BACHELOR OF SCIENCE
ELECTRONIC & TELECOMMUNICATION ENGINEERING

Micro Strip Patch Antenna for 5G mmwave Communication

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DEDICATION

This thesis is dedicated to all of our honored teachers and parents for their prayers and support in assisting us in reaching our goal.

CERTIFICATE OF APPROVAL

Fazle Rabbi Rayhan , bearing ID No: T171043 submitted a thesis to International Islamic University Chittagong (IIUC) Department of Electronic and Telecommunication Engineering (ETE) entitled "Micro Strip Patch Antenna for 5G mmwave Communication," which was approved as suitable for partial fulfillment of the requirements.

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CANDIDATES DECLARATION

The work presented in this thesis is hereby stated not to have been submitted elsewhere for the award of any degree or diploma, and does not contain any illegitimate declaration.

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In the name of Allah, the Merciful One, the Merciful One, the Merciful One, the Merciful One, the Merciful One, the Merciful One, the Merciful One, the Merci All praise and glory to Allah (SWT) for blessing us with numerous opportunities and showering us with mercy and guidance throughout our lives. And may Allah's peace and blessings be upon Prophet Muhammad (PUBH), who will guide and encourage us in our lives. We would like to express our heartfelt appreciation and gratitude to our thesis supervisor, Abu Zafar Md. Imran, for his research initiative in this field, as well as valuable guidance and encouragement throughout the research period. We thank Engr. Syed Zahidur Rashid, Head of the Electronics and Telecommunications Engineering Department at IIUC, for providing us with the best department facilities and timely suggestions. We are also grateful to Engr. Abdul Gafur, the thesis convener, for his dedication and sacrifice. We also want to thank all of our teachers for their tireless efforts throughout our academic careers. And we are grateful to our parents for their support throughout our lives. We would also like to thank our friends for their direct or indirect contributions to the completion

ABSTRACT

This study shows a microstrip patch antenna that can operate in the 5G mm wave band with a return loss of - 67dB, gain of 7.386 dBi, and coverage of the resonating frequency of 28 GHz. A 22 and a 44 array antenna with the same form factor as the patch have been created in CST Studio Suite. In addition, the performance of a microstrip patch antenna is compared to that of an identical array antenna in this paper. The substrate Rogers RT 5880, with a dielectric constant of 2.2, was used in all of the simulated designs. Because of its small antenna design, this is extremely useful in modern devices. Furthermore, the proposed microstrip antenna has a gain of 7.386 dBi, as opposed to the array antennas' simulated gains of 13.07 and 15.5 dBi. The patch antenna has two circular parasitic elements and two slots, which have a significant impact on how well it performs.

TABLE OF CONTENETS

CHAPTER 2

CHAPTER 3

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

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

LIST OF ABBREVIATIONS

RT	Duroid 5880
MPA	Microstrip Patch Antenna
FSE	Faculty of Science and Engineering
ETE	Electronic and Telecommunication Engineering
IIUC	International Islamic University Chittagong
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	Two Dimension
VSWR	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 Outputs

Chapter 1
Introduction

1.1 Evolution of wireless communication

The transmission of data between two or more locations without the use of an electrical wire, fiber optic cable, or other continuous controlled medium is known as wireless communication. Radio signals are used in the majority of wireless communications. With continuous advancements and growth in the mobile and telecommunications sectors, the evolution of generation bands has proven to be one of the best technologies ever seen. It all began with the 1G mobile system, which only transmitted analog signals, and was follow by 2G mobile technology, which transmitted digital signals. Following the success of the 1G and 2G mobile technologies, the 3G technology was introduced. Its successor, 3G, offered faster data transfer rates than 2G. Long Term Evolution is the name given to the fourth generation of mobile technology . Many services have been integrated into 4G, including entertainment, multimedia, mobile apps, and others. The foundations for 5G mobile technologies were OWA and Open Transport Protocol. Wireless communication is being evaluated from generation zero to generation five.

Figure 1.1: Communication evolution [1]

1.2 Technology of the zero generation

The OG process is commonly referred to as the Mobile Radio Telephone system. It was referred to as pre- cellular system. Because this system analog signals served as carriers. Traditional mobile telephony, in which PTT enables half-duplex communication, MTS, and an advanced variation of MTS, IMTS which offers a full duplex system, are the first steps in the evolution of communication. AMTS is another technology used to improve customer communication. In the communications world, these are all referred to as 0G technologies.

1.3 Technology of the first generation – 1G

The first generation of mobile wireless communication technology is referred to as 1G. Mobile telecommunications development began in the 1980s and was completed in the early 1990s. In 1980, Japan Telephone and Telegraph, based in Tokyo, introduced the world's first cellular system. In the 1980s, Nordic Mobile Telephone and were two of Europe's most popular analog systems. Other analog systems were also introduced throughout Europe. It used voice services and was based on Advanced Mobile Phone System technology. With a data rate of 32 kHz and a waveband of 825-885 MHz, the AMPS system used frequency division multiple access.

1.3.1 Features of 1G

- Frequencies of 800 and 900 MHz
- 10 MHz bandwidth
- Digital switching technology
- Voice-only mode of service
- Frequency Division Multiple Access is a type of access.

1.4 Technology of second generation – 2G

The NFAP allocates spectrum for second generation mobile services in the 900 and 1800 MHz bands. This GSM-based second generation mobile service is currently provided by five carriers. Airtel, for example, provides 2G service in the ITU-designated E-GSM band (900 MHz).

1.4.1 Features of 2G

- The electronic system (switching).
- It is possible to wander.
- Enhanced security via encrypted voice communication
- The very first internet connection with a low data rate
- Low data rate is one of the disadvantages of the 2G technology.
- Mobility issues
- Mobile devices have less functionality.
- Limited user base and hardware capabilities

1.5 Technology of third generation – 3G

The foundations of 3G technologies are CDMA and FDMA. Value-added services such as mobile television, GPS, and video conferencing are used in 3G technologies. The most important aspect of 3G technology is its high data transfer rates. In order to use broadband technology, the ITU sells multiple frequency rates. Users trust network authentication because it allows them to rely on their network as a dependable source of data transport. Because it supports all five major radio technologies, 3G technology is far more adaptable.. Because of industry collaboration, third-generation technology is now truly affordable. This arrangement was quickly implemented in order to encourage user adoption. This technology is built around wireless internet connectivity. In 2001, the WiMAX forum coined the term "WiMAX." This method does not require cables and can deliver 10 mbits/sec. It has the ability to connect you to a Wi-Fi hotspot.

1.6 Technology of four generation – 4G

It is essentially a more capable and feature-rich version of the previous 3G technology. From the consumer's perspective, though carriers believe the designation is justified because it informs the user that fast data transfer speeds are possible.. Long Term Evolution, also known as 4G, will be capable of providing mobile users with download speeds of 150Mbps and stationary customers with download speeds of 1Gbps. we can say that "4G is the fourth generation of wireless technology, enabling mobile multimedia anytime and anywhere, with global support and integrated personalized services." personal assistance In 4G networks, rate-adaptive coding techniques can be used. channel data derived from measured parameters or mobile terminal input To reduce the overhead associated with retransmission, a Hybrid ARQ method can be used. Space time codes and various antenna systems, such as smart antennas, can be used to further boost data speeds.

1.7 Technology of five generation – 5G

5G networks are cellular networks that segment the service area into small geographical units known as cells. All 5G wireless devices in a cell communicate with a cellular base station via radio waves sent via fixed antennas on frequency channels assigned by the base station. Software-defined platforms will manage networking functionality rather than hardware in 5G architectures. The 5G architecture is agile and flexible thanks to virtualization, cloud-based technologies, and IT and business process automation, allowing users to access data at any time and from any location. Network slices, which are software-defined subnetwork constructs, can be created in 5G networks. These slices can be used by network administrators to control network functionality based on users and devices. 5G also improves digital experiences via automation enabled by machine learning. Response times of fractions of a second require 5G networks to incorporate automation through ML and, eventually, deep learning and artificial intelligence. Proactive traffic and service management, as well as automated provisioning, will lower infrastructure costs while improving connectivity. Some parts of the world already have 5G service. 5G non-standalone services are the name given to these first-generation 5G services.

1.7.1 Features of 5G

- Data transfer rate 12Gbps - 114 faster than 4G and 4.5G networks.
- 900 times the bandwidth per square meter
- The number of connected devices per unit area can be multiplied up to 100 times.
- 99.999% uptime is generally expected.
- Full coverage
- 90% decrease in network energy use.

