BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATIONS ENGINEERING

Design and Simulation of a Q-band Millimeter-wave Microstrip Patch Antenna for 5G Application

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DEDICATION

This thesis is a tribute to the many inspiring professors and kind parents who have prayed for us and encouraged us along the way.

CERTIFICATE OF APPROVAL

The thesis entitled as "Design and Simulation of a Q-band Millimeter-wave Microstrip Patch Antenna for 5G Application" submitted by Mohammad Martuza Newaz Kaykobad bearing ID No: T181069, to the department of Electronics and Telecommunications Engineering (ETE) of International Islamic University Chittagong (IIUC) has been accepted as satisfactory for the fulfillment of the requirements for the Degree of Bachelor in Electronics and Telecommunications Engineering and approved as to its style.

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DECLARATION BY CANDIDATE

It is officially declared that the work that is given in this thesis has not been delivered anywhere else with the purpose of receiving any degree or certificate, and that this thesis doesn't contain any unlawful declarations.

Mohammad Martuza newaz kaykobad

T-181069

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In the name of Allah (SWT), the Most Merciful of the Merciful. All honor and glory belong to Allah (SWT), may He bestow upon us a bounty of opportunities, kindness, and instruction all the way through our lives. In addition, may the peace and blessings of Allah be upon His Prophet Muhammad (PBUH), who has been a wellspring of insight and motivation for us. To our thesis supervisor **Abu Zafar Md. Imran**, we would like to convey our sincere gratitude and obligation, as well as our thanks for the valuable assistance and encouragement he provided over the course of our studies because of his initiative in this area of academic research. We would like to express our gratitude to **Zahidur Rashid**, Chairman of the Electronics and Telecommunications Engineering Department at IIUC, for supplying us with the highest quality department equipment and for giving us fast advice. In addition, we are grateful to **Abdul Gafur**, the Convener of our thesis, for his unwavering commitment and selflessness. We are also extremely thankful to each and every one of our teachers for making the greatest effort to educate us during the whole of our schooling. And we will always be grateful to our parents for the assistance they have given us throughout our lives. In addition, we would like to take this opportunity to thank everyone of our family, friends, and well-wishers who were directly or indirectly engaged in the accomplishment of this thesis work.

Abstract

Several well-known benefits of microstrip patch antennas are their low profile, affordability, simplicity of manufacture, and conformance. Microstrip antennas are becoming a common fixture in the field of radiocommunication statement for the reason that of their poor cost, poor profile, and comfort of manufacture on circuit sheets. However, poor performance is limited bandwidth, low gain, and low capacity handling. Limit their use in specific situations. The fifth generation (5 G) of wireless communication, which will utilize high-frequency bands, will be significantly impacted by route loss. In order to support high-quality online learning and other 5G applications, we created a microstrip patch antenna in this research article. These 5G millimeter wave bands have a resonance frequency of 30 to 50 GHz. We have utilized a rectangular patch with a dielectric loss tangent of 0.0010 and a dielectric constant of 2.2 in the suggested design. Software called CST Studio is used to examine and simulate the design. This design has 7.40dBi gain with a great return loss. The return loss of this design is -52.52dB.

TEXT OF THE CHAPTER

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LIST OF SYMBOLS

Hz	Hertz
KHz	Kilo Hertz
MHz	Megahertz
GHz	GigaHertz
mm	Millimeter
cm	Centimeter
m	Meter
ε	Relative permittivity
L	Length
W	Width

C	Speed of light dB
Decibel λ	Lambda
Ω	Ohm
ε_r	Dielectric Constant

LIST OF ABBREVIATIONS

RT	Duroid 5880
IEEE	Institute of Electrical and Electronic Engineers
LTE	Long Term Evolution
5G	Fifth Generation
1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
FCC	Federal Communication Commission
SDR	Software Define Ratios
GSM	Global System for Mobile communication
3D	Three Dimension
2D VSWR	Two Dimension Voltage Standing Wave Ratio
WCC	Wireless Communication Centre
IE3D	Moment of Method Based EM
CST	Computer Simulator Technology

PCB	Printed Circuit Board
BW	Bandwidth
RL	Return Loss
Q	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
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
GPRS	General Packet Radio Service
MIMO	Multiple Input Multiple Output

Chapter 1

1 INTRODUCTION

1.1 Wireless Communication Evolution

The mobile radiocommunication statement system has progressed over many iterations since the introduction of the first-generation mobile network in the early 1980s. Global need for additional connections drove a rapid advancement in mobile communication standards to accommodate more users [1].

The transfer of data between two or even more unconnected places is known as wireless technology, or simply wireless. The most widely utilized wireless technologies employ radio waves. The term "wireless" has appeared twice in the history of communications, each time with a somewhat different meaning. Up until the different word radio supplanted it in 1920, it was largely used for the initial radio wave transmission and receiving technologies, such as in wireless telegraphy. In the 1980s and 1990s, the phrase was resurrected primarily to describe digital equipment that could connect wirelessly. Long-distance communications are one service that wireless operations offer that wired operations cannot or do not economically or practically deliver [2]. Communication evolution is seen in Figure 1. Let's examine the stages of wireless technology development for mobile communication.

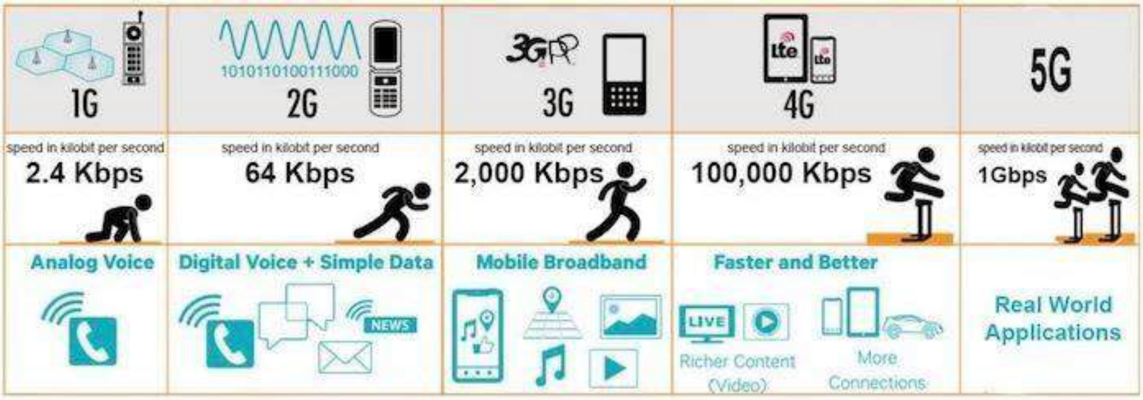

Figure 1 Evolution of Wireless communication [1]

1.2 Zero Generation Wireless Communication (0G)

The term "Zero Generation" (or "0G") describes the period of time before the development of mobile telephony, which includes the radio communicators some of the people used in their sedans before the development of modern-day cell phones. [3].

The very first wireless phone technology is known as 0G or Zero Generation, became available. Mobile carriers put up the calls since there were few viable communication channels at the time. These mobile phones were unable to handle the handover feature, which involves changing the channel frequency while travelling. The term "zero generation" describes the early 1970s pre-cellular mobile system. Before mobile phones were invented, some customers, for instance, carried radio telephones in their vehicles. Modern cellular mobile phone technology was created by the mobile radio telephony system. They are stated to as 0G Systems.

Considering that they were cellular phones from the first generation's forebears.

PTT, MTS, IMTS, and AMTS were among the technologies utilized in 0G systems. These systems are frequently referred to as pre-cellular systems since they were the forerunners of the first generation of cellular handsets. [3].

1.3 First Generation Wireless Communication (1G)

At initially, there was nothing known as 1G. Only the development of 1G Technology made portable radiocommunication statement viable. To all intents and purposes, it was a vocal connection, and 1G wasn't even used until 2G was implemented. In terms of technology, 1G is dated. It belongs to the first wave of mobile network technologies. [3].

Japan's Tokyo metropolis saw the commercial introduction of 1G in 1979 thanks to the NTT DoCoMo company. The majority of people utilized this generation of cellular telecommunications for a very long period. NMT standards, that were constructed on 1G technology, were adopted by a number of Nordic nations in 1981, including Norway, Sweden, Denmark, Finland, Switzerland, Netherlands, Eastern Europe, and Russia. Similar to AMPS, TACS in the UK, and many others, AMPS began to be utilized in North America and Australia.

Other issues with 1G include its low capacity, inconsistent handoff mechanism, and weak voice connectivity. Furthermore, there was no protection because audio communications were replayed in wifi towers, leaving them open to unwanted parties. In the USA, AMPS, which debuted in 1982, was the first 1G standard. For this system, the FCC designated a 40 MHz channel in the 800-900 MHz frequency band. ES, a second 10 MHz of bandwidth, was given to AMPS in 1988. The communication systems used in Italy, France, and the UK were RTMI, RadioComm, and YACS, respectively. West Germany, Portugal, and South Africa all adopted the telecom standard known as C-450. Portable radio set handsets and such machineries as the AMTS, MTS, PTT, and IMTS are among the elements of the First-Generation system, which succeeded the 0G system.

1.3.1 Cons of the 1G system

1G system Disadvantages are given below

- Poor sound quality brought on by interference
- Short battery-operated lifetime
- Large-screen portable devices
- Lessened safekeeping
- Limited cell coverage and a limited user base
- Wandering wasn’t imaginable across comparable arrangements. [1].

1.4 Second Generation Wireless Communication (2G)

The term "second generation wireless telephony technology" (or "2G") refers to telecom network innovations that were introduced in 1991 by Radioing in Finland using the GSM standard [4]. ITU 2G is a collection of mobile communications standards created by the ITU. Voice data is compressed and multiplexed using CODEC techniques in this technology. This technique enables 2G to combine more calls per unit of bandwidth.

There are primarily two technologies that makeup 2G. A few examples of TDMA standards include GSM, which is widely used over the globe, PDC, which is only used in Japan, iDen, which is used in specific regions of the US and Canada, and D-AMPs, which was GSM's forerunner. Due to GSM, the second 2G slice, CDMA, is presently less popular than TDMA. IS-95, often known as CDMA One, is the most popular CDMA technology that is utilized in several regions of Asia and the
Americas [4].

1.5 GPRS (General Packet Radio Service) 2.5G

2.5G emerged as a wireless technology generation in between 2G and 3G. The domain of packet switching was added. This made it possible to submit any inquiry to network stations in the form of compact packets as opposed to a continuous, realtime connection. Since the transmissions were made in the form of tiny packets, battery life was further improved. The inquiry would continue where it left off if the network went down and then came back on, so there would be no need to start from scratch. The "General Packet Radio Services" are discussed to as being "second and half generation." The data rate offered by GPRS ranges from peaking at 56 Kbit/s to peaking at 115 Kbit/s. It supports features including WAP, AMMS, and internet features like email and WWW access. GPRS often bills for data transmission in megabytes of traffic transported, while traditional circuit switching bills for data communication in minutes of connection time. [5].

1.6 Third Generation Wireless Communication (3G)

The third-generation (3G) wireless network technology offers mobile devices highspeed bandwidth (high data transmission rates). Due of the fast data transmission rates, 3G networks will be able to provide multimedia services that combine speech and data. Particularly, 3G wireless networks enable the utmost data transmission speeds listed below:

- 2.05 Mbits per second to fixed devices.
- 384 Kbits/second for devices that move slowly, such a phone carried by a walker.
- 128 Kbits/second for quick diplomacies, including mobile phones in affecting cars.

The 3GPP and 3GPP2 are two specification-setting organizations that support the global 3G goals.

Developed GSM core networks, also known as UMTS, are the focus of 3GPP 3G standards. This covers GPRS, EDGE, and UTRA.

The 3GPP2 specification is calculated for CDMA2000 systems, which are based on CDMA (Code Division Multiple Access).

1.6.1.1 Advantages of Third Generation Wireless Communication Below

are some of the benefits of 3G connection for users:

- The need for new radio spectrum to reduce system congestion.
- Increased security, dependability, and bandwidth.
- Cooperation among service suppliers.
- Data rates that are fixed and changeable.
- Data rates that be asymmetric.

1.6.1.2 Disadvantages of Third Generation Wireless Communication

There are some drawbacks of 3G. They are:

- Base station and cellular infrastructure upgrades to 3G are quite expensive.
- Extremely expensive spectrum licenses, network deployment expenses, users receiving phone subsidies, etc.

1.7 Fourth Generation Wireless Communication (4G)

4G, is the stage of broadband mobile communications that precedes 5G and replaces 3G [6]. A 4G connection, in its simplest basic form, allows mobile devices to join cellular services via an antenna that broadcasts via radio waves. MIMO and OFDM technologies give the 4G network's transmission and reception capabilities. Comparing MIMO and OFDM to 3G, they both provide increased capacity and bandwidth. Compared to TDMA and CDMA, the two main 3G technologies, OFDM operates more quickly. 4G has far less congestion issues than 3G due to MIMO's increased user capacity. In contrast to 3G, which only supports speech over a circuit-switched network and only uses IP for data, 4G is an IP-based specification for both voice and data. In comparison to managing various network technologies for voice and data, managing an all-IP network like 4G is more efficient for mobile network providers. Following are the difficulties that the 4G mobile network is said to have resolved:

According to the fact that phones can send and receive large amounts of data quickly for increased security, 4G communication has added an IP function to mobile phones.

In the case of the fourth-generation wireless technology, users can download at a speed of 100 Mbps for mobile access and 1 Gbps for local mobile network access while stationary.

The hybrid technology used in 3G, which combined CDMA and IS-95, was replaced with a new technology called OFDMA in the 4G network. Compared to TDMA or CDMA in the past, OFDMA is more effective.

Below are several 4G system drawbacks:

1. Expensive hardware and infrastructure
2. Most nations have costly spectrum, and the price of the frequency bands is very high.
3. It is obligatory to have a high-end mobile device that is both expensive and capable of 4G.
4. Upgrades that take a lot of time and have a broad distribution [1].

1.8 Fifth Generation Wireless Communication (5G)

It mainly indicates fifth generation mobile network. This 5G connectivity is the latest current international wireless standardized communication and supersedes all previous generations of cellular connections, including 1G, 2G, 3G, and 4G. With the assistance of 5G, a cutting-edge network that links almost everyone and everything, even machines, objects, and devices—will be possible [7].

