39.3 × 30.65	28	-46.1	6.61
Proposed	**4.236 × 3.063**	**27.38**	**-58.84**	**7.193**

4.5 Final Design Result 5G Microstrip-Patch antenna

All results from the Microstrip patch antenna are summarized in Table 5. The FCC has certified that this antenna has a low return loss throughout the whole frequency range of 28 GHz. The antenna also has a VSWR of 1. When compared to other modern designs, the antenna's gain is rather respectable. Extending the bandwidth to 27.38 GHz by 7.193 dB. The antenna's directivity is around 7.615 dBi, demonstrating a high level of directional performance. This single-element antenna's efficiency and radiation efficacy span 90% of the usable band.

CHAPTER 05

Conclusion

The results of this study show that the gain and efficiency of the Patch antenna for microstrip (MPA) designed in CST Microwave Studio are optimized for operation in the 27.38 GHz band. Altering the feedline spacing and then designing the antenna to take advantage of the improved performance is how antenna optimization is accomplished. The antenna results are compared to the most recent models from related studies.

5. Achievements

The research proposed a 5G microstrip patch antenna that is fed by 50 probes. The proposed antenna has a return loss of -58.84 dB at the 27.38 GHz frequency. The calculated antenna has a very small value of the voltage standing wave ratio (VSWR) across its usable frequency range. According to the FCC, the antenna has a bandwidth of about 2.4 GHz, which covers the complete spectrum of 28 GHz [1]. The antenna's gain is greater than 7.193 dBi, making it more potent than any existing antennas uncovered by the aforementioned review of the relevant literature. Newer models incorporate high-gain antennas. Some of them are also too large to be conveniently integrated into mobile phones, while others don't cover the whole frequency range recommended by the FCC. As a result, the suggested antenna array is a promising option for integration into forthcoming 5G mobile devices.

5.1 Limitations

Beam steering, which would make the proposed antenna more suitable for use in mobile phones, is missing from it.

5.2 Future Work Field

Including a beam directing facility in the antenna expands its field of view. As a follow-up to the design and simulation, a physical antenna prototype should be constructed so that its performance may be evaluated and compared to that predicted by the model.

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