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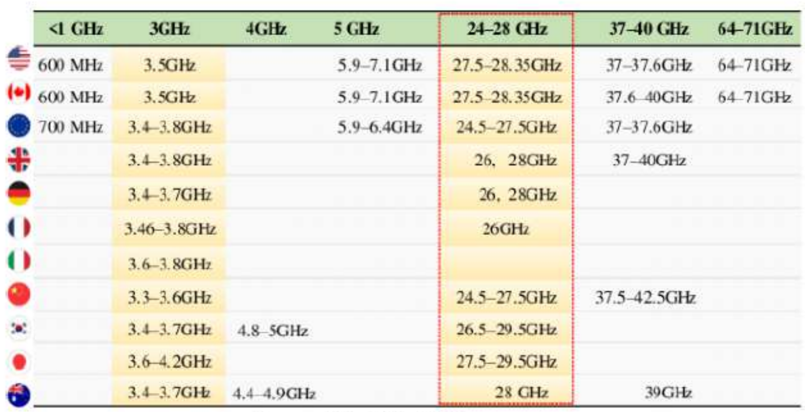
Table 1.1: Comparison generation of wireless communication technology [6]

Comparison	**2G**	**3G**	**4G**	**5G**
Introduced in year	1993	2001	2009	2018
Technology	GSM	WCDMA	LTE, WiMAX	MIMO, mm Waves

Access system	TDMA,CDMA	CDMA	CDMA	OFDM, BDMA
Switching type	Circuit switching for voice and packet switching for data	Packet switching except for air interface	Packet switching	Packet switching
Internet service	Narrowband	Broadband	Ultra band	Wireless World Wide Web
Bandwidth	25 MHz	25 MHz	100 MHz	30-300 GHz
Advantage	Multimedia features (SMS, MMS) internet access and SIM introduced.	High security, International roaming.	High speed handoffs, global mobility.	Extremely high speed, low latency.
Application	Voice calls, short messages	Video call, mobile TV, GPS	Hight speed application, mobile TV, wearable devices.	Hight resolution video streaming, robots and medical procedure.

1.8 The global 5G spectrum



	<1 GHz	3GHz	4GHz	5 GHz	24–28 GHz	37–40 GHz	64–71GHz
	600 MHz	3.5GHz		5.9–7.1GHz	27.5–28.35GHz	37–37.6GHz	64–71GHz
	600 MHz	3.5GHz		5.9–7.1GHz	27.5–28.35GHz	37.6–40GHz	64–71GHz
	700 MHz	3.4–3.8GHz		5.9–6.4GHz	24.5–27.5GHz	37–37.6GHz	
		3.4–3.8GHz			26, 28GHz	37–40GHz	
		3.4–3.7GHz			26, 28GHz		
		3.46–3.8GHz			26GHz		
		3.6–3.8GHz					
		3.3–3.6GHz			24.5–27.5GHz	37.5–42.5GHz	
		3.4–3.7GHz	4.8–5GHz		26.5–29.5GHz		
		3.6–4.2GHz			27.5–29.5GHz		
		3.4–3.7GHz	4.4–4.9GHz		28 GHz	39GHz	

Figure 1.2: Global 5G spectrum

1.9 The FCC is driving key spectrum initiatives to enable 5G

Across the low-band, mid-band, and high-band, including mmWave

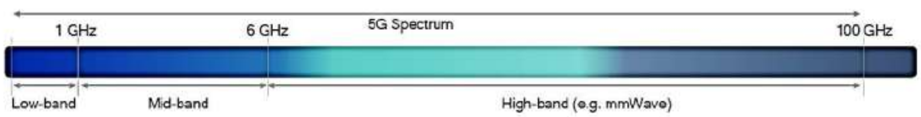


Figure 1.3: Spectrum for 5G [8]

1.9.1 Low-band

Public auction for the Broadcast Incentive

- After the assignment phase, a piece of the700 MHz spectrum was successfully auctioned off, generating 20 billion in profits.
  Contains 72 MHz of licensed spectrum and 16 MHz of unlicensed spectrum.
- The FCC allotted 4 x 3 MHz at 700 MHz for broadband, primarily for utilities.
- Spectrum availability is timed to coincide with 5G.

1.9.2 Mid-band

Residents' access to broadband radio

- 145 MHz in the 4.5 GHz range were opened up for sharing with incumbents, PAL 4 and GAA 3.
- The FCC allowed early GAA installations in September 2016, and the PAL auction was concluded in September 2019.
- The FCC awarded 4.8 4.0 GHz in March 2020. The auction is set for December 2019.
- The FCC issued NPRMs for 4.35.3.55 GHz and 4.89 4.88 GHz in September 2019. The auction of 3.45 3.55 GHz is scheduled for December 2018.
- The NTIA and FCC are looking towards repurposing 3.1 3.45 GHz for commercial usage.

1.9.3 High-band

Three mmWave auctions have been finished by the FCC, most recently the biggest auction ever.

According to the FCC's allocation of 14.85 GHz in many mmWave bands in 2015, 70% of newly available spectrum is shared or unlicensed.

- In November 2018, the FCC issued a second order allocating 25.25 22.45, 23.75 22.25, and 46.2 44.2 GHz.
- In June 2017, the FCC proposed making 26.25, 28.5, and 44.5 GHz available for flexible wireless usage.

- In the bands of 2 8 and 24, the FCC has undertaken auctions.
- The auction for the higher 35, 36, and 88 GHz bands was finished by the FCC in March 2020.
- In addition to opening spectrum above 88 GHz, the FCC is proposing guidelines for the 68, 78, and 88 GHz bands.

19.2.1 Antenna frequency

An antenna's frequency wave cycles per second. Hertz is the frequency measurement unit, and one Hz equals one cycle per second. Because the wave in Figure 1.4 oscillates three times per second, the frequency is three hertz.

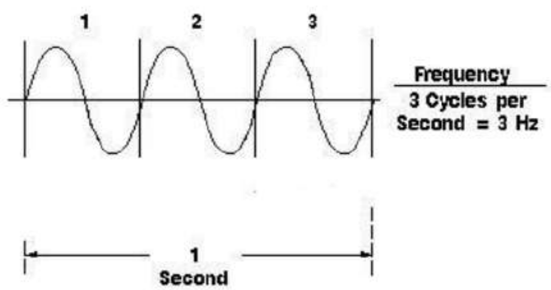


Figure 1.4: Diagram of wave frequency [10]

19.2.2 Bandwidth

Bandwidth refers to the precise rate at which data flows. It is the amount of data that can be transferred between two data points in a given amount of time. Bandwidth is used in many other technical disciplines. It is capable of wideband operation. Fractional Bandwidth is a term that is frequently used to describe bandwidth. The frequency range divided by the central frequency ratio yields the FBW. The Q antenna is also related to bandwidth.

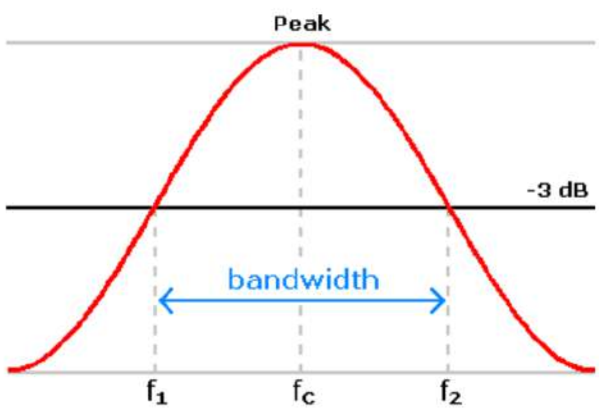
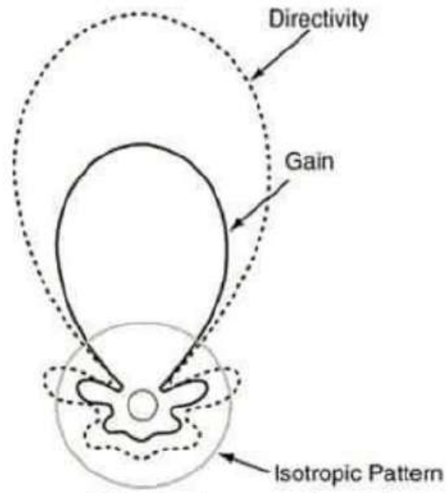


Figure 1.5: Bandwidth [11]

19.2.3 Directivity and gain



Most of the time, the reference would be the above-mentioned isotropic model's flawless spherical pattern. This value is expressed in decibels relative to isotropy, or dBi. A dipole antenna is also used as a reference, and the values are given in decibels (meaning decibels relative to dipole). Gain is a challenging specification to grasp. The gain of an amplifier and the gain of an antenna are vastly different. The amplifier, as an active device, injects energy into the system. An antenna is a passive device because it cannot generate energy. Gain is frequently misunderstood as an increase in output power over unity. In fact, this is impossible because the radiated power would be greater than the power put into the antenna.

Figure 1.6: Diagram of directivity and gain [13]

19.2.4 Radiation pattern

In general, it is the geometrical solid in space that contains all of the antenna's lobes. It is a receiving antenna's response to a signal with unit field intensity that comes from all directions. A single antenna's transmitting and receiving radiation patterns are identical. There are two types of radiation patterns to consider. These interference lobes have the same envelope as the envelope.