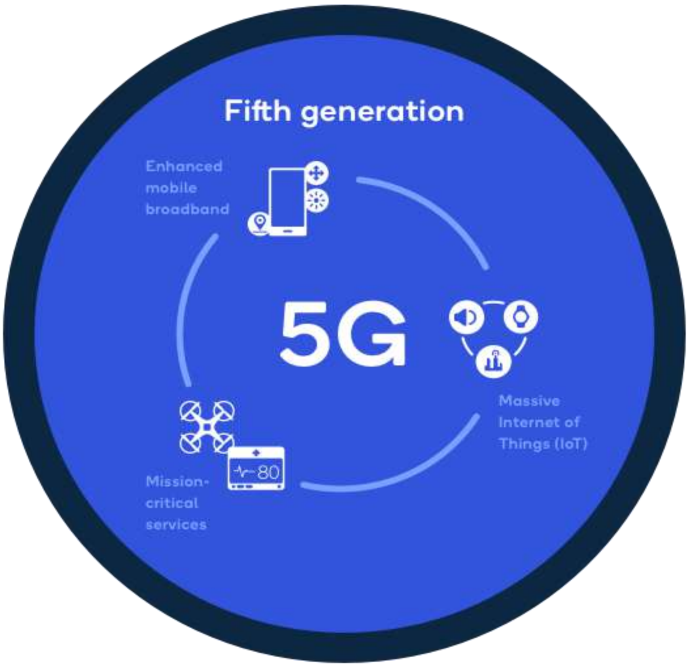

Figure 2 5G communication [7]

The distribution of the fifth generation, or 5G, of wireless technology technologies, is anticipated to begin around 2020. By providing improved bandwidth, fast information handover rates, and decreased delay to a billion electronic devices, 5G will enable wireless networks. This is one of the technological concerns that has received the most attention and promises to make self-driving cars, virtual reality, and the Internet of Things more accessible. A formal standard or formal document for 5G has not yet been finalized by telecommunications companies or regulatory authorities like 3GPP, WiMAX, or ITU-R. In terms of mobile wireless technology, 5G is regarded as the pinnacle of wireless communication technologies. Today, wired connectivity is all but obsolete. Currently, cell phones serve many more functions outside only being a means of communication. While earlier wireless technologies facilitated the ease of phone and information exchange, the fifth generation of wireless technologies is introducing a new level and transforming human existence into a truly portable life.

1.8.1 Structures of 5G

The following is a list of structures of 5G:

- Acquaintances to field close points of 1–10 Gbps.
- 1 ms is the delay.
- Per square foot, 1,000x bandwidth.
- They are 10 and 100 times more connected devices.
- 99.9 % availability
- Coverage of total area.
- 90 percent less system energy consumption [1].

The table below summarizes the current generation wireless communication technologies as well as provides a look back at past wireless systems. These technological advances have a long way to go in the next years, and they will undoubtedly introduce some fantastic and intriguing features. [3].

Table 1 shows the generation of communication

Generation	Speed	Technology	Time period	Features
1G	14.4 Kbps	AMPS, NMT, TACS	1970 – 1980	When wireless phones are only utilized for voice during 1G.
2G	9.6/ 14.4 Kbps	TDMA, CDMA	1990 to 2000	By starting normal users over a single network via multiplexing, 2G capabilities are made possible. Primary phones are utilized for both voice and data during the 2G era.

2.5G	171.2 Kbps 20-40 Kbps	GPRS	2001-2004	Increase of internet use, and data becomes increasingly relevant. Streaming and multimedia services are beginning to expand. Some of them are uses other things
3G	3.1 Mbps, 500-700 Kbps	CDMA-200 UMTS, EDGE	2004-2005	Enables streaming and audiovisual aid services. Worldwide accessibility and portability across many kinds of device, including phones, PDAs, etc., are made feasible.
3.5G	14.4 Mbps, 1-3 Mbps	HSPA	2006 – 2010	Delivers a high all over and speeds for sustenance higher data

4G	100300 Mbps. 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax, LTE, Wi-Fi	Now (Read more on Transitioning to 4G)	To retain up with the demand for data access utilized by different amenities, 4G speeds have been further boosted. Streaming in high resolution is now possible over 4G. There are newly released phones. It becomes rather chilly. The level of portability is raised with 4G. Traveling the world is not only a faraway fantasy.
5G	1-10 Gbps	Massive MIMO, Beamforming, mm wave	Soon (nearly 2020)	There isn't any 5G connectivity in use right now. If it is made accessible, then it will provide customers very fast speeds. I t would quickly and effectively
				use the speed that is accessible.

1.9 Final Thoughts

As technology improves, worldwide wireless communications may be expected. Wireless communication has the potential to greatly increase global productivity. It's not without its flaws, however; that's the case with any modern technological breakthrough. The potential for wireless technology's advancement is being stymied by problems including insufficient protection for sensitive data and public concern about the technology's potential harmful effects on society. More study and testing is needed to solve the issues plaguing wireless communications so that it may become an even more integral part of our lives. In the not-too-distant future, when the necessity for cables connecting individual gadgets looks to be coming to an end, wireless network will be highly significant [9].

1.10 Global 5G Spectrum Update

These frequencies are now the focus of efforts all across the globe. There are numerous new entries in the top 15 markets across several criteria of 5G mobile network connectivity in our newest comprehensive study of 5G global leaders compared to the previous 5G benchmark in March. Six categories see Bulgaria's entry; 5G Download Speed (316.8 Mbps) is where the country shines. South Korea, though, remains on top. The island of Puerto Rico comes close to cracking the top 15 most populous markets thanks to improvements in 5G Availability and 5G Reach and in the quality of its video streaming services, but falls short. To top it all off, Singapore has made it into the top 15 markets in the world for 5G download speeds despite the recent paucity of available spectrum. [10].
Global top 5G speed countries are shown in Figure 3

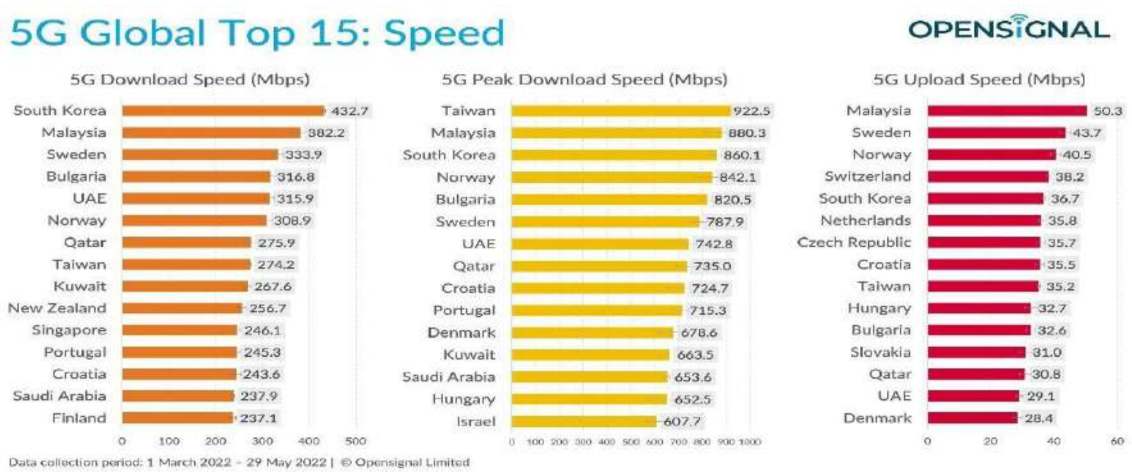

Figure 3 Global top 5G speed countries [10]

1.10.1 Crucial Spectrum Initiatives to Enable 5G are Being Led by the FCC

"This represents a significant program being led by the FCC with the intention of freeing up additional bandwidth in the United States for the use of cellular systems. It will be necessary in order to preserve and achieve the United States' leading position in 5G," AT&T chief executive Doug Alder says of the agency's 5G initiative.

Figure 4 FCC investigation on 5G [11]

1.10.2 Low-Band

Auction of Broadcast Incentive

1. After the assignment phase, the successful auction of spectrum in the 600 MHz band generated net proceeds of $19.8 billion.
2. There are two permitted channels totaling 70 MHz, and an additional 14 MHz is available for unlicensed usage.
3. The timing of spectrum utilization is optimal for 5G. [12-13].

1.10.3 **Mid-Band**Error! Bookmark not defined.

Residents Broadband Radio Services

1. We are starting up a 150 MHz frequency in the 3.5 GHz band with 3-layer collaboration with the current operators (PAL1, GAA2) and the spectrum's previous owners (incumbents).
2. In 2017, the FCC published PAL guidelines to make them 5G-ready.
3. CBRS Association was suitably launched to promote an LTE-based ecosystem.
4. FCC has alerted those interested in the 3.7–4.2 GHz and 5.9–7.1 GHz bands to begin collecting data. [12-13]

1.10.4 **High-Band**Error! Bookmark not defined.

The Spectrum Frontiers Decision came out in 2016, and the Second Decision came out in 2017.

1. Various millimeter Wave bands start opening up at 11 GHz.
2. Seventy percent of newly released music is pirated or illegally distributed.
3. Always in agreement. There is another another nominated spectrum for IMT-2020, and the FCC has inquired for public remark on it.
4. There is another another nominated spectrum for IMT-2020, and the FCC has inquired for public remark on it.
5. Adding the following frequencies: 24.25–24.45 GHz, 24.75–25.25 GHz, and 42.5–42.5 GHz. [12-13]

1.10.5 Band limits for 5G mm-wave bands.

In order to increase available bandwidth, licensed and unlicensed radio frequencies must be shared.

Licensed Frequencies

1. 27.5 GHz – 28.35 GHz
2. 37.6 GHz – 38.6 GHz
3. 38.6 GHz - 40 GHz

Common and unrestrained frequencies

1. 37 GHz– 37.6 GHz
2. 64 GHz- 71 GHz [12-13].

1.10.6 5G Spectrum in Europe

Emphasis on the 3.4–3.8 GHz mid-band and the 26 GHz high-band (24.25-27.5 GHz) Important European Member States and the European Commission's Radio Spectrum Committee (EC RSC) are driving legislative initiatives to expedite the implementation of 5G throughout the EU.

Auctions are expected to take place in the 3.4-3.8 GHz and 26 GHz bands in 2017 and 2018.

- The government's tactic for 5G in the United Kingdom was released in March of 2017.
- In 2017, Ofcom intended to sell 150 MHz of frequency between 3.4 and 3.6 GHz; in 2018, and 2019 they planned to auction 110 MHz of spectrum between 3.6 and 3.8 GHz.
- Ofcom has released a work platform on the availability of the 26 GHz spectrum to facilitate the timely organization of 5G.
- In 2018, the Italian government is planning to sell off spectrum at 0.7 GHz, 3.6–3.8 GHz, and 26.5–27.5 GHz.
- The Irish government has successfully auctioned off 350 MHz of 5G spectrum.
- The Spanish government held a procurement for certificates in the 3.6–3.8 GHz band in 2018 in response to market demands and operator requirements.
- The 26 GHz band is Spain's primary emphasis. In 2018, at least 1.4 GHz of bandwidth will become accessible.
- Austria, Belgium, and Switzerland are among the nations planning to release their radio frequencies to the public in the 2018–2019 time period [12-13]

1.11 Antenna Definition

A specialized transducer called an antenna changes radio-frequency wave energies into electrical energy. There are two fundamental types: the sending antenna with electrical energy from the equipment and generates a radio-frequency field, and the reception antenna, that is absorbs RF energies and sends sporadic current to the apparatus. The most familiar category of antenna used in wireless network applications is the microstrip patch antenna, which is utilized for wireless communications. Typically, only microwave frequencies are appropriate for using microstrip patch antennas.

1.11.1 Frequency

A common definition of frequency emphasizes the occurrence of an occurrence over a certain interval of time. The frequency of an event is defined as its occurrence rate over a certain time interval. The conventional definition of frequency is the number of existences of a signal all over a certain while retro (one second). In physics, a periodic signal is one that occurs at regular intervals (every 'T' second). For a sinusoid, the bandwidth is just the reverse of the period (T). Frequency diagram is shown in Figure 5 and Figure 6 . In engineering, high frequency refers to the rate of repetition of a signal or vibration, whether it be radio waves, sound waves, mechanical vibrations, or electromagnetic radiation. Frequency is measured in hertz, a unit introduced to the International System of Units by German physicist Heinrich Hertz (Hz). The frequency (in hertz) of a signal or event that occurs at regular intervals of one second.

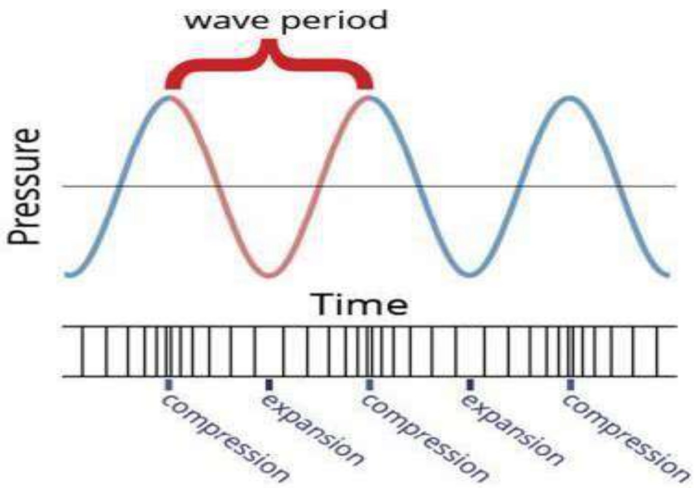

Figure 5 Frequency Diagram

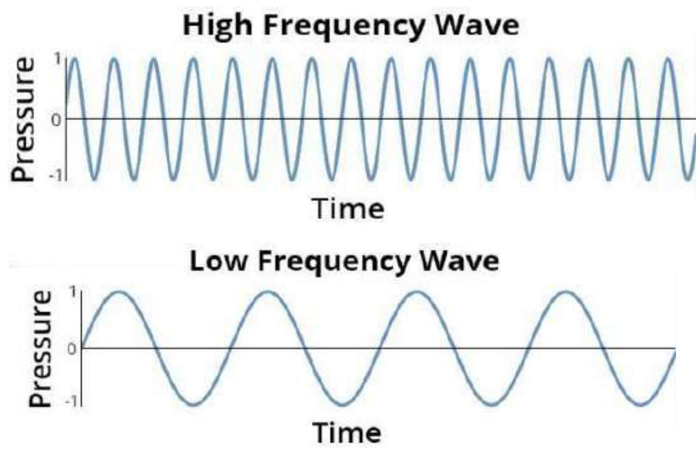

Figure 6 Frequency Diagram (HFW), (LFW)

1.11.2 Bandwidth

Bandwidth in communications systems refers to the maximum amount of information that can be sent from one location to additional across a system connection or an internet access in a given expanse of time, often one second. A radio antenna's bandwidth is the range of frequencies across which it can transmit or receive reliably without losing signal strength. In the process of picking an antenna, bandwidth is often a crucial consideration. For instance, a number of common varieties of antennas simply cannot function in wideband mode because their bandwidths are just too small. Diagram of bandwidth is shown in Figure 7.

