BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATION ENGINEERING

Design A 5G ANTENNA SUB-6GHz FOR WIRELESSCOMMUNICATION

Submitted by

Md. Ariful IslamT-181049

Supervised by

Engr. Md. Razu Ahmed

Professor & Chairman

Dept. of Computer and Communication Engineering

International Islamic University Chittagong

Department of Electronics and Telecommunication Engineering

International Islamic University Chittagong Kumira, Sitakunda,Chittagong

CERTIFICATE OF APPROVAL

The project report on " **Design A 5G ANTENNA SUB-6GHz FOR WIRELESS COMMUNICATION**" Submitted by **Md Ariful Islam(T-181049), Mohammad Zobair (T-181082)** in partial fulfillment of the requirements for achieve the Bachelor degree of Science in Electronic and Telecommunication Engineering (ETE) and accepted as to style and contents by:

Board of Examiners

Engr. Abdul Gafur Associate Professor Dept. of ETE, IIUC	Convenor
Engr. Syed Zahidur Rashid Associate Professor Dept. of ETE, IIUC	Chairman
Engr. Md.Razu Ahmed Chairman, Dept of CCE	Supervisor

DECLARATION BY CANDIDATES

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.

MD. Ariful Islam

____

Md Ariful Islam T-181049

Acknowledgements

In the name of the all-powerful, forgiving Allah. All thanks and glory belongs to Allah (SWT), who has provided us with a wealth of chances as well as mercy and wisdom throughout our lives. The Prophet Muhammad (SM), who has guided and inspired us throughout our lives, may Allah's peace and blessings be upon him.We value Engr. Md. Razu Ahmed, our thesis advisor, for his work in this area of study, as well as his helpful advice and motivational support during the research process. We are grateful to Sayed Zahidur Rashid, head of the IIUC Department of Electronics and Telecommunication Engineering, for providing us with timely advice as well as the department's top-notch facilities. We also thank our thesis convener, Md. Humayun kabir Rabbi , our thesis co-advisor, for his dedication and sacrifices. Additionally, we would like to thank all of our professors for their dedication to helping us succeed academically. We also remember the lifelong assistance provided by our parents. We also like to express our gratitude to our friends and well-wishers for their direct or indirect support in helping us finish this thesis.

Abstract

Due to their low cost, small profile, and simplicity of production in circuit boards, micro strip antennas have become a crucial component of modern electronics. The newest phase of wireless communication is known as 5G. While used separately, the 4G and 5G bands have been employed in many nations. In order to construct a dual-band microstrip patch antenna for both 4G and 5G applications, that is the main goal of this study endeavor. The antenna runs at 2.6GHz for 4G applications and 4.5GHz for 5G applications and was built and tested using CST Microwave Studio. The gains of this microstrip patch antenna are 7.1 dBi and 7.2 dBi, respectively, while the reflection coefficients are -19.99 dB (VSWR = 1.263) and -35.79 dB (VSWR = 1.03). Both frequencies exhibit directivity above 8dBi and a combined efficiency of at least 75%+. Due to its excellent gain performance, this dual-resonance antenna can be included into communications systems.

TABLE OF CONTENTS

Contents

LIST of SYMBOLS

Short Form	Full Form
Hz	Hertz
KHz	Kilo Hertz
MHz	Mega Hertz
GHz	Giga Hertz
MM	Millimeter
CM	Centimeter
M	Meter
ε	Relative permittivity
L	Length
W	Width
C	Speed of light
Db	Decibel
Λ	Lambda
Ω	Ohm
ε_r	Dielectric Constant

LIST OF ABBREVIATIONS

RT	Droid 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	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 Output

Figure List

List of Table

Chapter 1

1 Introduction

1.1 Evolution of Wireless Communication

The transfer of information between two or more places that are not physically connected is known as wireless communication, or simply wireless. For further details, visit "Telecommunication" on wikipedia. The most widely utilized wireless technologies make use of radio waves. The term "wireless" has appeared twice in the history of communications, each time with a somewhat different meaning. Up until the new word radio supplanted it in 1920, it was largely used for the first radio wave transmission and receiving technology around 1890. In the 1980s and 1990s, the phrase was once again used, mostly to describe digital equipment that could connect wirelessly. Services like long-distance communications are provided through wireless operations, which are neither practicable or practical to perform using wires.We are currently in the fifth generation of communication evolution [1].

Figure 1 Evolution/Enhancement of communication [1].

1.1.1 Zero Generation Wireless Technology (0G)

Zero generation refers to the early 1970s pre-cellular mobile phone system. Some subscribers had radio telephones prior to the invention of cell phones. I A portable radio telephony system serves as the foundation for contemporary cellular mobile phone technology. They are referred to as 0G (Zero Generation) Systems since they were the precursors to the first generation of mobile phones.

The technologies used in Zero Generation systems included Push to Talk (PTT), Mobile Telephone System (MTS), the Telephone Service (IMTS), Advanced Mobile Telephone System (AMTS), Norwegian Offending Land-Mobil Telephone (OLT), Public Land Mobile Telephony (PLT), and Swedish Mobile Telephony System D. (MTD). Users of the system included loggers, construction managers, realtors, and celebrities. The communication mechanism allowed for just voice communication [2].

1.1.2 First Generation Wireless Technology (1G)

The term "1G" refers to the analogue-based first-generation wireless telephone technology. They made their debut as analog cell phones in 1980. The first cellular system was introduced by Nippon Telephone and Telegraph (NTT) in 1979 and went live in Tokyo, Japan. The most widely used analogue systems in Europe were Nordic Mobile Telephone (NMT) and Total Access Communication System (TACS). Along with these two, a number of other technical companies introduced analog systems throughout Europe in the 1980s. Cellular network solutions, on the other hand, are unable to provide handover and roaming capabilities as well as interoperate across national boundaries [6].