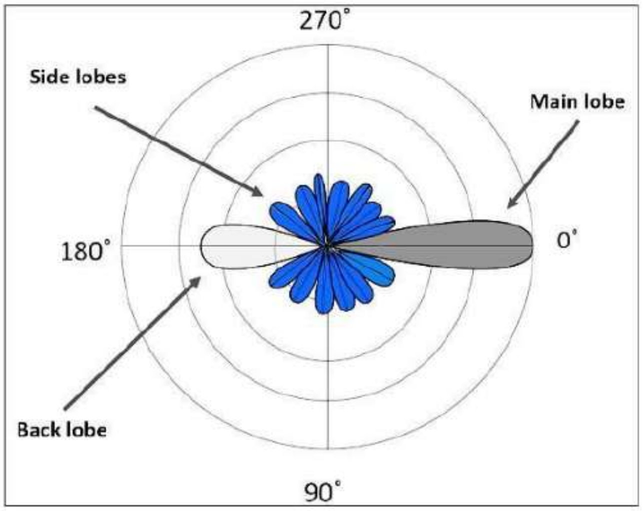


Figure 1.7: Diagram of radiation pattern [14]

19.2.5 Polarization

There are three types of antenna polarization: linear, circular, and elliptical. Linearly polarized antennas transmit RF energy in a single plane, either horizontal or vertical in reference to the Earth's surface, or at an angle between the two. Vertically polarized antennas radiate energy parallel to the Earth's surface, while horizontally polarized antennas radiate energy perpendicular to it. In theory, circular polarization is defined as a 90-degree out-of-phase linear combination of equal magnitude horizontal and vertically polarized waves. This is analogous to a wave revolving in time at a constant rate, polarized either left or right, and encompassing the horizontal, vertical, and any planes in between.

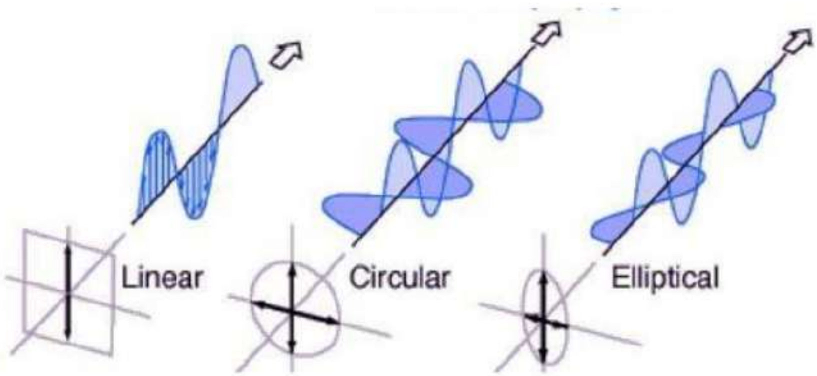


Figure 1.8: Polarization Liner, Circular and Elliptical [16]

19.3 Microstrip patch antenna

This type of antenna is gaining popularity due to its numerous advantages. Patch antennas are available in a variety of configurations and shapes. All of these variants have been thoroughly examined in recent years. There are also various feeding methods. The method of feeding an antenna can help maximize the antenna's overall performance, including return loss and radiation patterns. a microstrip patch antenna with a radiating patch on one side and a ground plane on the other The patch is usually made of conductive metals such as copper or gold and can be made in any shape. The radiating patch and feed lines are typically photo etched on the dielectric substrate. To facilitate analysis and performance prediction, the patch is frequently square, rectangular, circular, triangular, elliptical, or any other common shape. Microstrip patch antennas emit radiation due to fringing fields between the patch edge and the ground plane.

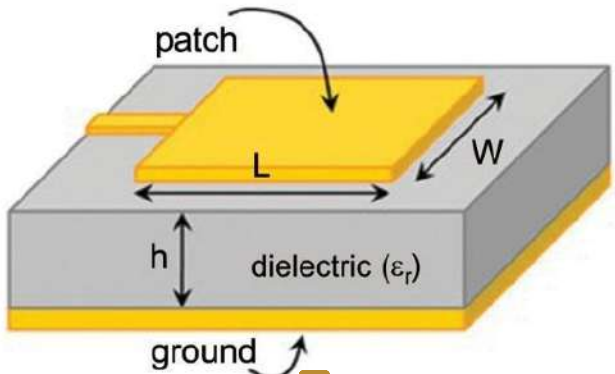


Figure 1.9: Structure of microstrip patch antenna [17]

19.3.1 Advantage of microstrip patch antenna

19.3.1.1 Maintain a low profile.

19.3.1.2 Low cost.

19.3.1.3 Linear and circular polarization are also possible.

19.3.1.4 Dual band and dual polarization are options.

19.3.1.5 No cavity support is required.

19.3.1.6 Easily integrated with microwave IC.

19.3.2 Disadvantage of microstrip patch antenna

19.3.2.1 Limited bandwidth.

19.3.2.2 Power handling is limited.

19.3.2.3 Gain is little.

19.3.2.4 It is difficult to attain polarization purity.

19.3.2.5 End-fire radiation is poor.

19.3.2.6 Extraneous radiation emitted by the feed.

19.4 Microstrip antenna feed technique

There are several feeding mechanisms for microstrip patch antennas. There are only a handful popular or commonly applied feed techniques:

- Line feed microstrip
- Coaxial probe power supply
- Feed for aperture coupling
- Feed for proximity coupling

19.4.1 Microstrip line feed

This is a feeding method. One side of the Microstrip patch is directly connected to a metallic microstrip feed.

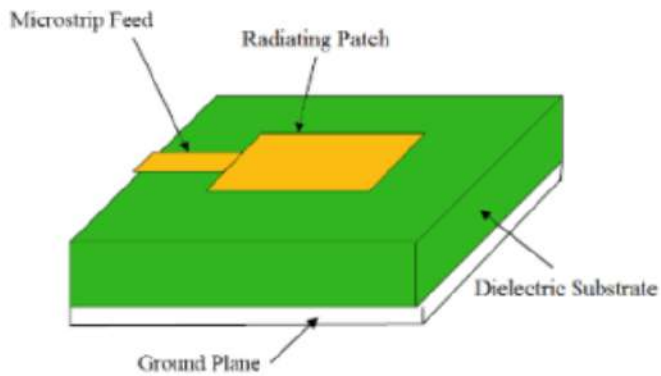


Figure 1.10: Microstrip line feed [18]

19.4.2 Coaxial probe feed

In microstrip patch antennas, this is a common feed mechanism. A coaxial connection is used for feeding in this procedure. This feeding strategy has the advantage of allowing the feed point to be placed anywhere within the radiating patch to match the input impedance.

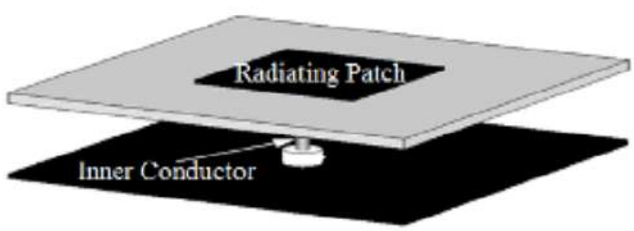


Figure 1.11: Coaxial probe feed [18]

19.4.3 Aperture coupling feed

Positioning the radiating patch and the feed line is another feeding strategy. A slot is a connecting point between the patch and the feed line. the difficulty of fabricating multiple layers, which increases antenna thickness.

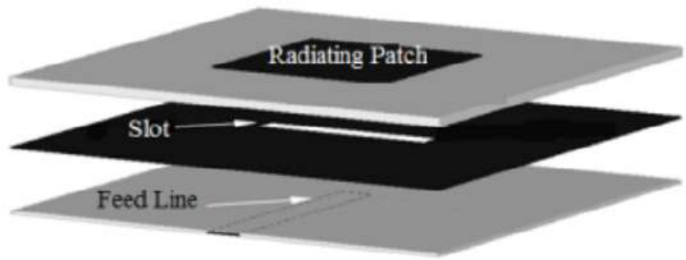


Figure 1.12: Aperture coupling feed [18]

19.4.4 Proximity coupling feed

This technique is also known coupling technique. The feed line is placed between the approach, and the radiating patch is placed on top of the upper substrate.