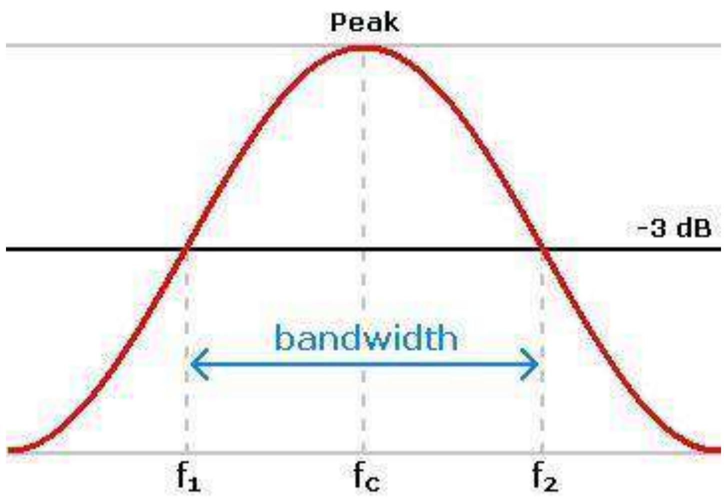

Figure 7 Diagram of bandwidth

1.11.3 Input Impedance

Input impedance describes the relationship between voltage and current at the antenna's connection points. It's an important indicator of the antenna's resonance. The input impedance's real and imaginary components are computed. The insertion loss's true value represents the amount of power emitted or absorbed by the antenna. The antenna's near field power is represented by the imaginary component of the input impedance. When both the real input impedance and the imaginary impedance of an antenna are zero, we say that the antenna is resonant.

The input impedance of an antenna is affected by its length and width. There are two components to an antenna's impedance, the real (Rrad) and the reactive (Rohmic) parts, indicated by the symbol Z. (X).

1.11.4 Impedance Matching

By definition, impedance matching takes place when the values of the transmitter and reception impedances are close to one another or whenever they are reverse. For wireless communication between the circuitry and the antenna, impedance matching is crucial. It is essential that the impedances of the antenna, transmission line, and electronics all be matched in order to achieve the highest level of efficiency between both the antenna and the receiver or transmitter. Whenever they speak about tuning or leveling an antenna, we are talking to the process of matching the impedance of the antenna with the electronics across a whole large frequency range. This may also be referred to as tuning or leveling an antenna. The term "bandwidth" refers to the frequency range in which the impedance of the antenna is relatively near to 50 ohms at a specific value of voltage standing wave ratio., and VSWR is a measure of the quality of the match. Resonance is the phenomenon in which a gadget has its highest output in a narrow frequency band. Antennas are an example of resonant devices whose output may be enhanced by matching the impedance. Impedance matching is required, as indicated below:

1. If the impedance of the feedline and the source are the same, the power from the supply will be efficiently transmitted to the feedline.
2. If the feedline and antenna impedances are compatible, the feedline's power will be efficiently transmitted to the antenna.
3. The input resistance of the receiving amplifier circuit should match the output impedance of the antenna used as the receiver.
4. For a transmitter antenna, the transmission line impedance, the transmitter amplifier's output impedance, and the antenna's input impedance should all match.

1.11.5 Directivity And Gain

The term "directivity" describes the ability of an antenna to either focus its sent or received signal in a particular direction. Gain is commonly described as the ratio of the antenna's power output from the far-field input on the beam axis to that of an idealized lossless isotropic antenna, which is equally sensitive to signals from all directions. The two concepts, gain, and directivity, are related. When contrasting a bulb to a spotlight, the phenomenon of enhanced directivity helps to explain this relationship. In comparison to a 100-watt light bulb, a 100-watt spotlight will produce more light in certain directions while producing less light in others. The bulb is claimed to have less "directivity" than the spotlight. A high-directivity antenna is like a spotlight in this case. Gain is the practical benefit of directivity. Calculating gain is the same as multiplying efficiency by focus. A novel parameter () is introduced into the connection between gain and directivity, and it represents the antenna's efficiency. Gain and Directivity are shown in Figure 8

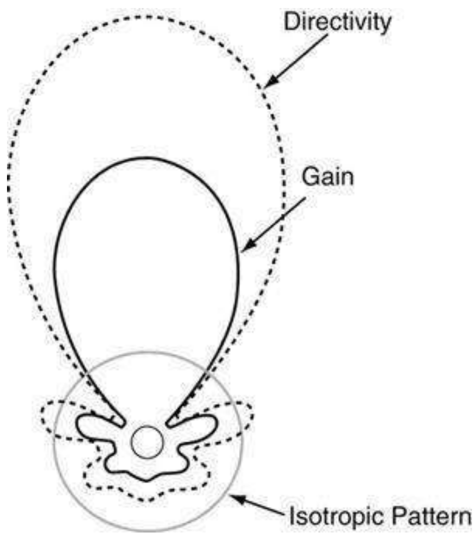

Figure 8 Gain and Directivity

1.11.6 Radiation Pattern

To better understand antenna engineering,the direction (angular) dependence of the strength of the radio waves emanating from the antenna is referred to using many different terminologies. These patterns are referred to as radiation pattern, antenna pattern, and far-field pattern. The radiation pattern is a description of the relative strength of the field that is radiated by the antenna at a specific distance. Due to the fact that the radiation pattern also reflects the antenna's capacity to receive signals, it is possible to refer to it as the "reception pattern" as well. It is difficult to depict the radiation pattern in a form that is understandable despite the fact that it has a three-dimensional structure. Figure *9* depicts the radiation pattern that was observed. Additionally requiring time is the process of measuring a threedimensional radiation pattern. It is common practice to construct a two-dimensional radiation pattern by measuring radiation patterns as slices of three-dimensional patterns. This allows the pattern to be shown conveniently on a screen or sheet of paper.

The presentation of these pattern measurements is either rectangular or polar.

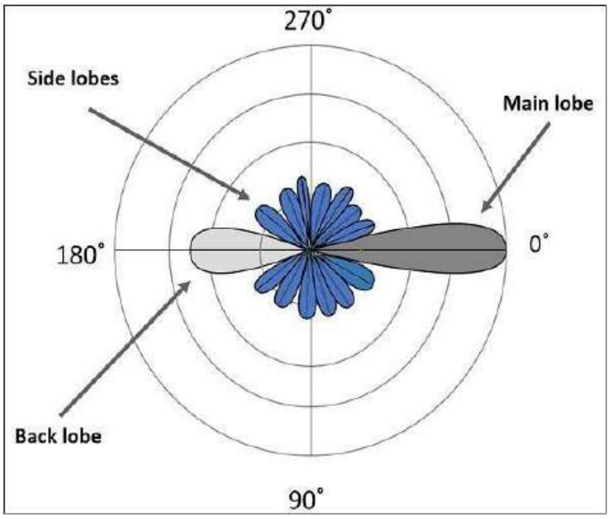

Figure 9 Radiation pattern

1.11.7 Voltage Standing Wave Ratio (VSWR)

Voltage Standing Wave Ratio (VSWR) is a metric for assessing the effectiveness of radio-frequency power transmission from a power source to a load through a transmission line. To put it another way, the continuous wave ratio is a measurement that compares the wave's maximum power to its lowest power (SWR). In terms of voltage, VSWR refers to the ratio of the voltage that is reflected to the voltage that is incident. A accurate and positive number will always be returned by calculating the VSWR for an antenna. When the VSWR is brought down, more power is sent to the antenna, and the antenna becomes better matched to the transmission system. The VSWR value has to be at least 1. This is the perfect situation since no electricity is reflected from the antenna. Figure 10 depicts the VSWR.

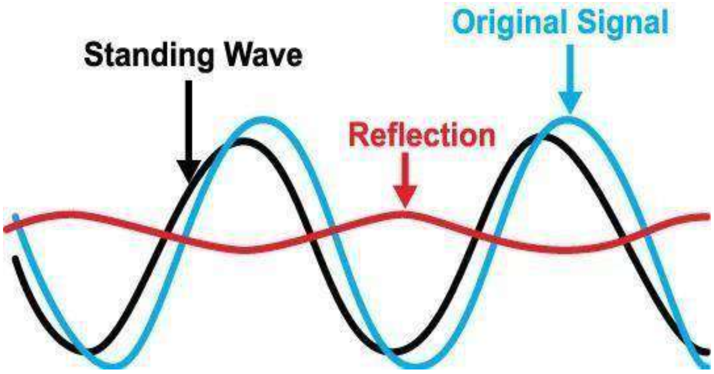

Figure 10 VSWR

1.11.8 Return Loss (RL)

The Return Loss of an antenna is the fraction of incoming radio waves that are attenuated relative to those that are let through. Compared to a short circuit, it is measured in dB. (100 percent rejection). Imbalance between both the antenna and feedline may also be described by its reciprocal, return loss (RL). The algorithm considers the influence reproduced by the antenna to the power distributed into the antenna from the transmission line, and displays the result as a ratio in decibels (dB). The VSWR is proportional to the RL. In actual use, S11 is the antenna parameter most often mentioned in discussions. S11 is equivalent to the return loss in reality (RL). S11 = 0 dB indicates that no power is emitted from the antenna and all of the input powers are returned. By extension, if the antenna is fed 3 dB of power and the S11 value is -6 dB, the reflected power will be -3 dB. A RL or S11 of -9.5 dB or less is considered acceptable, while a VSWR of 2 or less is considered optimal. According to this dissertation, RL of -10 dB is considered satisfactory.

[13].

1.11.9 Polarization

The antenna's polarization is determined by the electric field applied to the wave it generates. The antenna's polarization may be adjusted precisely by adjusting the electric field's intensity and amplitude. If the amplitude and phase of the electric field components are the same, then the antenna is circularly polarized. In the case of identical magnitudes and 90-degree phase differences, the antenna is said to be circularly polarized.

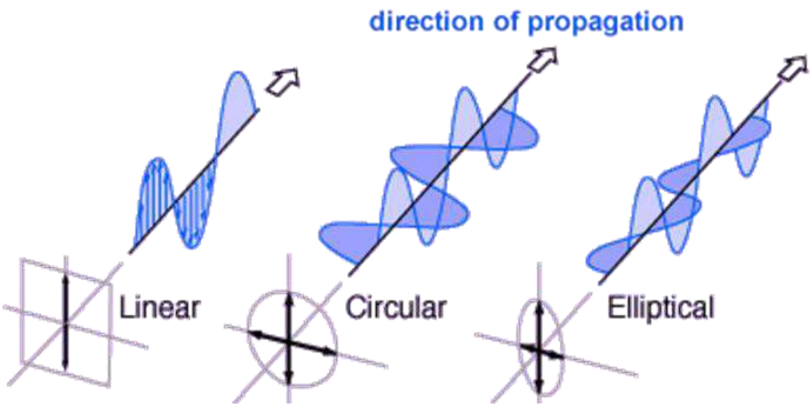

Figure 11 Polarization

Two linearly polarized antennas' projected electric fields must overlap for successful communication. Every linear antenna, however, may talk to a circularly polarized one. While a linear antenna can put out greater power since its radiation is directed in a single direction instead of being divided across two components, a circular antenna can function regardless of which way it is oriented. A circular or linear reader antenna may be used, depending on the task at hand; similarly, a tag with a circularly polarized antenna may be read from any angle. Figure 11 shoes three type of polarization.

1.12 Microstrip Patch Antenna

In Figure 12, we see a microstrip patch antenna, which is made up of a ground plane and a radiating patch on a dielectric substrate. The patch may have any form and is often constructed of copper or gold due to its conductivity. Typically, the dielectric substrate is photo etched to reveal the radiating patch and feed lines. In most cases, the patch is of a standard shape such a square, rectangle, circle, triangle, or ellipse to facilitate analysis and performance prediction. In general, the length (L) of a rectangular patch is 0.33330L 0.50, where 0 is the free-space wavelength. It is decided that the patch should be exceedingly thin, such that t=0 (where tis the patch thickness). Most dielectric substrates have a height (h) between 0.003 and 0.05 mm.

In most cases, the substrate's dielectric constant (r) will fall between the parameters of 2.2r12.

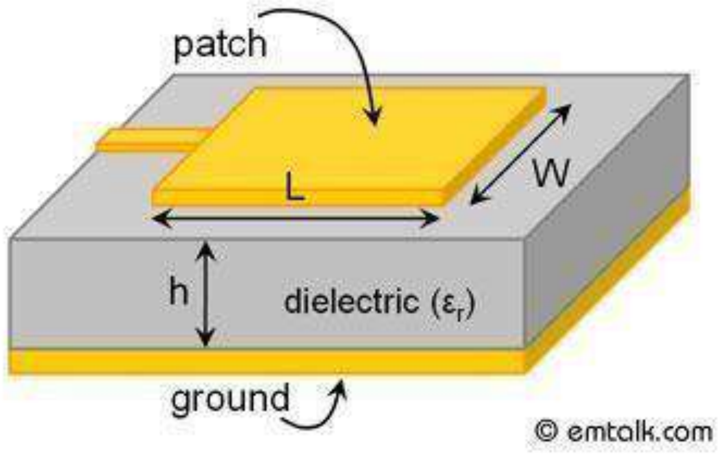

Figure 12 Structure of a Microstrip Patch Antenna [14]

In direction to emit radio waves, microstrip patch antennas rely on the fringing fields that exist between both the patch edge side and the ground plane. Antennas benefit from increased efficiency, wider bandwidth, and more effective radiation when mounted on a thick dielectric substrate with a low dielectric constant. Such a setup, however, results in a more substantial antenna. Using higher dielectric constants, which are less efficient and result in narrower bandwidth, makes it more difficult to construct a small Microstrip patch antenna. [14].

1.12.1 Microstrip antenna Feed methods

There are several methods for feeding a microstrip antenna, and they are described here Microstrip Feed Line

1. Coaxial / Probe Feed
2. Aperture Coupled Feed
3. Proximity Coupled Feed

1.12.2 Microstrip Line Feeding

This technique by feeding involves directly etching a microstrip feed line to the border of the patch, keeping the whole structure flat. Microstrip feed line, as seen in Figure *13*.