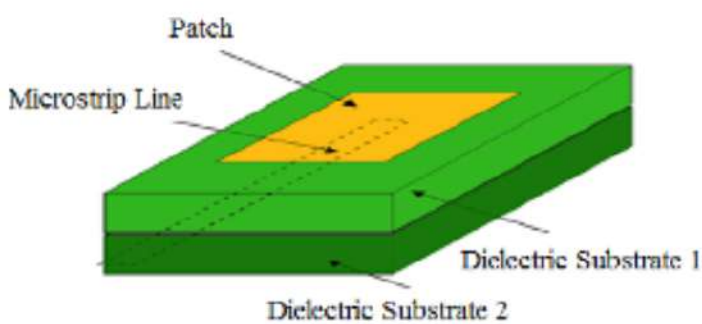


Figure 1.13: Proximity coupling feed [18]

19.4.5 CST Microwave Studio

A high-frequency electromagnetic analysis and design software suite. It simplifies the structure input process by providing a

ACIS modeling kernel-based sophisticated solid modeling front end The definition of your gadget is greatly simplified by strong graphic feedback. Before starting the simulation engine, a fully automated meshing technique is used after the component has been modeled. CST MICROWAVE STUDIO is an excellent piece of equipment. There are time domain and frequency domain solvers in the program. CST is in charge of additional solver modules for specialized applications. CAD file import filters and SPICE parameter extraction improve design options while saving time. CST provides computer solutions for electromagnetic design and analysis that are precise and efficient. Our easy-to-use 3D EM modeling technology enables you to choose the best approach for modeling and automating equipment at a wide range of frequencies.

19.5 Motivation

Wireless communication has grown in popularity over the years due to its low cost, adaptability, portability, and other benefits. As a result, demand for mobile connections and data rates has increased rapidly. Mobile data traffic has grown dramatically over the last three decades. The Internet of Things has expanded the scope of these requirements yet again. To meet this growing demand, the telecom industry has produced new generations of standards almost every decade. They have resulted in 5G, which will be deployed in the early 2018s to achieve the goals of connecting more than 120 billion wireless devices, millisecond latency, 12 Gbps data speed, and the internet of things. Path-loss at high frequencies is one of the most difficult challenges for 5G implementation, so we designed an antenna that can handle it.

Chapter 02

Literature Review

2.1 Paper Review

This chapter will discuss the work of other authors associated with the study "Performance Analysis of mm Wave 5G Microstrip Patch Antenna," which is critical for successful mobile application testing with the current fifth generation antenna (5G). An antenna model and simulator that performs better and is easier to manufacture.

1.2 A Rectangular Microstrip Patch Antenna at 28 GHz for 5G Applications

Due to the demands for small, fast, and wide bandwidth systems, communication systems have been pushed into the fifth generation. A rectangular microstrip patch antenna operating at 28 GHz is designed and simulated in this study. The patch measures 6.247 mm by 7.984 mm by 0.8 mm when compacted. The proposed antenna has a 72.18% efficiency, 13.52 dB return loss, 972 MHz bandwidth, 6.68 dB gain, and a resonance frequency of 27.892 GHz. To match the 52 microstrip feedline and radiating patch, an inset feed transmission line technique is used. A Roger RT Duroid 6543 substrate with a height of 0.5 mm and a dielectric constant of 2.2 was used in the design. It also has a loss tangent of 0.0007. Computer Simulation Technology Microwave Studio was used to calculate the antenna's geometry, and simulation results were presented and examined .

1. **28 GHz Microstrip Patch Antenna for 5G Applications**

The design and simulation of a microstrip patch antenna for 5G communication at 28 GHz are described in this paper. The antenna has a center frequency of 27.89 GHz, a maximum reflection coefficient of -12.48 dB, a very wide bandwidth of 691 MHz, and a high gain of 6.69 dB. It operates on the frequency band of the Local Multipoint Distribution Service. The transmission line of the antenna is an inset feed. The substrate, measuring 0.254 mm in height and having a dielectric constant of 2.2. HFSS was used to display and analyze simulation results, as well as calculate antenna dimensions.

2.An Ultra-Slim MIMO Antenna for 5G Smartphones

In the MIMO application of mobile devices, a low-profile wideband antenna is used. To create the antenna, inverted-F antennas are mounted to a synthetic magnetic conductor. To increase bandwidth, a surface wave mode on the AMC is excited in addition to the local resonant mode at the frequency of in-phase reflection. The design of the IFAs and their placement on the AMC produce efficient radiation in the presence of a surface wave. A 7-element MIMO antenna, for example, is designed and built. The antenna's overall dimensions are 138 mm by 70 mm by 0.95% mm. The measured efficiency exceeds 52%, and the bandwidth ranges from 3.5GHz to 3.9GHz. The working platform is unimportant.

2. A 28 GHz Microstrip Patch Antenna Design and Analysis for 5G Communication Systems

This paper describes the design and performance of a 28GHz microstrip patch antenna for fifth-generation communication systems. The antenna is designed to operate at 28 GHz and is constructed from a FR-6 substrate with a thickness of 0.288 mm and a dielectric constant of 4.8. CST is then used to simulate it. According to the simulation results, the beam has a gain of 7.398 dBi, a directivity of 7.519 dBi, an efficiency of 84%, and a bandwidth of 1.792 GHz. The proposed antenna outperforms other comparable designs in terms of bandwidth, beam-gain, return loss, and radiation efficiency. As a result, the proposed antenna outperforms previous work and could be a candidate antenna type.

3. A wideband MIMO antenna with high isolation for 5G application

This letter describes a wideband antenna design with improved isolation that covers the frequency range 1.7-4.2 GHz. The basic structure of the proposed MIMO antenna is a meandering monopole; a dual-band is generated by involving a meandering L-shape strip and an inverted-F strip, then coupling with a parasitic strip to generate wideband. You can improve the isolation between two adjacent input ports by etching two H-shape slots and two split-ring resonator slots at the ground. Vertically distributed symmetrically rotating antenna elements surround the dielectric plate. The MIMO array's overall dimensions are 57 mm by 130 mm by 10 mm. A good layout can reduce the user's impact on antenna performance, allowing each antenna element to operate normally. The prototype is being constructed, tested, and simulated

5. Optimization of Microstrip Patch Antenna Design Parameters at 28 and 38 GHz for 5G Applications

This effort was motivated by the fact that 5G antenna design is currently a significant and challenging issue. 5G antenna designers at 28 and 36 GHz are struggling to meet 5G requirements. This issue is adequately addressed in the following literature review. A single element MPA's return loss and gain are 15.8 dB and 6.7 dB, respectively, at 38 GHz, and -13 dB and 7.6 dB, respectively, at 56 GHz. The return loss was close to -14dB, demonstrating the effectiveness of the antenna. The tri-band MPA was developed to support 5G. This antenna's bandwidth was 910 MHz at 28 GHz and 460 MHz at 36 GHz. Additionally, gains of 7.20dB at 28 GHz and 5.60dB at 36 GHz were obtained. Given that the 5G bandwidth standard is 3 GHz, filling the channel bandwidth with such capacity is difficult. In addition, the increase is less than that required for standard 5G. It was created a one-of-a-kind multiband MPA with bandwidths of 5.9 GHz at 38 GHz and 8.59 GHz at 56 GHz. The entire working frequency is wasted because the expanded bandwidth consumes more battery power than the actual 5G antenna. Furthermore, at 56 GHz, the gain is 8 dB and at 38 GHz, it is 5.8 dB, which does not meet 5G requirements. Air was used as the substrate for a single-element high-gain antenna.

2. Microstrip Antenna Design with Improved Bandwidth

A new broadband patch antenna architecture is proposed in this study. To produce the suggested antenna's broadband functionality. Antenna characteristics and their effects on bandwidths are investigated for various inclination angles. The antenna has an 8.98 dBi maximum gain and a broadside radiation pattern that maximizes radiation across all operating bands. The recommended antenna construction is designed, manufactured, and tested to achieve the desired performance. When the results of the simulation and experiment are compared, it is clear that they are very similar. Traditional microstrip patch antennas' primary limitation is their small bandwidth, which severely limits usage. Engineers, scientists, and researchers began working tirelessly to increase patch antenna bandwidth as a result. To increase bandwidth, slots and notches of various sizes and shapes can be loaded onto the patch or ground plane. Although other methods of increasing bandwidth exist, this technology makes it simple to manufacture, load, and increase bandwidth without adding bulk to the structure.

4.A millimeter-wave microstrip patch antenna and a 26-element array for 5G communication.

For use in 5G communication, this paper proposed a millimeter-wave microstrip patch antenna and its 2/3 array. a relative permittivity of 2.3, was used to make the millimeter-wave microstrip patch antenna, and the substrate cut slots were filled with air. The microstrip line feeding method is used to feed this antenna, which has a relative permittivity of 1. The proposed antenna would have a return loss of 14.56 dB and a gain of 8.9 dB at 33.78 GHz. The 12-element antenna array is 4352 mm 2 in size and made of air as the heterogeneous substrate as well as low-cost RT/duroid 5880 material. At resonant frequency 30.78GHz, the 2/5 array has a return loss of 48.63 dB.

1. **Microstrip Patch Antennas with Parasitic Patches and Shorting Vias for Increased Bandwidth**

Two new microstrip patch antennas with numerous parasitic patches and shorting vias have been proposed to increase bandwidth. A standard triangle patch antenna can be extended to form two more resonances, resulting in a wider antenna bandwidth. The measured 12-dB impedance bandwidth of this antenna between 6.7 and 7.552 GHz is 18.8 percent. This antenna was also constructed and tested. This article first builds a one-of-a-kind microstrip patch antenna with numerous parasitic patches in order to construct three resonances. Two additional resonances can be achieved when parasitic patches are used in the design of the proposed antenna, greatly increasing the bandwidth. A parametric approach was used to assess the effect of dimension factors on antenna performance. The previously mentioned antenna is then fitted with two shorting vias, which allow the input impedance to be reduced at specific frequency ranges, further expanding the bandwidth. To validate the design principles, two examples of the suggested antennas were built and tested.