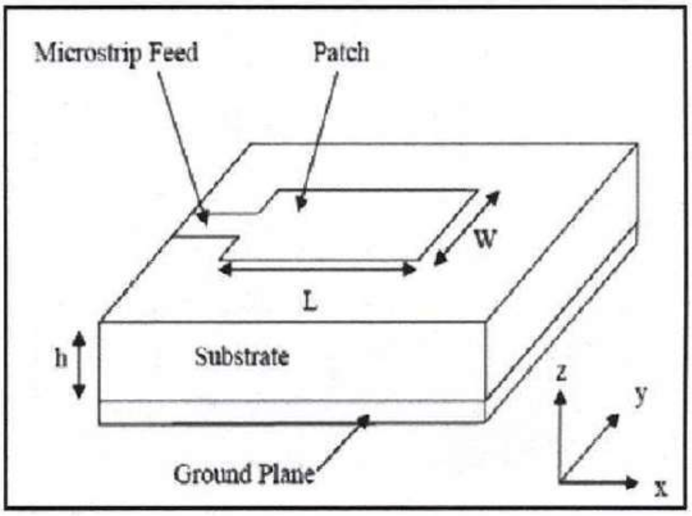

Figure 13 Microstrip Line Feeding [13]

1.12.3 Coaxial or Probe feeding

The coaxial connector's tube bundle is attached to the radiating patch via the substrate, and the connector's outer conductor is soldered to the ground plane.

Figure *14* depicts a coaxial feeding arrangement.

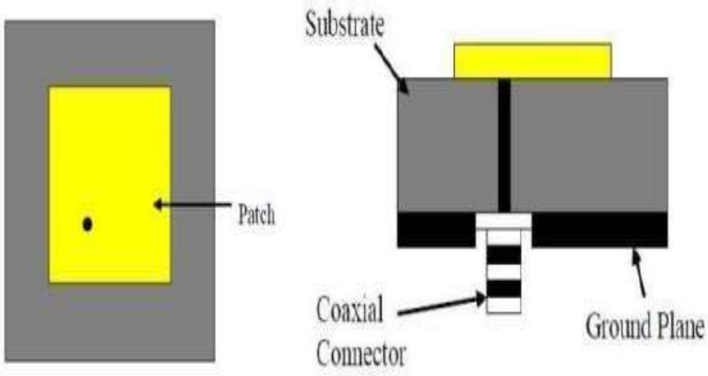

Figure 14 Coaxial / Probe feeding [13].

1.12.4 Aperture Coupled Feed

Two platforms are used for the aperture interaction in this sort of feed, with the ground plane in between. Below the lower substrate, where the radiating patch and microstrip line are located, is where the ground plane may be found. An electrically narrow hole or slot carved into the ground plane provides the coupling. Aperturecoupled feeding is seen in Figure 15.

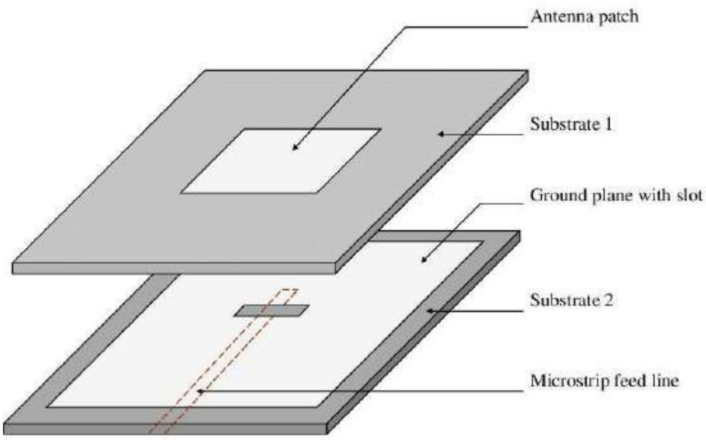

Figure 15 Aperture-Coupled Feed [13].

1.12.5 Proximity Coupled Feed

The acronym "ECMSA" may also refer to electromagnetically coupled systems. It, too, is composed of a pair of substrates. The radiated patch is situated on top of the upper substrate, whereas the microstrip feed line is placed between the two substrates.

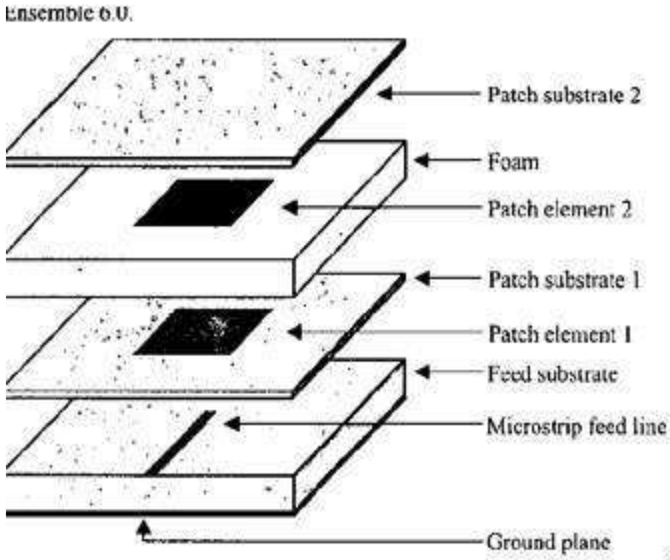

Figure 16 Proximity-Coupled Feed [13].

1.12.6 The Pros and Cons of Microstrip Antennas

Microstrip type antennas are becoming popular for use in wireless communication day by day due to their small footprint. This means they work well with the antennas already built into devices like cell phones and pagers. Microstrip patch antennas are often used as monitoring and communication antennas on projectiles because to their small size and conformability.

The following is a list of the advantages that come with using a microstrip antenna:

1. Microstrip antennas are characterized by their tiny volume and small weight.
2. Since they are capable of being produced at a cheap cost, they are also able to be produced in huge numbers.
3. They have a structure that is low-profile and flat, and they are easily made comfortable and familiar to the surface of the substrate., and they have this configuration by default.
4. It is capable of both linear and circular polarization and supports both of them.
5. Microstrip antennas are readily compatible with microwave integrated circuits and may be incorporated with them (MICs).
6. They are able to do operations at dual as well as triple frequencies.
7. When placed on hard surfaces, they have a high level of mechanical durability.

The following is a list of some of the drawbacks of using a microstrip antenna:

1. Compared to other antenna types, microstrip antennas have a very limited frequency range.
2. They are not very productive.
3. Getting anything out of them isn't worth anything.
4. Unwanted radiation from feeds and connectors harms them.
5. Unless using antennas with a tapered slot, the end-fire radiator is subpar.
6. Their ability to withstand power is limited.
7. Excitation of surface waves.

The antenna quality factor of microstrip patch antennas is very high (Q). An antenna with a high Q has a restricted bandwidth and poor efficiency because of the losses associated with it. Increasing the dielectric substrate's thickness decreases Q. When the source's output is increased, more and more of the power is transferred to a surface wave. Since surface waves are eventually dispersed at the dielectric bends, contributing to deterioration of characteristics, they should be considered a waste of power [14].

1.13 Designing Tool

This particular sector is for designing tool that we use for our design of antenna. The designing software is CST studio.

1.13.1 CST Microwave Studio

CST MICROWAVE STUDIO is a leading program for 3D electromagnetic modeling of high-frequency structures (CST MWS). CST MWS allows the user to do SI and EMC analyses, as well as analyses of high-frequency components such antennas, filters, couplers, planar and multi-layer structures, and more. It includes tools for solving problems in both the Time Domain and the Frequency Domain. Filters for importing certain CAD files and extracting SPICE parameters expedite the design process and enhance the available design options. Computer Science and Technology (CST) offers accurate and efficient computational solutions for the design and analysis of electromagnetic systems.

1.13.2 Motivation

Wireless communication's initial success may be attributed to its various advantages, including low initial investment, adaptability, portability, and convenience. Since then, the need for mobile connections, data rates, and mobile data traffic has skyrocketed. Internet of Things (IoT) has increased the scope of these needs once again. The telecommunications industry has been developing new compeers of standards practically each period to keep up with the increasing demand. In response, in the early 2020s we may expect to see the rollout of 5G networks designed to accommodate the needs of connecting hundreds of billions of wireless devices with latencies measured in milliseconds and data rates of 10

Gbps and more through the internet of things and other technologies [15]. The highfrequency path loss is one of the main obstacles to the introduction of 5G, which is what drove us to create an antenna The high-frequency path-loss is one of the main obstacles to the introduction of 5G, which is what drove us to create antenna.

1.13.3 Essence

The telecommunications sector is developing quickly. A new generation emerges roughly every ten years. The previous one, 5G, is the one that researchers are most interested in. With the massive advancements in wireless technology, we have gone from 4G to 5G. After IMT-Advanced, 5G is the next generation of wireless expertise protocols. The Internet of Things, huge machine connectivity, and device to device ultra-reliability are all aided by the development of 5G, which is coming with higher capabilities than current 4G and will provide a improved concentration for wireless system users (IoT). We need to create antennas that are compatible with 5G technology since wireless communication is impossible without the use of an antenna. When it comes to wireless communication, the microstrip patch antenna is now the greatest widespread opportunity for antenna design. This antenna type can provide compact final products because of its diminutive dimensions. The microstrip antennas may be simply etched into a printed circuit board. Microstrip patches may be etched into a wide variety of forms, including rectangles, squares, triangles, etc. This is because they are easier to make and have a cheaper per-unit cost. Their versatility extends to their ability to sustain a wide range of frequencies (dual, triple). Both linear and circular polarizations are supported. Because of their low mass, they are easy to transport. Transmissions on the existing 4G network occur in frequency ranges below 6 GHz. However, the spectrum resources of these bands are insufficient to meet the needs of 5G [10]. Because of this, we need to upgrade to frequencies between 6 and 300 gigahertz. Therefore, the Federal Communication Commission has designated the 27.5-28.35 GHz spectrum for 5G wireless communication [10], joining the 3.4-3.6 GHz, 5-6 GHz, 24.25-27.5 GHz, 37-40.5 GHz, and 66-76 GHz bands. There have been a number of studies on the topic of high gain microstrip patch antenna design for 5G communication at 28 GHz [2] and 38 GHz. However, not all of these antennas cover the whole 28 GHz and 38 GHz bands as specified by the FCC, and some of them are too big to work with a 5G mobile phone. Thus, it is crucial to create an antenna that works with 5G cellphones and covers the 34.49 GHz and 40.16 GHz bands.

Chapter 2

2 LITERATURE REVIEW

2.1 Overview of "Release 15 on 5G Standards" Update by 3GPP

Participants in the 3GPP (3rd Generation Partnership Project) get together on a regular basis to work on a unified set of standards for wireless communication. Standards for 5G are currently being defined by 3GPP. Three key performance metrics have been recommended as prerequisites for 5G by the International Telecommunication Union. [16]:

- With peak bandwidth speeds of >10 Gbps, improved mobile broadband
- >1M/km2 interconnections for very dense machine-to-machine networks
- Low-latency communications with a delay of less than 1 millisecond

The Table 2 below provides an overview of specific technical requirements laid out as the 2020 minimum requirements.

Table 2 TECHNICAL REQUIREMENTS OF 5G [16].

Metric	Requirement	Comments
Peak data rate	DL: 20 Gb/s UL: 10 Gb/s	Assuming optimal conditions, a single eMBB mobile device may be used provided
Peak spectral efficiency	DL: 30 b/s/Hz UL: 15 b/s/Hz	One eMBB mobile device, best case scenario with optimal use of available resources
User experienced data rate	DL: 100 Mb/s UL: 50 Mb/s	5% user CDF from eMBB throughout
Area traffic capacity	Indoor hotspot DL: 10 $Mb/s/m^2$	eMBB

User plane latency	eMBB: 4 ms URLLC: 1 ms	Single users for small IP packets for DL and UL (eMBB and URLLC)
Control plane latency	20 ms (encouraged to consider 10 ms)	Transition from idle to active (eMBB and URLLC)
Connection density	1 M devices per km2	For mMTC
Reliability	99.9999% success prob.	32 L2 bytes within 1 ms at cell edge
bandwidth	>100 MHz; up to 1	Carrier aggregation allowed
	GHz in > 6GHz	

Creating a whole new 5G standard is a massive undertaking. When it comes to New Radio (NR), 3GPP has split the 5G standardization into two distinct releases: Release 15 covers NR Phase 1, while Release 16 covers NR Phase 2. LTE and NR share several components, such as the use of orthogonal frequency division multiplexing, which is included in NR Phase 1.

However, there are also differences between LTE and NR as summarized in Table 3

Table 3 Differences Between LTE And NR [16].

	LTE	NR
Frequency of Operation	Up to 6 GHz	Up to 6 GHz, ~ 28 GHz, ~ 39 GHz, other mm Wave bands (Up to 52 GHz)
Carrier Bandwidth	Max: 20 MHz	Max: 100 MHZ (at < 6 GHz) Max: 1 GHz (at > 6 GHz)
Carrier Aggregation	Up to 32	Up to 16
Analog Beamforming (dynamic)	Not Supported	Supported
Digital Beam forming	Up to 8 Layers	Up to 12 Layers

Channel Coding	Data: Turbo Coding Control: Convolutional Coding	Data: LDPC Coding Control: Polar Coding
Subcarrier Spacing	15 kHz	15 kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz
Self-Contained Sub frame	Not Supported	Can Be Implemented
Spectrum Occupancy	90% of Channel BW	Up to 98% of Channel BW

There is a lot of new gear that has to be set up for New Radio's complete release to work properly (NR). We aim on utilizing the existing hardware for as long as possible, thus a phased approach has been planned. The first, called non-standalone (NSA), will rely on the preexisting LTE core, while the second, called standalone (SA), will employ an NR core and be completely independent of the LTE core network.

It has been made clear via the introduction of certain new language which gadgets are capable of communicating with one another. [16]:

- Evolved Node B (LTE eNB): A device that can connect to either the present LTE core network or the Evolved Packet Core (EPC).
- eLTE eNB is an upgraded version of LTE eNB that is capable of connecting to both the EPC and NextGen core.
- LTE enhanced node B (eNB) is the 5G New Radio (NR) counterpart of the gNB.
- NG: Interface between the NextGen core and the gNB (Next Generation)
- NG2 is the control plane interface that connects the RAN to the core network (S1-C in LTE)
- NG3 is the user plane interface that connects the RAN to the core network (S1-U in LTE) In the RAN4 conference that took place in May 2018, several operating frequency bands were discussed and shown in Table 4. It is vital to take notice that band n261 has been introduced, and even more remarkable is the fact that band n259 has been eliminated. Band n259 was formerly specified as the frequency range 31.8 GHz–33.4 GHz Time Division Duplex (TDD), but this range has since been changed. This band was first pointed out

as a band for investigation, however in November 2017, CEPT withdrew it from consideration for 5G.

Table 4 FREQUENCIES OF INTEREST IN SEVERAL LOCATION [16]

NR Operating Band	Uplink (UL) and Downlink (DL) Operating band BS transmit/receive UE transmit/receive FUL _low-FUL _ high FDL _ low – FDL _ high	Duplex Mode
n257	26,500 MHz – 29,500 MHz	TDD
n258	24,250 MHz – 27,500 MHz	TDD
n260	37,000 MHz – 40,000 MHz	TDD
n261	27,500 MHz – 28,350 MHz	TDD

The 30 GHz to 50 GHz range is also being investigated for potential application in 5G NR. This frequency adjustment is being monitored and reported on in detail in Technical Report 38.815. The accompanying frequency chart, culled from that technical report, gives a more visual overview of the relevant frequencies at various places.

2.2 Paper Review

In The works of other investigators that are connected to this thesis, "Design of a Millimeter-wave Multi-band Microstrip Patch Antenna for 5g Application," will be discussed in this section. This section is essential to the success of research into the fifth-generation (5G) mobile application using the current antenna. As a result, an antenna with superior performance and simple manufacturing should be designed and simulated.

1. Analyzed Topic, “Single Feed Compact Millimeter Wave Antenna for Future 5G Applications.”

In paper study [17], we propose a single-layer compact planar antenna that can be printed on a cheap dielectric substrate (RTduroid 5880) and that can resonate at two frequencies (28 GHz and 38 GHz) for use in future 5G wireless transmission applications. Parametric analysis and the finite element method (FEM) solution of Maxwell's electromagnetic equations revealed peak gain 8.05 dB and bandwidth 921 MHz at the 28 GHz band, and peak gain 8.28 dB and bandwidth 1.0451 GHz at the 38 GHz band. Furthermore, the concept of merging undesirable narrow bandwidths considerably improves bandwidths for both resonance frequencies.

2. Analyzed Topic, “Broadband Elliptical Slotted Patch Antenna for 5G Communications.”

For future 5G communications, the authors of this study [18] propose using a broadband patch antenna with an elliptical slot. The suggested antenna takes up just 0.127 mm in height and has a surface area of 4.2 mm2. Rectangular ground through an elliptical slot and a T-shaped slotted patch are used with a 50-ohm microstrip transmission line feeding technique. The constructed antenna features an omnidirectional radiation pattern, enough gain, and operates in the 22 GHz to 48 GHz range, covering all three 5G frequency bands. Using the designed antenna array, we found that we could obtain a gain of around 18 dBi at 28 GHz and 21 dBi at 38 GHz. The antenna proposed in this research has the potential to be used for the next 5G wireless communication.

3. Analyzed Topic, ‘’Millimeter wave microstrip patch antenna for 5G mobile communication’’

In this work [19] demonstrates a small patch antenna on a cheap substrate, making it a good candidate for use in downsized electrical devices. It can function at either 38 or 54 GHz in frequency, with a bandwidth of 1.94 or 2 GHz. It consists of a PEC patch, a PEC ground, and a Rogers RT5880 (lossy) substrate. The substrate is a typical 0.508mm thick and has a dielectric constant of 2.2 and a loss tangent of 0.0013. The substrate is 6mm x 6.25mm and the patch is 2mm x 2mm. Specifically, the feeding technique based on microstrip lines is used. An array with four components separated at 4mm has been suggested for mobile data applications at millimeter wave frequencies of 38.6GHz, 47.7GHz, and 54.3GHz with bandwidths of 3.5GHz, 2.5GHz, and 1.3GHz, respectively. The proposed antenna is modeled in CST Microwave Studio simulations.

4. Analyzed Topic, “A Novel 28 GHz Beam Steering Array for 5G Mobile Device with Metallic Casing Application.”

In this research, the efficiency of a recently developed beam-steering antenna array in the 28 GHz band was analyzed for the purpose of this article. The suggested antenna array demonstrates excellent performance in terms of return loss, antenna gain, radiation patterns, and the ability to guide the beam. In the antenna array that has been suggested, there will be 16 cavity-backed slot single-element antennas employed through the metallic rear shell of the mobile phone. In addition to this, there will be two eight-element phased array antennas created on the left and right sides of the device.In addition to being able to guide their beams in any direction, the eight elements of each phased array antenna may provide a gain of more than 15 dBi in the boresight direction. 10 dB-bandwidth was measured to be close to 27.5-30 GHz for the predicted cavity-backed slot antenna element [20].

5. Analyzed Topic, “Broadband Printed-Dipole Antenna and Its Arrays for 5G Applications.”

Broadband printed-dipole antennas and their arrays are proposed in this letter for use in 5G wireless cellular networks. In order to power the proposed antenna across a broad frequency range, a microstrip line is folded and a rectangular slit is cut into it to create an integrated balun. The 45° slant helps keep the printed dipole small. The highest gain of the single-element antenna is 5.8 dBi, and the |S11 | 10-dB bandwidth is 36.2%. (26.5-38.2 GHz). When a stub is put between two printeddipole antennas, the mutual coupling is reduced to 20 dB (0.42-0.61 at 26-38 GHz) at a center-to-center distance of 4.8 mm. Its usefulness as a beamforming space heater is shown by constructing 8-element linear arrays using it. The stubs allowed for a broader scanning angle, higher gain, and less side lobe in the array's lowfrequency range. [21].

6. Analyzed Topic, “Design a single Band Microstrip Patch Antenna at 60 GHz

Millimeter Wave for 5G Application.”

This piece of study [22] proposes a microstrip patch antenna that may be used in 5G wireless networks. This antenna performs on a single frequency band and functions on it. This particular antenna for a single band is a radiated patch that has been modernized and now has both a H slot and an E slot. The reproduction antenna is constructed on a Rogers RT-5880 dielectric substrate. This particular substrate has a loss tangent of 0.0009, a relative permittivity of 2.2, and a height of 1.6 millimeters. CST Microwave Studio is used to do a simulation of the antenna. At 60 GHz, the return loss of the virtual antenna has been determined to be 40.99 decibels. The proposed antenna has a gain of 5.48 dB at 60 GHz, a radiation efficiency of -1.549 dB, and a total efficiency of -2.423 dB. All three of these efficiencies contribute to a total efficiency of -2.423 dB. The diagrams indicate that the main frequency need to be at 59.93 GHz, with the bandwidth spanning the range of 57.981 GHz to 62.009 GHz. The recommended antenna has a straightforward construction and may be built for a low cost. Cutting the H slot and the E slot helps enhance the impedance bandwidth by a little amount.

8. Analyzed Topic, “Directive Antennas for Future 5G Mobile Wireless

Communications”

In this piece of research, a single antenna that has a high degree of directionality is recommended for usage in the future of mobile wireless communications that employ the 5G standard [13]. The Wilkinson array and the series feed array are both examples of gain augmentation techniques that are available. Both the Wilkinson array and the series fed array were successful in achieving a realized gain of 10.58 dB apiece. The proposed antenna component is an elliptical patch printed on a low permittivity grounded substrate. It is fed by a 50 microstrip line on the opposite page of a second thin dielectric layer with a larger permittivity through an elliptical aperture cut in common with the ground plane.

9. Analyzed Topic, “A Millimeter-Wave Connected Antenna Array for 5G

Applications.”

In order to provide 5G wireless networking at high data rates in the future, a wideband new printed linked antenna array architecture is put forth in this work at the 28 GHz band. The antenna's planar, tiny, and compact design made it suitable for usage in mobile phone applications. Peak gains of 4.29 dBi to 6.68 dBi for four switched beam sites were achieved using a 44 Butler matrix [23].

10. Analyzed Topic, “Design of Dual-Band Meta surface Antenna.”

This study [24] suggests a metamaterial antenna for simultaneous functioning of two 5G wireless bands. The metasurface consists of a grid of square patches with a single layer, which is excited by two microstrip feeding slits dug into the earth. In order to make better meta-surface patterns for dual-band operation, the characteristic mode analysis is used. The metasurface exhibits resonant modes at 30

GHz, 38 GHz, and 41 GHz. The ground's sculpted grooves are also resonant, increasing the frequency range. The return loss is tolerable in the frequency bands of 23.75 and 28.8 GHz and 36.24 and 40.52 GHz with proper impedance matching. We find simulated gains of 8.8-10.17 dBi over the 28 GHz band and 9.46-12.6 dBi over the 38 GHz band while operating in an ideal environment.

11. Analyzed Topic, “Slot-Based Connected Antenna Arrays for 5G Mobile

Terminals.”

In order to develop a compact and aesthetically pleasing array antenna, the authors of this research [25] suggest using connected antenna arrays (CAA). The CAA method provides improved wideband antenna responses than conventional methods when working with millimeter waves. Additionally, its antenna is smaller in size, making it possible for it to be integrated into mobile phone terminals. This research proposes using a slot-based connected antenna array for regular-sized mobile phone terminals, which would improve signal strength and decrease interference. Includes both millimeter wave band (5G) and radio frequency (4G) antenna systems.

12. Analyzed Topic “60-GHz Array Antenna for mm-Wave 5G Wearable Applications”.

It is planned to use a 60-GHz mobile systems area antenna for 5 G mm-wave devices. The antenna has a number of patch antennas, a base, feed lines, parasites, and other components. The antenna has a fan-beam radiation pattern, with simulated 3-dB and 10-dB beam widths of 38.9 and 142.9 millimeters, respectively. The antenna's performance in a true wearable environment was shown by simulating the antenna's characteristics on a 60 GHz head phantom. [26].

13. Analyzed Topic “A Comparative Analysis of 5G mmWave Antenna Arrays on Different Substrate Technologies”.

They compare the effects of different substrate technologies on the performance of 28 GHz antennas used in 5G installations in this research [27]. To that end, we have designed, replicated, assessed, and evaluated 2X2 patch antenna arrays using five solid substrate technologies often used in the fabrication of integrated antennas. Measurements of the antennas' impedance bandwidth, efficiency, and gain are performed while using a variety of substrates. Antennas were built and measured for accuracy. It is remarkable how simulation and computing may influence one another.

14. “Design and Analysis of a Novel Patch Antenna Array for

5G and Millimeter Wave Applications”.

The future of wireless networks for communications revolves on a multi-band highgain antenna. This study provides a comprehensive evaluation and design of antennas with 1x4 linear and 2x2 planar ranges. The arrays were built using Rogers RT/duroid5880 (lossy) substrates. All the way on the tangent, the failure size is 0.508 mm, the density is 2.2, and the dielectric constant is 0.0013. Multiband antenna arrays, they may resonate at frequencies in the K band, Ka band, or V channel. Across a linear range, the highest and lowest values are 14.22 dB at 44.8 GHz and 9.9 dB at 67.8 GHz. At 29 GHz, a planar antenna's gain is at its peak (12.34 dB), whereas at 38 GHz, it's at its lowest (8.5 dB). With all resonance frequencies, both antennas radiate at a 90% efficiency. The benefits of the linear setup array are greater than those of the planar setup array, but the bandwidth and loss of the planar array return are greater [28].

15. Analyzed Topic, “Substrate Integrated Gap Waveguide Circularly Polarized

Slot Antenna.”

This study [29] presents a substrate integrated gap waveguide-based circularly polarized antenna with a large bandwidth for 5G millimeter wave applications (SIGW). The SIGW is excited by a microstrip transmission line, and an angled aperture is mounted on the SIGW's metal layer. In a moment, we'll analyze the mechanism of circularly polarized radiation. Results from the simulations suggest that the axial ratio bandwidth is 3 dB from 27.3 to 28.8 GHz, and 10 dB from 24.8 to 31.7 GHz.

16. Analyzed Topic, “Design of a Tri-Band Microstrip Patch Antenna for 5G

Application.”

In this article [30], a triple band microstrip patch antenna for 5G wireless communication is suggested. The antenna substrate is Rogers RT Duroid-5880, which has a 0.25 mm thickness and a relative permittivity of 2.2. Two distinct commercial electromagnetic modeling programs, IE3D and HFSS, are used to design and simulate the projected antenna, and the results of each are compared. At three 5G bands, the planned antenna's reflection coefficient is greater than 10 dB.

Peak gains at 24.4 GHz, 28 GHz, and 38 GHz are 6.65 dBi, 7.02 dBi, and 5.05 dBi, respectively.

17. Analyzed Topic, “Modified Triple Band Microstrip Patch antenna for Higher 5G bands”

In this research study [31], we discuss the construction of a modified triple band microstrip patch antenna that operates in greater 5G bands. This antenna operates at a frequency of 28 GHz. The antenna is built on a substrate made of RT/Duroid 5880, which has a dielectric constant of 2.2, and its dimensions are 30 millimeters by 40 millimeters by 1.6 millimeters. The return loss of the suggested antenna design is -12.5114 decibels (dB) at 28 GHz, -16.5928 decibels (dB) at 31.45 GHz, and -15.7107 decibels (dB) at 34.6 GHz, respectively. At 28 GHz, it has a -10 dB impedance bandwidth of 1.37 GHz (27.47–28.84 GHz), while at 31.45 GHz, it has a -10 dB impedance bandwidth of 0.11 GHz. Both of these figures are in the range of 27.47–28.84 GHz (31.38–31.49 GHz). The antenna has a very low signal loss at 28 GHz, with a maximum gain of 3.7308 dB, and a very small value of voltage standing wave ratio (VSWR), both of which are lower than the crucial value of 2. This antenna is designed to be used in the countries of Japan, South Korea, and the United States of America.

18. Analyzed Topic, “mmWave Novel Multiband Microstrip Patch Antenna Design for 5G Communication”

In this research, the authors [32] provide an original design for a mmWave multiband patch antenna that is suitable for 5G communication. The 5G mmWave antenna has a maximum bandwidth of 5.5 GHz and a corresponding 8.67 GHz, and its operating frequency range is somewhere between 37 and 54 GHz. Microstrip technology was used in the development of the 5G mmWave multiband antenna, which has portability, affordability, low profile, high gain, and efficiency among its list of desirable characteristics. CST MWS, a modeling program, was used during the development of the 5G antenna. It has dimensions of 7.2 mm3 on the shorter end and 5.0 mm3 on the longer end, although its volume is just 0.787 mm3. It is sufficient for the 5G multiband antenna to have a realized gain of 5 or 6 dBi for it to perform its intended purpose. It is simple to install into smart devices and makes it easier to communicate over 5G networks.