3.2 High Gain 4×4 Microstrip Rectangular Patch Array Antenna for C-Band Applications

A C-band satellite receiving antenna with a high gain is required to connect with the long-distance wireless transmission between the ground station and satellite. Microstrip antennas have several advantages over other types of antennas, including low profile, ease of fabrication, ease of feeding, ease of integration with other microstrip circuit elements and systems, and ease of use when used in an array to boost directivity. This paper proposes a microstrip array antenna with a 44-rectangular patch radiating element, microstrip line feeding, and quarter-wavelength transformer impedance matching. Higher directivities and higher gains are the goals of the array antenna technique. This study took into account a FR-4 Epoxy substrate with thickness and dielectric constant of 1.6 mm and 4.3, respectively, to deploy the antenna structure, respectively The antenna design is parameterized and designed to simulate using CST Microwave Studio for the best performance. The overall gain of the 4*4 microstrip rectangular patch array antenna is 13.7 dB, and the return-loss graph shows that its working bandwidth is 734 MHz, spanning frequencies of 3.794 and 4.528 GHz. According to these results [42], the proposed antenna design is suitable and promising for C-band satellite applications.

2. Linear 4 4 Array Design Using Substrate-Integrated Waveguide Patch Antenna for 28GHz mm-Wave Applications

This paper describes the design of a modified and substrate-integrated wave guide-fed linear array patch antenna for millimeter-wave applications at 28GHz. The first step is to add slots to each element of a 4 x 4 array structure, which are then used to excite patches. The port count was reduced from N2 to N in the subsequent design. Only this A 4 x 4 array antenna requires two ports to be configured. This feeding technique reduces fabrication costs as well as circuit complexity. The substrate integrated wave guide feeding technique has a low side-lobe power level and suppresses side-lobes. The proposed system produced average gain values of 7.2dBi while having a reflection co-efficient of 18.5dB across the band.

Chapter 3

Methodology

3. 1 Methodology

The formal, theoretical examination of the techniques used in a field of study is known as methodology. It entails a theoretical assessment of a variety of approaches and beliefs relevant to a specific field of study. Norms, theoretical frameworks, stages, and quantitative or qualitative research methodologies are all common concepts. A technique is a predetermined sequence of steps or methods. This phrase can refer to a field or industry's customs, such as the research techniques used in a specific study. A methodology, on the other hand, differs from a technique in that it does not seek to provide answers. A methodology is concerned with providing theoretical support to determine whether an approach or set of procedures is applicable in a given situation [50].

3.2 Research Design

The research design serves as the framework for addressing the study's problems. A study project model specifies research tools such as an experimental design, a research question, dependent and independent variables, data collection methods, and a statistical analysis plan.

The research design for the study was as follows:

- Analyzing of the development of 5G technology.
- Studying requirements of the antenna for 5G networks.
- Choosing the millimeter wave band for 5G.
- Researching the literature on current 5G antennas and microstrip antennas.
- Studying The process of creating a microstrip antenna needs to be researched.
- Determining the variables required to build an antenna.

- Finding the ideal dimension values for different parameters like the patch length, patch width, substrate thickness etc.
- Determining the ideal design for 5G applications requiring high bandwidth.
- Choosing your feeding strategy.
- Executing the procedure.

3.3 Pilot Study

A pilot study, pilot project, pilot test, or pilot experiment is carried out as a small-scale experimental study before beginning a full-scale research project to determine the feasibility, time, cost, hostile occurrences, and develop the nature of the study. It is finished before the research is organized. Pilot studies are typically conducted in the manner intended for the research. A pilot study cannot completely eliminate systematic errors or unanticipated issues, but it significantly reduces the number of errors so that the initial study does not waste time or effort.

Importance of Pilot Research:

- To put the protocol and/or study procedure to the test.
- To categorize critical variables and decide how each should be functionalized.
- To develop or evaluate This project's goal is the efficacy of research tools and procedures.
- To evaluate statistical elements in order to set up future research.

3.4 Software

The Technology for Computer Simulation Microwave Studio, a sophisticated tool for modeling high-frequency components in three dimensions. CST MWS can analyze high-frequency devices such as filters, couplers, antennas, single- and multi-layer structures, as well as SI and EMC effects, accurately and quickly. CST works by discretizing Maxwell's integral equation, according to the Computer Simulation Technology manual. CST Microwave Studio is also said to use central finite difference methods to compute time derivatives. Several books claim that when combined with the FDTD method, CST is effective.

due to its unmatched performance. CST MWS is an easy-to-use tool that provides quick insight into the EM behavior of high-frequency designs behavior [51].

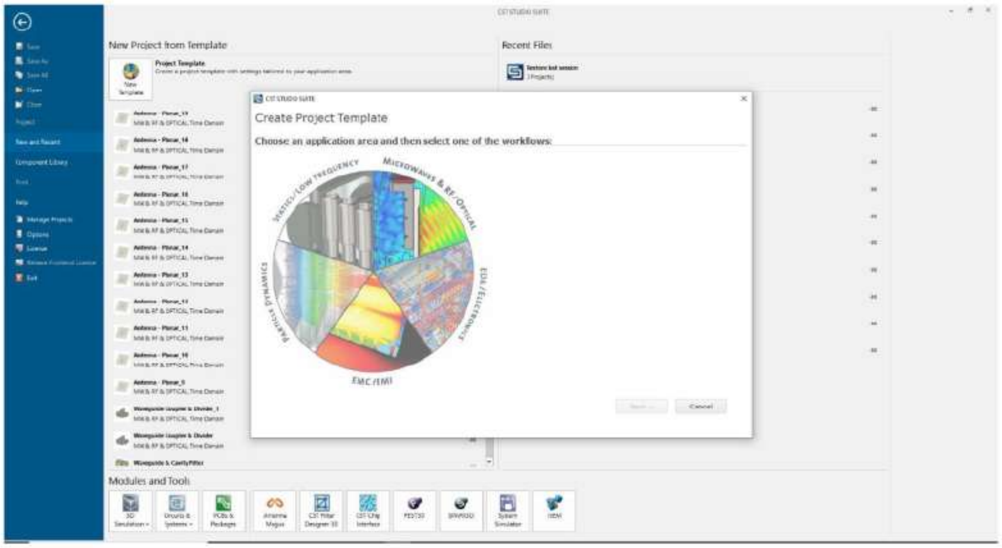


Figure: 3.1 Starting window of CST studio suite application

3.5 Design procedure

Step 1: The first step is to design an microstrip patch antenna, or single rectangular microstrip patch antenna , which is intended to operate in the 28 GHz band.

Step 2: Save the designed antenna and simulate the antenna built.

Step 3: Save the outcome if the antenna satisfies the criteria

Step 4: Optimize the parameters of the antenna to improve the performance of the antenna.

Step 5: This step involves designing a 4x4 array of planar antennas that is intended to improve gain, efficiency, reflection Coefficient and directivity.

Step 6: Save the structure and test the antenna array that was constructed.

Step 7: Save the outcome if the antenna satisfies the criteria.

Step 8: Optimize the parameter of antenna array that is designed to improve performance.

Step 9: To Improve the performance of the designed Microstrip patch array antenna further design a 5x5 array of planar antennas that is intended to improve gain, efficiency, reflection Coefficient and directivity.

Step 10: Save the designed antenna and simulate the antenna built. If the outcome isn't satisfactory, optimize the design.

Step 11: Save the outcome if the antenna satisfies the criteria having to improve gain, efficiency, reflection Coefficient, bandwidth and directivity.

Step 12: Compare the results to those 3x3 array, 5x5 array antennas with single rectangular microstrip patch antenna .

3.6 Antenna Design by Equation

The first step in antenna design is to choose an appropriate dielectric substrate with the required thickness. Dielectrics help to maintain mechanical and electrical stability. They are used to reduce antenna size and aid in the generation of displacement current, which produces a magnetic field that varies in strength over time according to Ampere's Law. This time-varying magnetic field, according to Faraday's rule, can result in a time-varying electric field, which can then result in a propagating electromagnetic field. In this method, a substrate can be used to improve the antenna's radiating capabilities. provides a list of common dielectric substrates and their properties.

Table 3.1: Substrates List

Name of the Dielectric Material	Dielectric constant
FR-4	4.4
RT Duroid-6002	2.94
Rogers RO 3200	3.02
Rogers RT Duroid-5880	2.2
Rogers RT Duroid-5870	2.33
Nylon	3.4
Teflon	2.1

Equations (1) -(5) were used to measure the length and width of the antenna [3].