19. , “Dual-band Microstrip Patch Antenna Array for 5G

Mobile Communications”

In this study [33], we describe the plan for a dual-band 5G communication system that utilizes an MPA array consisting of eight elements. The proposed antenna array operates between 28 and 38 GHz with a modest footprint of about 1616 mm2. The main radiator is etched with a slit in the form of an inverted U to provide a dualband response. The outcomes indicate that the planned array has the potential in the direction of achieve resonance at the necessary frequencies. The proposed antenna array also has omnidirectional emission patterns and offers sufficient gain for both frequency ranges.

20. Analyzed Topic, “83 GHz Microstrip Patch Antenna for Millimeter Wave Applications”.

This work [34] presents the design and implementation of a 5G high-speed datatransfer rectangular microstrip patch antenna operating in the Millimeter-Wave (mm-wave) band between 75 and 110 GHz (Wband). The antenna in question is a microstrip design with a single element. With a core frequency of 83 GHz and a fractional bandwidth of 3.76 percent, the antenna can receive signals between 81.3717 and 84.4912 GHz (about 3.12 GHz). The proposed antenna's small and minuscule size, as well as its excellent impedance matching, bandwidth, and radiation qualities at the operational band, all lend credence to its potential as a 5G mm-wave antenna.

21. Analyzed Topic, “Design of a Millimeter Wave Microstrip Patch

Antenna and Its Array for 5G Applications”.

Analyzed Topic

In this research article and accompanying study, a millimeter-wave microstrip patch antenna and array is presented for usage in 5G applications. The 5G Microstrip patch is constructed on a Rogers RT Duroid 5880 substrate. This particular substrate has a relative dielectric constant (r) of 2.2, a standard thickness of 0.787 mm, and a tangent (tan) of 0.0013. This particular antenna has a return loss of -19.5 decibels and a resonance frequency of 24.85 gigahertz. This is due to the fact that employing arrays allows them to maximize the amount of profit they make[35].

22. Analyzed Topic, "A Single-Band 28.5GHz Rectangular Microstrip

Patch Antenna for 5G Communications Technology".

The recommended antenna has lower return loss and stronger efficiency characteristics, as described in this work [36]. The 28.5 GHz operating frequency (Ka-band) was used, which is a common spectrum for 5G connection. The suggested model, which utilizes a Patch with dimensions of 7.885 mm * 8.935 mm * 0.5 mm, has achieved return loss of -48.309 dB, gain of 7.425 dB, VSWR of 1.007129, and directivity of 8.141 dBi. In order to meet the problems of 5G Communication Systems, it is simple to improve the model's gained gain and efficiency.

23. Analyzed Topic, "Return Loss and Gain Improvement for 5G Wireless Communication Based on Single Band Microstrip Square Patch Antenna".

This study [37] proposes using a microstrip square patch antenna operating at 28 GHz for a single frequency band. They suggested a millimeter-wavelength antenna with strong gain and robust protection against path loss for usage in future 5G communication.

At an operating frequency of 28 GHz, the suggested square patch antenna is constructed and simulated in CST Microwave studio. The batter improvement has been accomplished with the help of air substrate. Through the use of slotted cut, they may reduce their loss on return.

24. Analyzed Topic. "A low Profile Multiband Microstrip Patch Antenna For

5G Mm-Wave Wireless Applications"

In this research [38], the authors presented a multi-band microstrip patch antenna structure for use in 5G mm-Wave wireless networks, applications, and devices. Including the ground plane and the slotted inset feed line, the proposed patch antenna has a small rectangular-shaped construction measuring 8.6 x 9.2 x 0.6 mm3, making it ideal for usage in modern portable electronics. There are five different mm-Wave bands that this antenna can operate on: 23.80 GHz, 39.4 GHz, 66.2 GHz, 81.9 GHz, and 93.9 GHz. This microstrip antenna has a good gain for its size and weight. The proposed multiband antenna is competitive for a broad range of 5G mm-wave applications, services, and devices due to its compact size, flexibility, superb matching, wide impedance bandwidth, high gain, and high efficiency.

25. , "An Inset Fed Square Microstrip Patch Antenna to

Improve the Return Loss Characteristics for 5G Applications".

This work [39] proposes a millimeter-wave operating, rectangular microstrip patch antenna with enhanced return loss characteristics. A 30 GHz frequency is used by the proposed antenna. The authors of this research have included a diamond-shaped slot into their design to boost bandwidth. Shifting the suggested antenna's physical dimensions from the microwave to the THz area allows for a wide range of tuning options for its operating frequency.

26. Analyzed Topic, "A Square Microstrip Patch Antenna with Enhanced

Return Loss through Defected Ground Plane for 5G Wireless Networks"

In this suggested work [40], a rectangular microstrip antenna with a novel design is offered. The antenna is intended to work at 15 GHz. The bandwidth and return loss features are improved by etching diamond-shaped slots (DGS) onto the patch and the ground plane. Slots are designed for maximum efficiency by fine-tuning their coordinates and edge size. The results showed that the patch antenna with diamond slots and DGS provided more bandwidth and lower return loss than the control. Future 5G applications may benefit from the patch's recommended design, which can be modified for utilization with additional possible frequency bands by modifying the antenna's size.

2.3 Summary

Many well-known researchers were done on their research paper on designing microstrip patch antenna for 5G communication at millimeter wave bands around 28 GHz ,38 GHz, 40GHz and others. From the current research paper, it is clear that among the millimeter wave bands around 34.49 GHz and 40.16 GHz band is the average potential and important candidate for 5G wireless communication and many investigates have been achieved encompassing this band of frequency. To reiterate, the maximum difficult aspect of rolling out 5G will be designing antennas that have a high gain to compensate for significant path-loss, are sufficiently tiny to be able to be integrated into mobile phones, are efficient and are also easy to construct.

2.4 Objectives

- To design and simulate a single element microstrip patch antenna for QBand of 5G mmWave technology.
- To enhance the bandwidth of the antenna to cover as much bandwidth as possible of Q-Band by keeping other parameters in satisfactory level.

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Chapter 3

3 METHODOLOGY

3.1 Definition

The methodology is a section of your research paper, where you detail and defend the means through which you gathered and interpreted your data. In your thesis, dissertation, or research paper, the methodology chapter should include your procedures for gathering data and analyzing your findings [41]. A set of activities or processes is referred to as methodology. The methodologies utilized in a specific research project, as well as practices that are often applied across a field of study or business, may be referred to by this name. A methodology doesn't aim to maintain solutions; as a result, it is not the same as a method. A methodology, in one side, deals with the theoretical support for comprehending which approach or combination of procedures may be realistic to a certain instance. Research can be split into two components, qualitative research and quantitative research.

3.2 The Methodology Behind the Study's Layout

Research design is the method developed to answer the research questions. The study resources, counting the research question, dependent and independent variables, experimental design, and, if relevant, data collecting techniques and an appropriate arithmetic strategy, are outlined in the design of a research project.

Research Methodology in This Study:

- Research on the transition to 5G.
- Research on the 5G antenna standards needed.
- The millimeter-wave spectrum used for 5G wireless data transmission must be chosen.
- Research what has already been written on microstrip antennas and 5G antennas.
- Investigate the steps involved in developing microstrip antennas.
- CST Microwave Studio's antenna design process should be investigated.
- Parameters for antenna design may be calculated.

- Determine the most suitable substrate material.
- Determine the Optimal Substrate Depth
- Figure out the most effective method of feeding
- In other words, do what the process says.

3.3 Research In Progress

A pilot study, pilot project, pilot test, or pilot experiment is a preliminary study performed before a larger-scale research effort to determine feasibility, time, cost, hostile occurrences, and to refine the study design. It's done before the actual research begins. In most cases, pilot studies wind up being carried out exactly as anticipated. While it is true that a pilot study cannot eliminate all systemic errors or unforeseen issues, it may significantly reduce the number of these mistakes that cause unnecessary delays and additional work in the main study.

The Value of a progress study:

- The goal is to put the research method(s) and/or protocol(s) to the test.
- Identifying and prioritizing the best way to implement each functionalization for the various categories of relevant variables.
- To design or analyze research tools and methods for efficacy.
- To assess investigative metric values.

3.4 Software

Computer-Based Modeling and Simulation The 3D electromagnetic modeling of high frequency components is made possible by Microwave Studio (CST MWS), a potent tool developed by CST. Filters, couplers, antennas, single and multi-layer structures, and electromagnetic compatibility (EMC) and signal integrity (SI) impacts may all be quickly and accurately analyzed using CST MWS.

With its unrivaled performance, CST MWS is the go-to solution for cutting-edge R&D labs. CST MWS is a user-friendly EM analysis tool that provides immediate feedback on the high-frequency EM performance of systems [42].

3.5 Design Methodology

Step 1: In the first stage, an equation-based antenna design is used to create a rectangular microstrip patch antenna (MPA) with two components that can function in the frequency range between 34.49 GHz and 40.16 GHz.

Step 2: Secondly, several substrate materials are tested to determine which one is the most suitable for meeting the 5G standard.

Step 3: To determine the optimal feeding method for the needs of 5G, we will now test out a variety of them.

Step 4: The ideal substrate material, optimal substrate height, and optimal feeding mechanism were used to the construction of 34.49 GHz and 40.16 GHz antennas.

Step 5: Fifth, after you have an antenna design, save the structure and test it out in a virtual environment.

Step 6: Sixth, if the antennas pass the test, you should save the result.

Step 7: The seventh, is to enhance the performance of the Microstrip patch antenna that was created.

Step 8: Swift the parameter to boost gain and directivity.

Step 9: After you have finished developing the antenna, save the construction and run a simulation of it.

Step 10: We'll save the data if the antennas perform as expected.

Step 11: Improve the designed antenna's performance

Step 12: If the antennas pass the test, save the result.

Step 13: The outcome can be compared to current antennas.

Flow particular diagram of the research work shown in Figure 17.

3.5.1 Bases for Antennas

A suitable dielectric substrate of the correct thickness is chosen as the initial stage in antenna design (h). Electrical and mechanical stability can be increased with the use of dielectrics. They help generate relocation current, which generates a timevarying magnetic field (according to Ampere's Law), and so lower the antenna's physical footprint. By Faraday's law, a time-varying magnetic field can generate an equally time-varying electric field, resulting in a propagating electromagnetic field. To improve the antenna's ability to radiate, a substrate can be used [43].

Some common dielectric substrates name and dielectric constant are listed in Table 4 with their properties.

Table 4 LIST OF SUBSTRATES

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
Foam	1
TLC-32	4.3

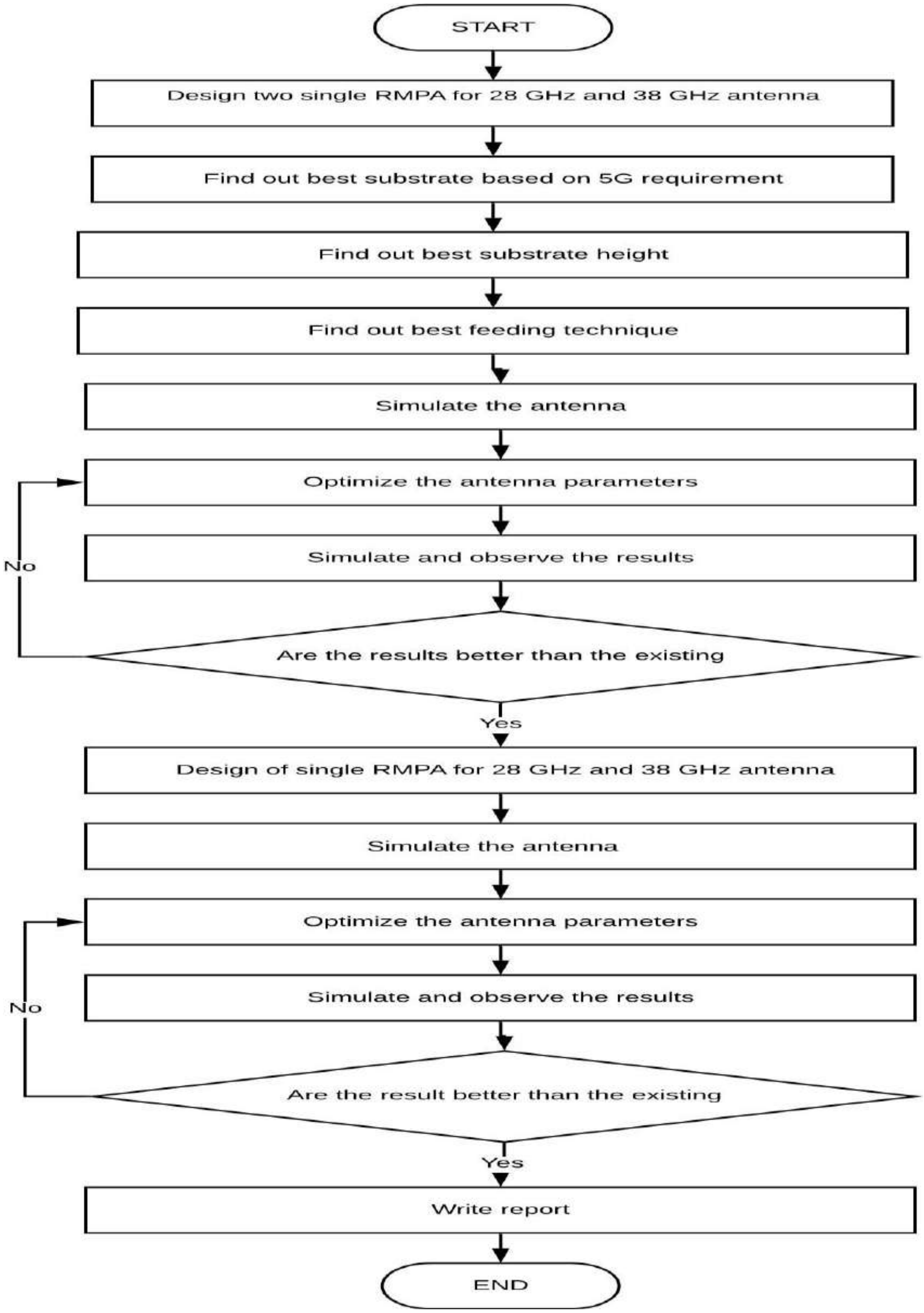

Figure 17 Flow Diagram of the Research work

The substrates listed in the above table have relatively high dielectric constants, which portends poor performance when trying to achieve a high gain antenna design. At first, we choose at random a substrate material, namely Rogers RT-

5880, since it has a dielectric constant near to 2.2 and is hence often used in MPA design. Then, decide on a material for the microstrip line and ground. This time around, you may go between Copper, Silver, or Gold. Silver's conductivity is far greater than that of the other metals. However, copper is both tougher and less expensive than the other two. Consequently, copper's widespread use is expected [43].

3.5.2 Formulation of Antennas

This section on antenna design process is broken down into multiple subsections. The first step in antenna design is determining the dimensions of the radiating patch. Radiating patch antenna design parameters include substrate dielectric constant (r), substrate height (Sh), and resonance frequency [43]. Second, a strategy for feeding has been developed. This antenna's design makes use of two distinct feeding methods: inset feeding and quarter wave transformer feeding. We settled on a quarter-wave transformer feeding approach as the final option.

3.5.3 Radiating patch

1. Width design is important for good radiator design and to get desire resonance frequency of operation. So, width can calculate by using below equation (1).

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \qquad (1)$$

Where, c is the velocity of light in free space. f_r is the resonant frequency of operation.

ϵ_r is the substrate dielectric constant.

Calculating two parameters, including effective dielectric constant and extension of length, is required in order to get the actual length L. These parameters include effective dielectric constant and extended of duration. To begin, the effective dielectric constant must be determined by using the equation shown below (2).

$$\in_{eff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left(1 + \frac{10Hs}{w}\right) ----------------------(2)$$

Where,

Hs is the height of substrate. w is the width of the patch

2. Secondly, the following equation is used to calculate the length of an extension. (3).

$$\Delta L = 0.412\, h \frac{c(\varepsilon reff + 0.3)(WHs + 0.264)}{(\varepsilon reff - 0.258)(WHs + 0.8)} ----------------(3)$$

3. Finally, the actual length L is determining by below equation (4).

$$Leff = \frac{c}{2fr\sqrt{\in eff}} ------------------------------------(4)$$

3.5.4 Feed-line

1. Microstrip inset feed is the essentially feeding inset the radiating patch for proper impedance matching. Figure 18 shows inset feed line design. For calculating the inset feed location is calculating below equation (5).

$$xo = \frac{L}{\pi} \cos - 1 \sqrt{\frac{Zo}{Z1}} ----------------------------(5)$$

Where,

Zo=50 Ω is the transmission line impedance.

Z1 is the characteristic impedance.

The characteristic impedance Z1 is calculating by below equation (6).

$$Zin = \sqrt{Zo * Z1} \text{ ------------------------------- } (6)$$

Where,

The calculator's input impedance, Zin, is one such parameter. In addition to the above, the inset feed also takes into account the feed width Fw and the feed length Fl. You may figure out those values using the formulas (7) and (8) that I've provided down below.

$$Wf = \frac{2Hs}{\pi}\left\{B - 1 - \ln(2B - 1) + \frac{\varepsilon r - 1}{2\varepsilon r}\left[\ln(B - 1) + 0.39 - \left(\frac{0.61}{\varepsilon r}\right)\right]\right\} \text{ --------- } (7)$$

$$Lf = 3.96 * Wf \text{ ------------------------------- } (8)$$

Where,

$$B = \frac{377\pi}{2Zo\sqrt{\epsilon_r}} \text{ ------------------------------- } (9)$$

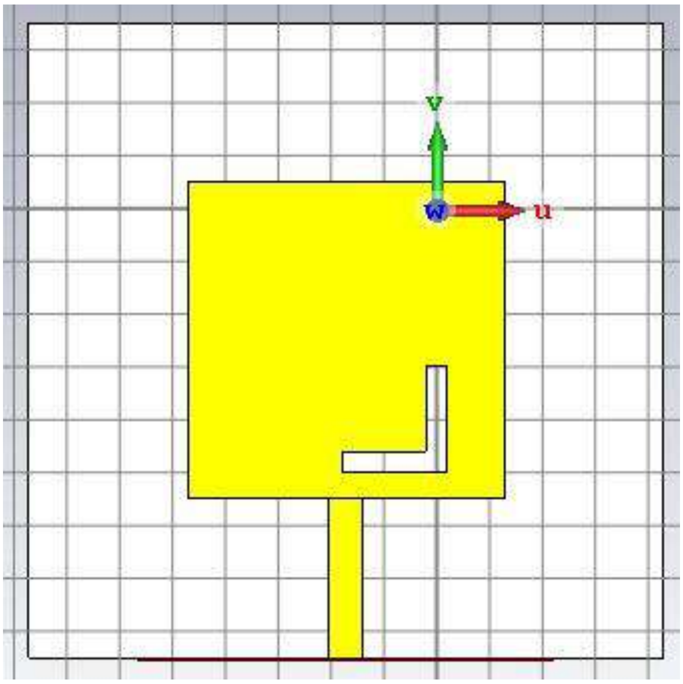

Figure 18 Inset feed line design

2. When matching impedance becomes a problem, the quarter wave transformer feeding approach is often used. The input line to a quarter-wave transformer is seen in. In this situation, the impedance of the feed line and the radiating patch must be same. In order to achieve impedance matching with a 50ohm transmission line, a second, narrower feedline is connected to the original.

At the end, the aforementioned nine formulae may be used to create an MPA that is tailor-made to meet the needs of 5G. CST microwave studio will then be used to design the antenna based on the computed parameters in Table 5.

Table 5 Parameter List

Description	**Parameter**	**Value(mm)**
Substrate length	Sl	12
Substrate Width	Sw	12
Substrate Hight	Sh	0.6
Length of Patch	Pl	6
Width of Patch	Pw	6
Hight of patch	T	0.0035
Length of Feedline	Fl	3
Width of Feedline	Fw	0.64
Length of Slot	Cl	2
Width of Slot	Cw	0.4

3.6 Shape and engineered values of antennas

Substrate elements, substrate height, and feeding method are three antenna design characteristics that have been worked on in order to determine the antenna design as described above. The next subsection demonstrates the antenna geometry based on the specified parameters.

3.6.1 Antennas designed

In terms of the three design factors required to specify an antenna's layout, the first is the antenna substrate components. In this case, we employ four distinct substrate components to build four distinct antennas, and then we finish the foam substrate elements by analyzing the antenna design results.

Table 6 below shows the results of applying the equations from the antenna technique section to the design parameters of a 28- and 38-GHz antenna. An interesting fact is that the substrate height Hs was set to 0.5mm and the feeding method was set to inset feeding for all substrate pieces. In the future, analysis may cause these two values to shift.

Table 6 Antenna Design parameter at 34.49 GHz and 40.16 GHz

Substrate name	Patch length Pl mm	Patch width Pw mm	Feed width Fw mm	Feed length Fl mm
Foam	6	6	0.64	3
Rogers RT5880	6	6	0.64	3
TLC-3.2	6	6	0.64	3
FR-4	6	6	0.64	3

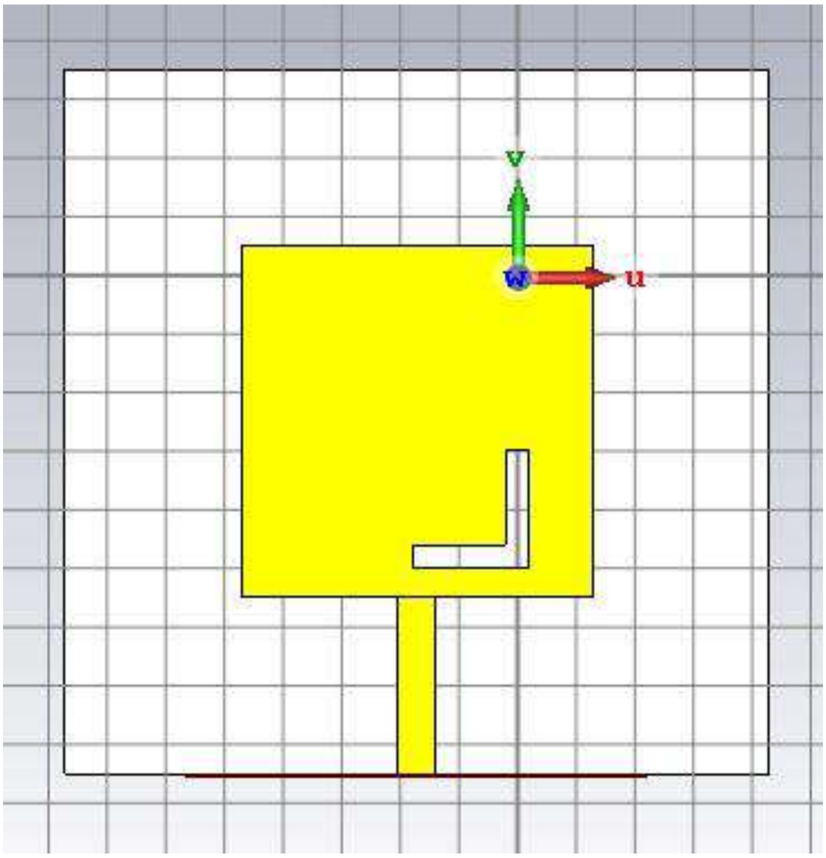

Figure 19 Front view of the antenna

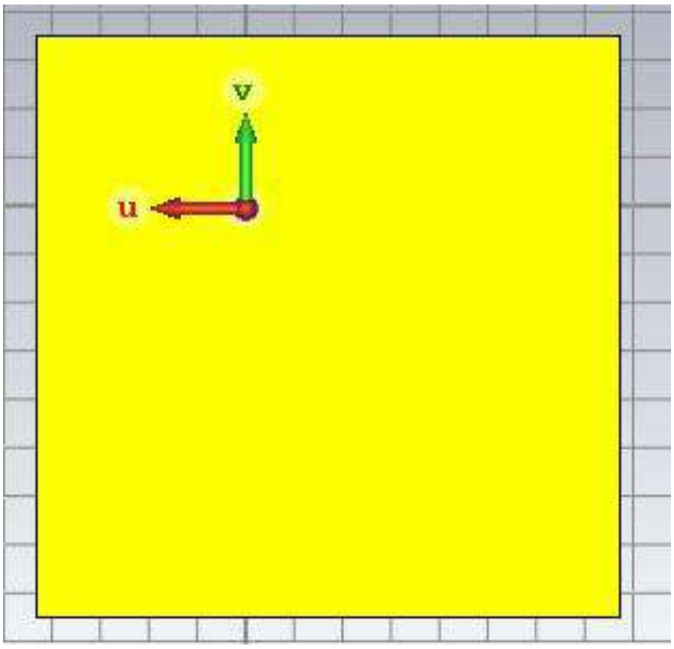

Figure 20 Side view of the antenna

Name	Expression	Value
t	= 0.0035	0.0035
Cl	= 0.4	0.4
Cvw	= 0.4	0.4
Ml	= 0.5	0.5
Sh	= 0.6	0.6
Fw	= 0.64	0.64
Cg	= 1.2	1.2
Cw	= 2	2
Cvl	= 2	2
Fl	= 3	3
cv	= 5	5
Pw	= 6	6
Pl	= 6	6
Sw	= 12	12
Sl	= 12	12

Figure 21 Parameter list

Chapter 4

4 ANALYZING SIMULATIONS AND THEIR OUTCOMES

In this section, the outcomes that remain founded after performance simulation of the designed antenna stand offered and analyzed.

4.1 The Outcome of a Simulation Using a Single Element Antenna

This study is divided into three sections, each of which provides an evaluation and discussion of the results obtained for one of three set parameters in antenna design. This study was done by monitoring seven outcome parameters. The final antenna design constraints are decided by watching antenna result parameters and the final antenna constructed with some of those design parameters.

4.1.1 Analysis the outcomes on substrate elements

This antenna design parameter includes four foam substrate components, roger RT5880. Notably, antenna size drops when VSWR substrate components are selected, although S11 parameter value does not. Instead, antenna efficiency, directivity, and gain decreased while switching from foam to FR-4. Figure 23 compares element bandwidth and S11 at 34.49GHz and 40.16GHz. Figure 24 shows 34.49GHz and 40.16GHz VSWR and antenna efficiency. Insufficient space prevented 40.16GHz parameter views. FR-4 has 4.9GHz at 34.49GHz and 5.6GHz at 40.16GHz, which is higher than Foam. Notably, antenna size drops while switching from foam to FR4, yet VSWR, S11 parameter value does not change considerably. Instead, antenna efficiency, directivity, and gain decreased while switching from foam to FR-4. Figure 23 compares the substrate components' bandwidth and S11 parameter at 34.49GHz and 40.16GHz. Figures 24,25,26,27,28 illustrate antenna efficiency, VSWR, and directivity at 34.49 and 40.16 GHz for various substrate components.

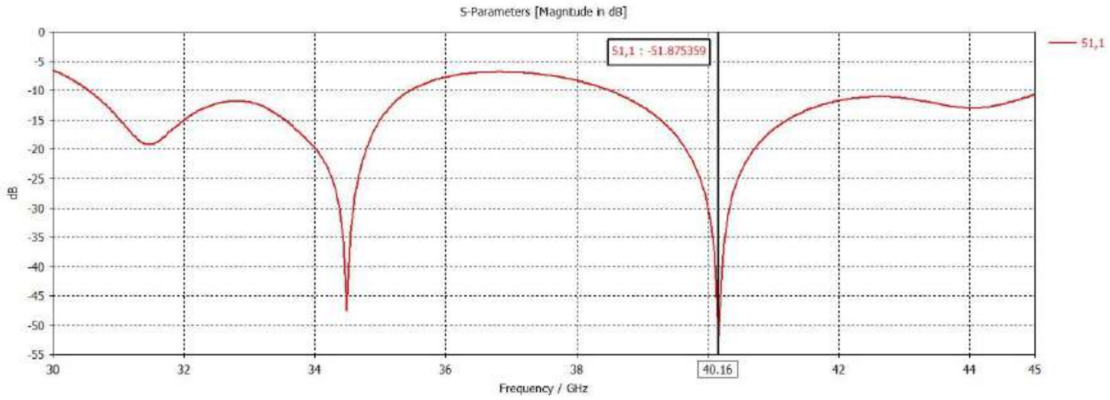

Figure 22 A view of the bandwidth and S11 parameter at 34.49GHz and 40.16GHz

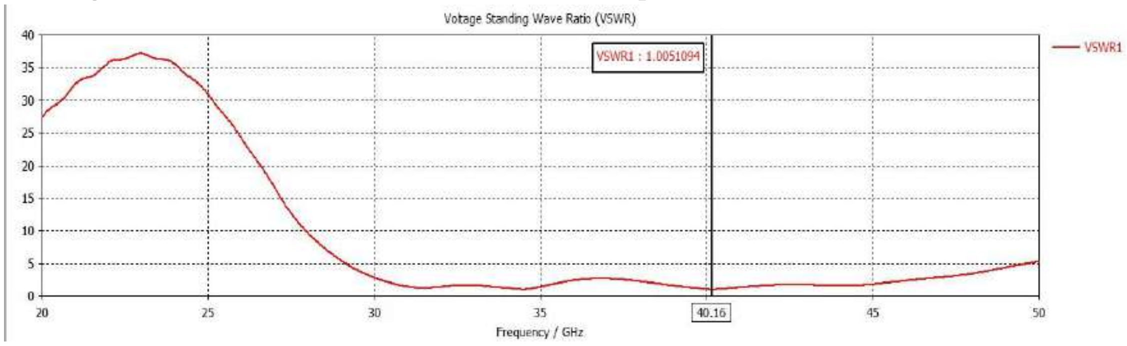

Figure 23 A view of the VSWR at 34.49GHz and 40.16GHz

The total antenna design parameters, including all of the aforementioned sub parameters, are shown for both 34.49 and 40.16 GHz. Also, the developed antenna's directivity and efficiency employing RT Rogger as substrate are 7.975 dBi and 79% at 34.49GHz and 7.975dBi and 77% at 40.16GHz, respectively. It is clear from the 5G requirement that in the future tiny cell design would need a high directivity antenna, and therefore antennas developed utilizing Foam material generate better gain than the other three substrates. This antenna's great efficiency means that 5G devices that use it won't drain their batteries as quickly.