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

Where, c = Velocity of Light (3×10^8□□$^{-1}$)

Effective dielectric constant is given by,

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

Where,

□□□□= Effective dielectric constant,

Dielectric constant of substrate, □r = 2.2

Height of dielectric substrate, h =0.50 mm

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

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

The actual length of the patch is given by,

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

Where,

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

The basic parameters of the microstrip patch antenna are calculated using the formulas above and are shown in Table 3.2.

Table 3.2 Antenna Dimension

Parameters	mm
Substrate Length	6.36
Substrate width	9.43
Substrate Thickness	0.5
Patch Length	3.18
Patch width	4.71
Patch Thickness	0.035
Ground Length	6.36
Ground Width	9.43
Ground Thickness	0.035
Feed line length	4.04
Feed line Width	0.45
Gap Width	0.20
Parasitic Element	0.4(Outer radius) 0.035(Height)
Slot 1 Length(V)	1.80
Slot 1 Width(V)	0.07
Slot 2 Length(H)	0.20
Slot 2 Width(H)	3

This table shows the parameters that were used for the single element antenna radiating at 28 GHz in mm wave 5G.

3.7 Antenna geometry and designed parameters

The first step is to select the dielectric material that will act as the antenna's substrate. calculate a number of parameters with good dimensions The proposed antenna is constructed with Rogers RT 5880 as the substrate material and copper conductor material for the patch and ground planes 4.2 and 4.3.

3.7. 1 Microstrip patch Antenna

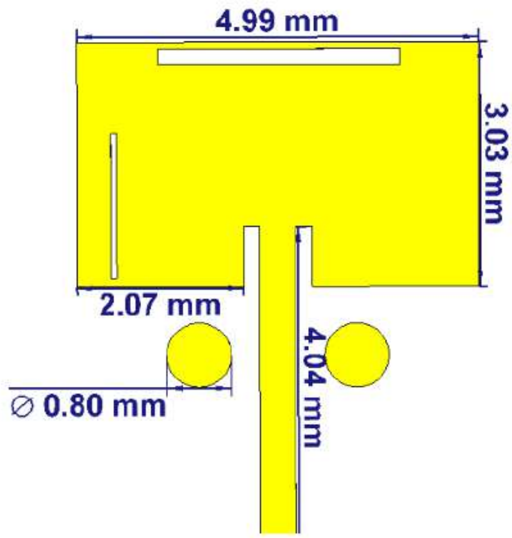


Figure 3.2: Top view of the designed Microstrip patch Antenna

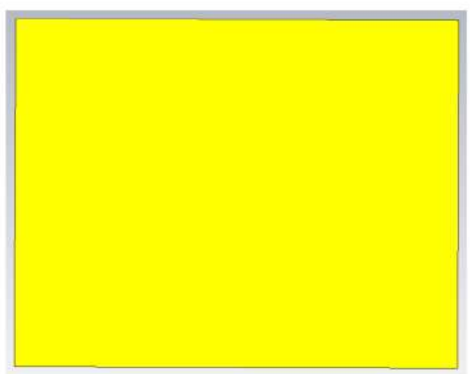


Figure 3.3: Back view of the designed Microstrip patch Antenna

Calculates the suggested antenna design parameters for 28 GHz using the equations from the antenna approach section. The substrate's height was set to 1.5 mm. This parameter may change in the future as a result of the analysis.

With the same from factor of the patch and Substrate a 2×2 and a 4 ×4 Microstrip array antenna has been designed. In the result analysis section, the simulated results of the microstrip patch antenna and array antennas were discussed.

3.7.2 2×2 Microstrip Array Antenna

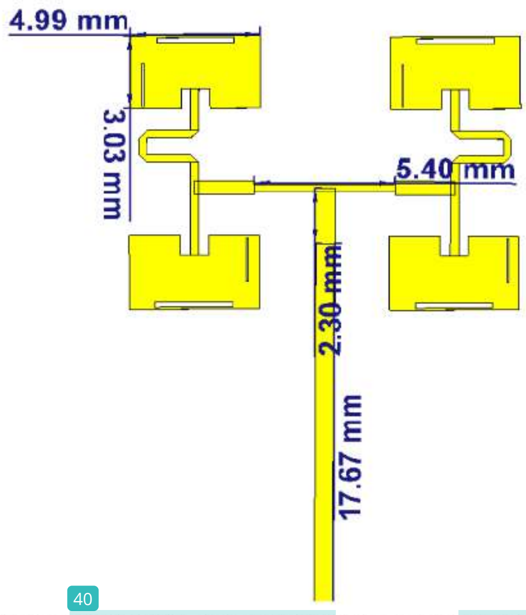


Figure 3.4: Top view of the designed 2×2 Microstrip Array Antenna

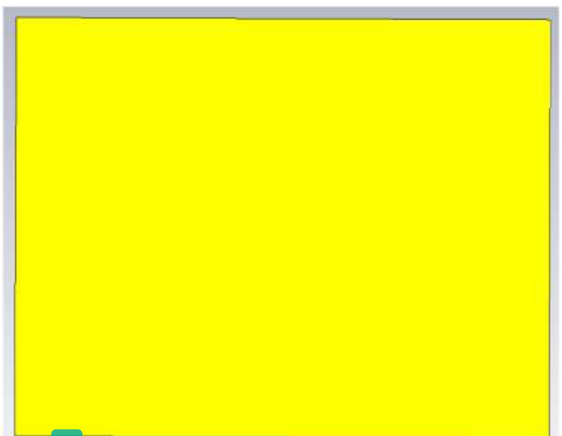


Figure 3.5: Back view of the designed 2×2 Microstrip Array Antenna

3.7.3 4×4 Microstrip Array Antenna

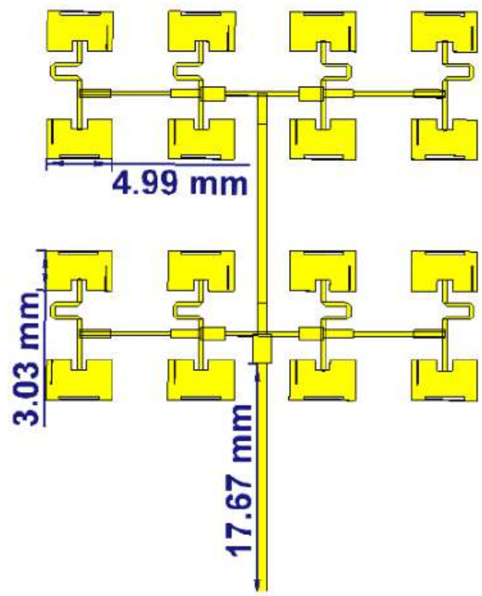


Figure 3.6: Top view of the designed 4×4 Microstrip Array Antenna

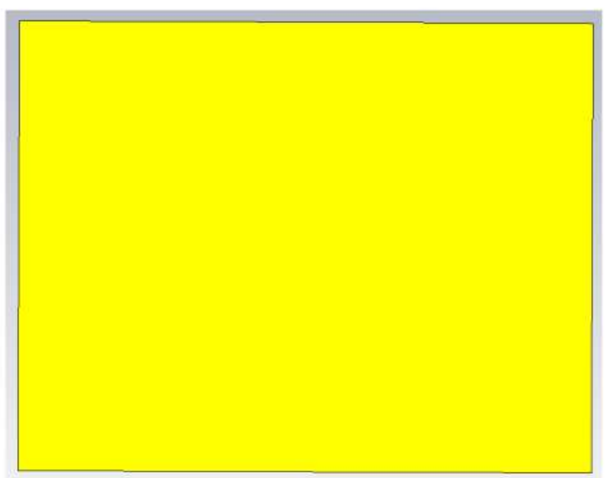


Figure 3.7: Back view of the designed 4×4 Microstrip Array Antenna

Chapter 4
Simulations and Result's Analysis

4. 1 Simulation Results of the Designed Antenna

This section's investigation and discussion of the results focuses primarily on different antenna parameter dimensions. During the analysis, all of the parameters presented in this study were tracked. The appropriate antenna is then constructed using those design parameters.

4. 1. 1 Result analysis of the Designed Antenna

The proposed design process and variables for a mm-wave microstrip patch antenna will be calculated using an RF calculator by adding the desired resonant frequency, the dielectric constant, and the substrate thickness. After entering the values for E=2.2, thickness 0.5mm, and resonating frequency of 28 GHz, the patch's calculated dimensions are 3.18mm in length, 4.71mm in width, and 0.035mm in thickness.