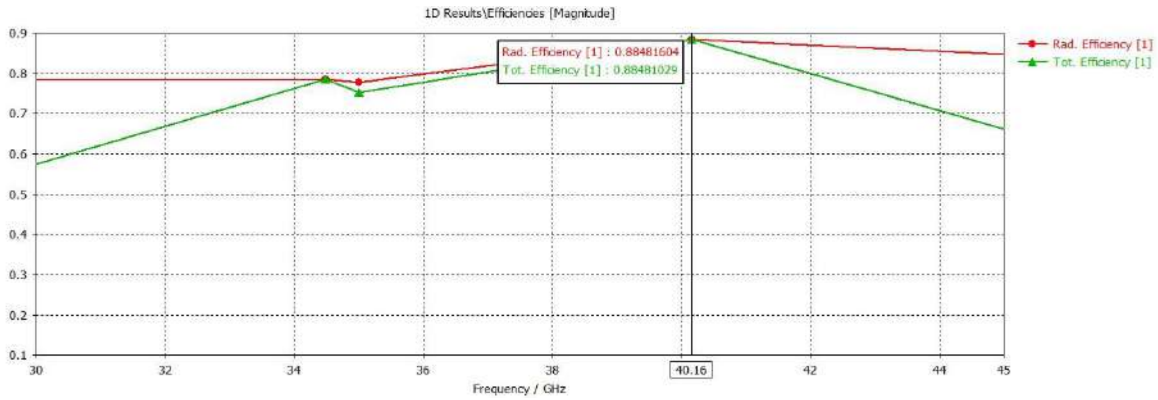

Figure 24 The efficiency of antenna elements at 34.49 GHz is shown.

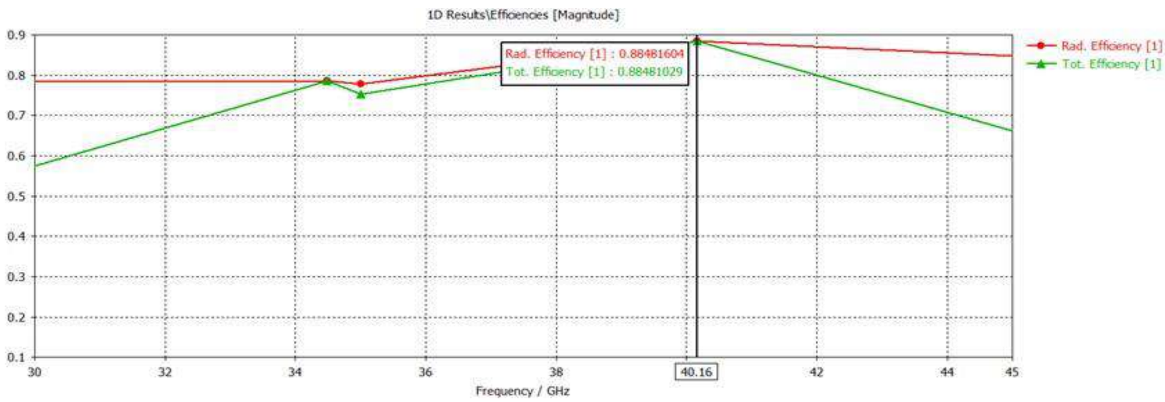

Figure 25 The efficiency of antenna elements at 40.16 GHz is shown.

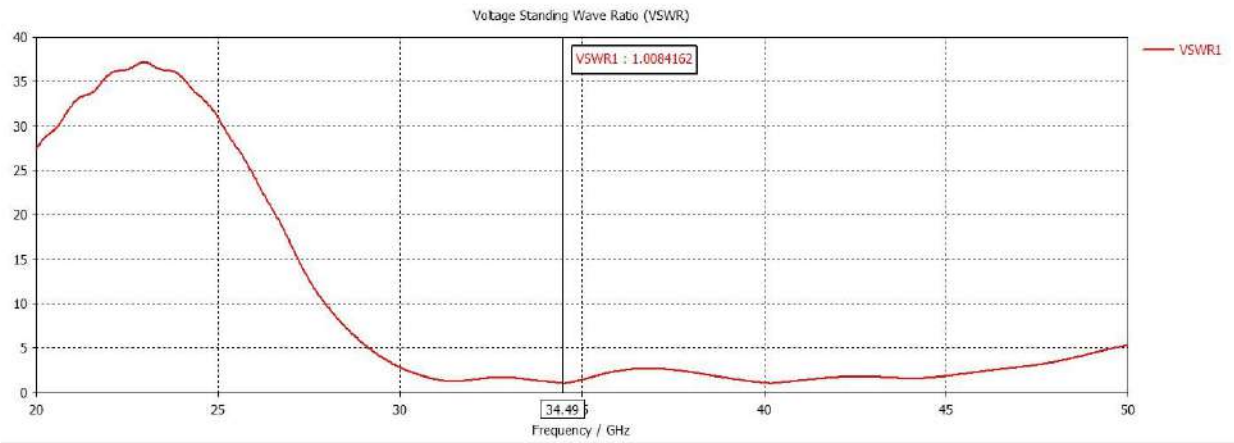

Figure 26 A VSWR of antenna elements Shown at 34.49 GHz is shown.

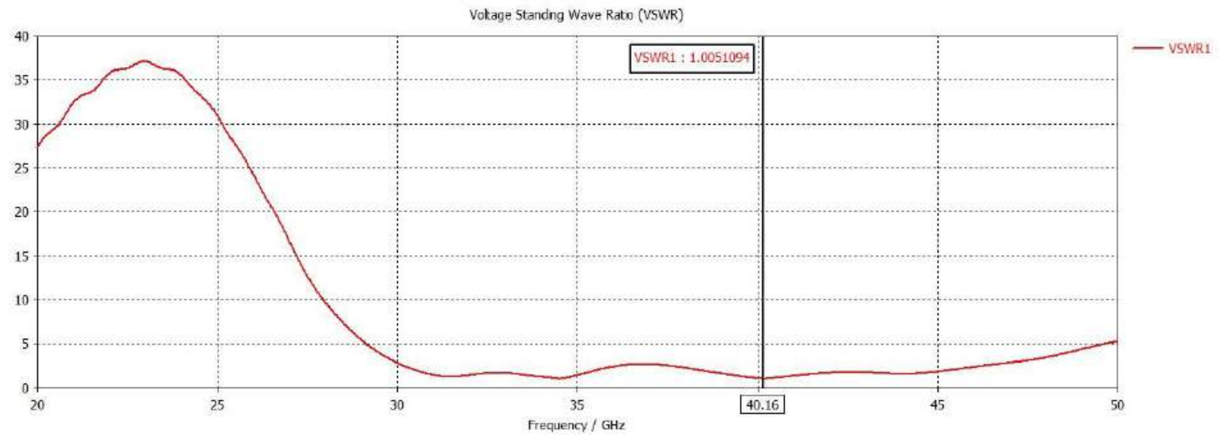

Figure 27 A VSWR of antenna elements Shown at 40.16 GHz is shown.

At the end, it's safe to say that the antenna built on a foam substrate meets all the criteria for 5G the best of the four options. In order to construct a final antenna that can function at both frequencies, Foam was chosen as the foundation material.

4.1.2 Analysis on outcomes of Different substrate heights

From the aforementioned, foam is chosen as the antenna's substrate. After that, antennas are created using various foam heights, and the results are displayed below. In Table-4.1, the findings of antennas developed with substrate heights of Sh=0.6mm and Sh=0.55mm show that directivity rises from Sh=0.55mm to Sh=0.6mm, and antennas utilizing Sh=0.6 mm covered greater directivity at 40.16GHz and 34.49GHz. When antenna substrate heights are increased from Sh=0.55 to Sh=0.6mm, antenna efficiency, return loss s11, and bandwidth decrease dramatically. The antenna size grows from Sh=0.55mm to Sh=0.6mm.

The foam antenna with Sh=0.6mm substrate height covers 5G criteria better than the other. Foam substrate height Hs=0.6mm is used for developing the final antenna for both operating frequencies.

4.1.3 Analysis on outcomes of different feeding technique

Once the two parameters for the antenna design have been decided upon via the aforementioned debate, the antenna is designed using two distinct feeding methods for the selected parameters. Here, we provide the results of our investigation of the relevant parameters for these antennas.

The data shown in Table 7 show that switching from an inset feed to a quarter wave transformer feeding approach boosts directivity and efficiency, respectively, by 7.975dBi and 78% at 40.16GHz. Additionally, productivity is raised. Additionally, the antenna with the quarter wave transformer feeding approach achieved better directivity and efficiency than the antenna with the inset feeding technique, although not showing significantly more variation. Larger, more efficient antennas with greater range of coverage are necessities for tiny cells of the future, as is well knowledge. The final antenna for both frequencies is designed using a feeding strategy based on quarter-wave transformers.

Antenna design	Directivity (dBi) at 34.49 GHz, 40.16 GHz	VSWR at 34.49GHz, 40.16GHz	S11 (dB) at 34.49GHz ,40.16GHz	Gain (dB) at 34.49GHz ,40.16GHz	Bandwidth at 34.49GHz ,40.16GHz	Size(mm2) at 34.49GHz ,40.16GHz	Efficiency at 34.49GHz ,40.16GHz
Standard [14]	7-10	1>==<2	<=-10dB	6-9	As per needed	As per needed	Above 70%
roger RT5880	7.975, 7.975	1.008, 1.005	-47.55, -51.87	6.89, 6.89	4.9, 6.66	12*12, 12*12	77, 79
Substrate height Hs=0.6mm	7.975, 7.975	1.008, 1.005	-47.55, -51.87	6.89, 6.89	4.9, 6.66	12*12, 12*12	77, 79

Table 7 Parameters of the three antenna designs, including their subparameters, are compared and contrasted.

4.2 By comparing it with the current standalone component

The accompanying Table 8 provide a comparative analysis of the planned study and the existing literature. Based on these side-by-side comparisons, it is clear that the suggested antenna, which was developed using the aforementioned three characteristics, better suited the 5G standards than the prior work.

Table 8 Analysis in Contrast to Previously Used Single-Element Antennas

Antenna ref.	**year**	**Return loss (-)**	**Gain (dBi)**	**bandwidth**	**Size (mm^2)**
[32]	2017	10 dB	6.26	4 GHz	3.7×3.25
[19]	2017	20 dB	5.42	3.5 GHz	3.25×2.3
[33]	2017	16 dB	7.8	2.5 GHz	3.2×4.23
[44]	2017	25 dB		1.1 GHz	30×19.9
[45]	2018	32 dB	8.05	600 MHz	5.17×3.15
[46]	2018	16 dB	2.28	1.2 GHz	1.2×1.4
[31]	2018	19.3	7.02	900 MHz	3.4×4.1
[47]	2018	46	6.61	470 MHz	4.02×3.58
Proposed	**2022**	**52.52 dB**	**7.409**	**11.552GHz**	**6×6**

Chapter 5

5 CONCLUSION

The primary goal of this study was to outline the microstrip patch antenna design in accordance with the 5G standards. The fact that the current antenna design complies with the unique requirements of 5G was the driving force behind this development. As a result, such an antenna does not completely comply with all 5G criteria. Three antenna design parameters—substratum components, substrate heights, and feeding methods—are used to successfully complete this project. Later, three parameters were determined for these three antenna design parameters by a study of the antenna outcome parameters, with foam serving as the substrate element, a Sh=0.5mm substrate height, and a quarter wave transformer serving as the feeding method.

Following that, single element antennas and antenna arrays constructed at 34.49 GHz and 40.16 GHz utilizing those characteristics met the 5G standards and produced results that were superior than those of earlier studies.

5.1 Achievements

This thesis successfully designs and simulates high-gain, single-element, microstrip patch antennas operating at 34.49 GHz and 40.16 GHz using a 50probe feed. This suggested antenna can function in the 34.49 GHz and 40.16 GHz bands with a return loss of less than 10 dB. The virtual antenna has a very low vertical standing wave ratio (VSWR) of less than 1, keeping the nominal value between 1 and 2. The antenna has a bandwidth of around 5 GHz, which is more than enough for any use. With a gain of 7.975 dBi at 34.49 GHz and 7.975 dBi at 38 GHz using a single element, these antennas are more compact than those identified in the reviewed literature. Furthermore, the antenna array was developed for use on both frequencies. Newer designs have included antennas with a high gain. Some of them, however, are too large to comfortably fit within mobile phones, while others don't cover the whole frequency spectrum as specified by the FCC. That's why the suggested antenna has a great chance of being included in next-gen 5G smartphones.

5.2 Limitations

The suggested antenna does not have the capacity of beam steering, which would make it more suitable for usage in mobile phones. This would make its use in mobile phones more straightforward.

5.3 Future Update of This Research

The antenna's coverage angle may be increased with the use of a beam-steering capability, which can be included. By improving impedance matching the total efficiency can be improve. Additionally, the planned and simulated antenna need to be manufactured in actuality for the purpose of seeing how it performs in a realworld setting and contrasting the results of the simulation with those measured.

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