4.3 Optimized Simulation Results

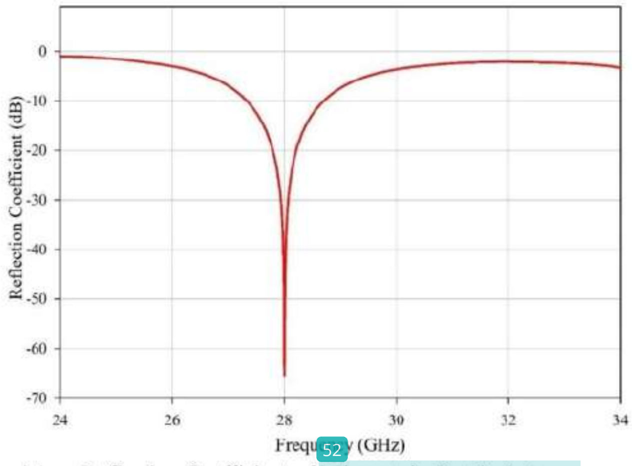


Figure 4.1 Reflection Coefficient of Microstrip Patch Antenna

the more easily the antenna will fit into a device or transmission line. The proposed Microstrip patch antenna has an S11 parameter of -58 dB and a bandwidth of 2.578 GHz, while the 23 microstrip

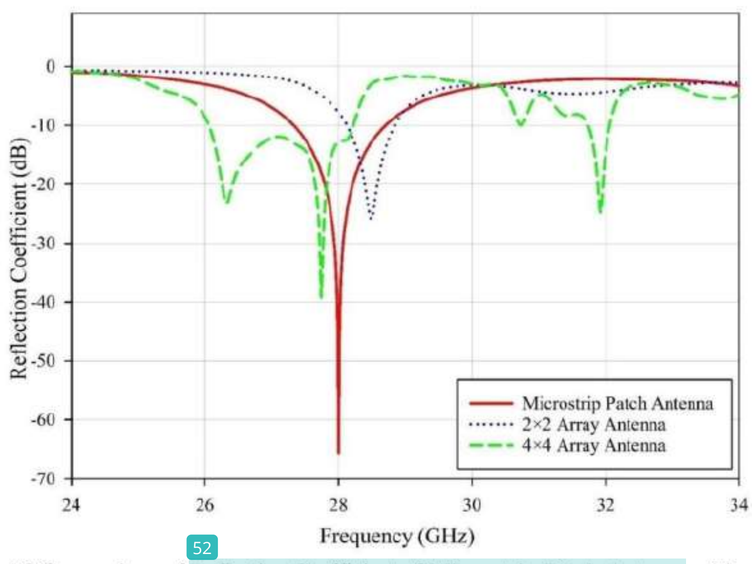
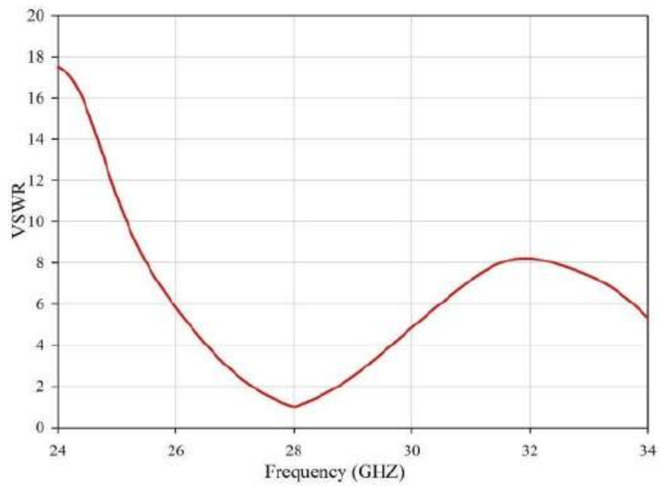


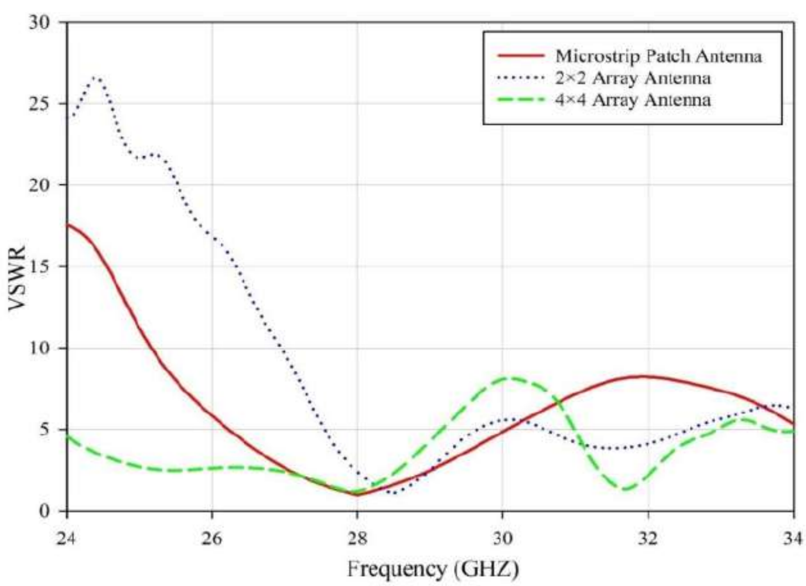
Figure 4.2 Comparison of Reflection Coefficient of Microstrip Patch Antenna with array

4.2.2. Voltage Standing Wave Ratio (VSWR)

The VSWR of an antenna indicates how well it is impedance matched to the radio or transmission line to which it is connected. A VSWR of 3.0 to 4.0 is required. The proposed antenna has a VSWR of 1.003 at 28 GHz, which means that almost no power is reflected from the antenna in this case, which is ideal.

Figure 4.3: VSWR of Microstrip Patch Antenna





4.2.3 Gain and Directivity

The amount of power that an antenna can transmit in the direction of peak radiation is defined as its antenna gain. The antenna has an excellent gain of 7.534 dBi for a small form factor compact microstrip antenna. Gain is an important factor in determining an antenna's performance. To increase our profit, we have altered our performance. A microstrip array antenna aids in achieving a higher gain. Gain in a 22 microstrip array is 13.07 dBi, while gain in a 44 microstrip array is 15.5. The highest gain of the antenna in one direction is known as directivity. Directivity follows the same pattern as gain; higher directivity is obtained by moving to a larger element array.

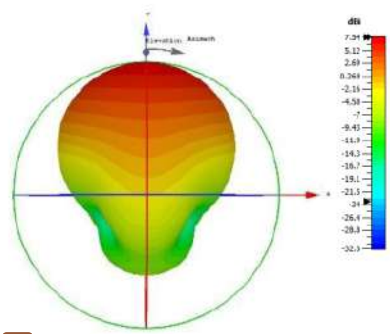


Figure 4.5: Microstrip Patch Antenna Gain

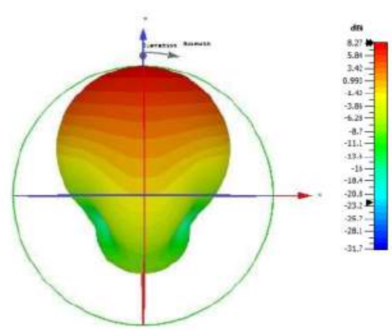


Figure 4.6: Microstrip Patch Antenna Directivity

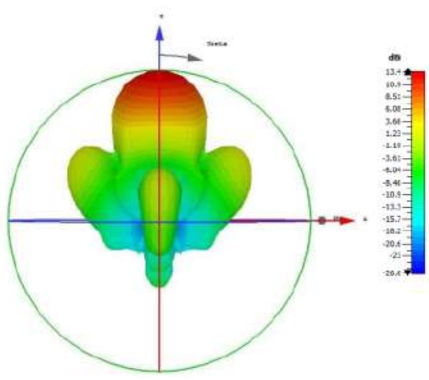


Figure 4.7: 2×2 Array Antenna Gain

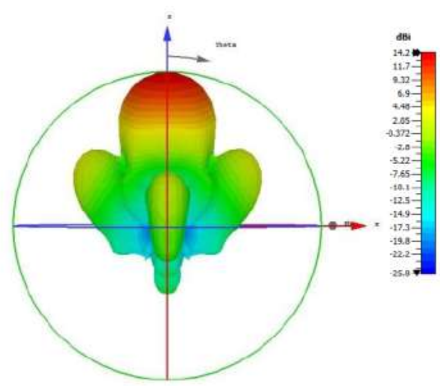


Figure 4.8: 2×2 Array Antenna Directivity

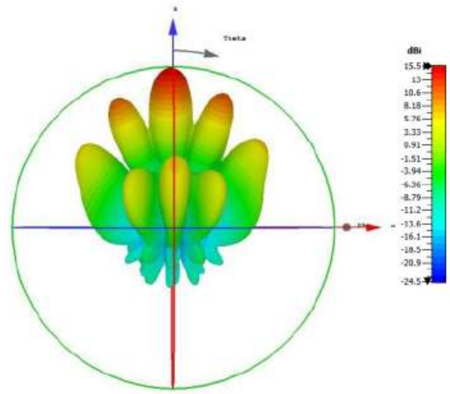


Figure 4.9.: 4×4 Array Antenna Gain

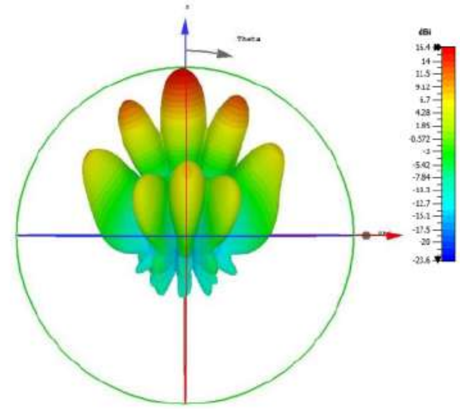


Figure 4. 10: 4×4 Array Antenna Directivity

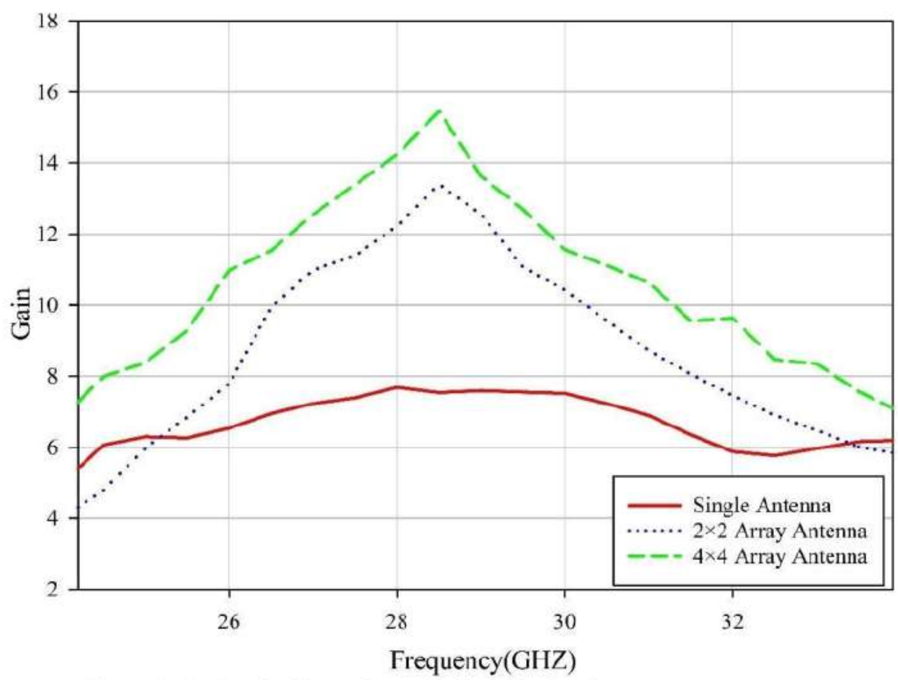


Figure 4.11: 1D gain Comparison of Microstrip Patch Antenna vs Array Antenna

4.2.4 Efficiency

An antenna's efficiency is defined as the ratio of power delivered to the antenna to the power radiated by the antenna. The majority of the power available at the antenna's input is radiated away in a high efficiency antenna. The majority of the power in a low efficiency antenna is absorbed as losses within the antenna or reflected away due to impedance mismatch. The proposed antenna has an efficiency of 84%.

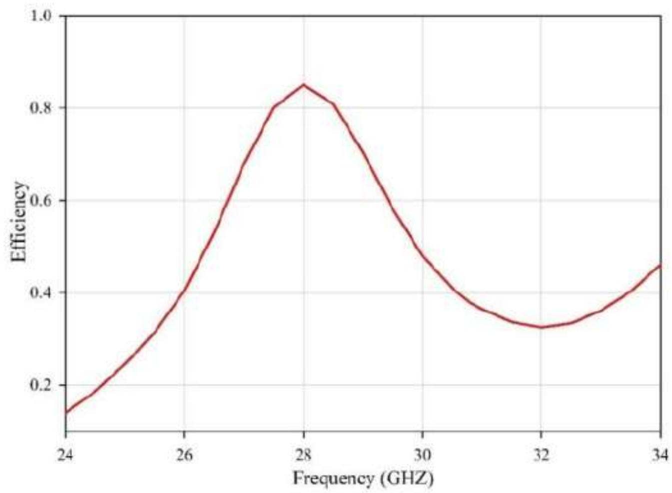


Figure 4.12: Efficiency of Microstrip Patch Antenna

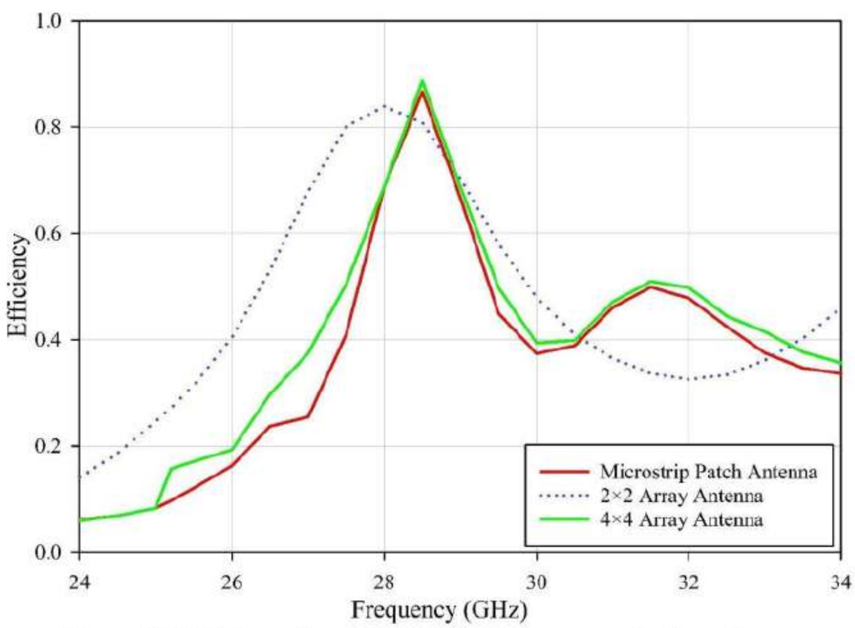


Figure 4.12: Efficiency Comparison of Microstrip antenna Vs Array Antenna

4.2 Comparison

The following table compares mm Wave microstrip patch Antennas. According to the comparison table, our proposed antenna has a significantly better reflection coefficient than the other antenna, with a reflection coefficient of -58dB. Furthermore, when compared to the other antenna in that table, our proposed antenna has a significantly higher gain.

Table 4. 1 Comparison Table Array with Recent Research Work

Reference	Gain	Bandwidth	S11(dB)	Efficiency
[1]	6.72 dB	1.1 GHz	-17.4dB	N/A
[2]	6.87dBi	0.87GHz	-27dB	N/A
[3]	6.14 dBi	N/A	<10dB	N/A
[4]	5.126dBi, 5.011dBi	N/A	-17 dB, -20.45 dB	N/A
[5]	6.63 dB	847 MHz	-13.48 dB	70.18%
[6]	6.69 dB.	582 MHz	–12.59 dB	N/A
[7]	5.14dB			N/A
[8]	5 dBi and 6 dBi	5.5 GHz, 8.67 GHz	-25.8/ -27.8 dB	N/A
[9]	5.32 dBi	4.10 GHz	-39.70 dB,	N/A
[10]	7.44 dBi	N/A	-20, -27, -40 dB	N/A
Proposed Antenna: Slotted microstrip patch antenna	7.6 dBi	1.57GHz	-67dB	86%
2×2 Microstrip Array Antenna	-25.75 dB	13.07 dBi	-28.75 dB	86%
4×4 Microstrip Array Antenna	-21.66 dB	15.5 dBi	-38.86 dB at 27.74 GHZ & -24.47dB at 31.9GHz	88%

Chapter 5

Conclusion

The primary goal of this research was to develop a 5G compatible microstrip patch antenna. We attempted to change the dimensions of the parameters in an attempt to improve the project's results, which significantly increased the antenna's bandwidth, return loss s11, and VSWR. Using those characteristics, a single-element antenna operating at 28GHz was built, meeting 5G requirements and outperforming previous trials. The fact that current antennas fall short of 5G's exact requirements motivated this work. As a result, we altered the parameter dimensions to make this task more efficient, which had a significant impact on the antenna's bandwidth, return loss, and VSWR.

5. 1 Achievements

A reflection coefficient of -67dB, gain of 7.6dBi, bandwidth of 1.57GHz, efficiency of 86%, and it resonates at 28 GHz, which is licensed in mm wave in the United States, Canada, the United Kingdom, Germany, Australia, Japan, and South Korea. The substrate is Rogers RT 5880 with a permittivity of 2.2, and the patch and ground are copper aeneled. In this study, the results of a 22 microstrip array and a 44 microstrip array with the same from factor are compared, resulting in an overall good performance.

5.2 Limitations

Efficiency and From factor are concerns with the proposed array antenna. We need to make improvements to these parameters for microstrip patch antennas in order to make them more useful for 5G applications.

5.3 Future Work

According to previous findings and simulation analysis, our proposed array antennas from factors were all below average when compared to previous research. More work may be required to minimize the consequences.

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