One major problem of first-generation mobile technologies is that they do not work together across national borders. Additionally, 1G has poor voice communication, a faulty handoff system, and inadequate capacity. There were The Federal Communication Commission uses the 800-900 MHz frequency range (FCC). Expanded spectrum, or 10 MHz more capacity, was granted to AMPS in 1988. (ES).

In Italy, France, and the United Kingdom, the RTMI, Radio COMM, and YACS communication systems were employed. The C-450 telecom standard was adopted by Portugal, South Africa, and West Germany.

The 0G system, which featured mobile radiotelephones and innovations including the Push to Talk (PTT), Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), and Improved Mobile Telephone Service, was superseded by the 1G system (IMTS).

- It was started in the '80s and completed in the '90s.
- It allowed for data transfers at up to 2.4 kbps.
- Advance mobile phone system (AMPS), a first-generation mobile phone system, was first established by the US.
- Users can only make voice-over calls to other countries using this technology [2].

1.1.3 Second Generation Wireless Technology (2G)

Digital technology were used to create the Second-Generation wireless network in the 1990s. The first nation to adopt 2G was Finland in 1991. It provided features including the Multimedia Message Service (MMS), Short Message Service (SMS), and photo messages (MMS). Similar to 2G, digital encoding allows data to be communicated such that only the intended recipient can receive and decode it. Text messages and audio signals are digitally encoded in this manner. The 2G network is safer for both the transmitter and the receiver. A digital signal CODEC is used for 2G multiplexing and compression (compression-decompression algorithm). Digital multiple access technologies, including as TDMA and CDMA, were used in the 2G system. For communication over a multiplexed channel, TDMA splits the signal into time slots, whereas CDMA gives each user a different code. In the The Global System for Mobile Communications (GSM), Personal Digital Cellular (PDC), IS-136, and iDEN are TDMA technologies. The Digital Enhanced Cordless Telecommunications (DECT) standard is used for portable mobile phones. GSM was the original 2G network. Out of all mobile wireless technologies, it is the mobile standard that is used in more than 212 countries throughout the world.GSM technology was the first to offer cross-border roaming between several mobile phone operators, enabling users to use their phones internationally. GSM employs TDMA technology to multiplex up to 8 calls per channel in the 900 MHz and 1800 MHz frequency ranges. Up to 14.4 kbps of circuit-switched data and speech can be transmitted through it. A new block of Spectrum was also put up for auction in the US by the FCC Band 1900 MHz. Over the past 20 years, this technology has undergone continuous improvement to provide better services. On the foundation of the original GSM, numerous fresh technologies have been industrialized, including certain cutting-edge systems referred to as 2.5 generation (2.5G) systems [2].

1.1.4 GPRS (General Packet Radio Service) 2.5G

A mobile wireless standard known as 2.5G, which stands for "second and half generation," was created in the interim between its predecessor, the second generation, and its successor, the third generation. The "General Packet Radio Services" are referred 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 Wireless Application Protocol (WAP), Access Multimedia Messaging Services (AMMS), and internet features like email and World Wide Web (WWW) access. While conventional circuit switching for data communication bills each minute of connection time, GPRS often charges by the megabyte of traffic transferred

1.1.5 Third Generation Wireless Technology (3G)

Organization for Telecommunications Standardization The third generation of wireless communication technologies, or 3G, is what is used to describe them. It replaces 2.5G and comes before 4G. In order to offer a single, constant wireless network standard for all nations on the earth, the International Telecommunication Union (ITU) has proposed using the global frequency range of 2000 MHz.The strategy is referred to as the "International Mobile Telephone 2000 Standard"(IMT-2000). One of three different forms of multiple access technology, CDMA 2000 was proposed by North American wireless telecommunication standards groups and is based on Code Division Multiple Access technologies. It can go up to 144 Kbps and has a channel width of 1.25 MHz. UMTS (WCDMA): FOMA, the first global commercial WCDMA service launched by NTT Do Como in 2001, to Japan. Its formal name is Wideband Code Division Multiple Access. Its maximum speed is 2 Mbps, and its channel width is 5 MHz.Three-generation (3G) Time Division Synchronous Code Division Multiple Access (TD-SCDMA) technology was proposed by the China Wireless Telecommunication Standards Group [6]. The project has been continued by the Third Generation Partnership Project (3GPP), which has created a wireless system that complies with the IMT-2000 requirements.The third generation, or 3G, of wireless technology became accessible in the year 2000. Peak data transfer speeds were formerly limited to 144 Kbps, but 3G has increased this to 2 Mbps. You'll need a smartphone or a multimedia mobile phone to use 3G technology. In 3G, data transfer rates and capacity were increased to enable web-based apps, audio, and video files are easier to access.By boosting network capacity through increased spectral efficiency, network operators can offer their users a more amazing assortment of more cutting-edge services as a result of the implementation of 3G technology.The 3G system features accessible in a portable wireless environment include video conferencing, mobile television, broadband wireless data, wide-area wireless phone calls, and GPS service. The following benefits of this network over the prior 2.5G network are listed [#]:

- Significantly faster data transfer rates.
- Updated streaming of audio and video
- A video conferencing system
- increased lightning-fast WAP and Web browsing speed
- Support for IPTV (TV over the Internet)

1.1.6 Forth Generation Wireless Technology (4G)

The fundamental idea behind 4G is network interoperability, which enables high-speed data transfer rates like 100 Mbps for both the server and the data receiver moving at 60 kph. The data transfer rate should not exceed 1 Gbps when the server and receiver are stationary.

Today's mobile networking technologies include 4G, which has replaced third-generation networks in many nations. To address the limitations and difficulties of 3G, which are difficult to implement and are capable of achieving its specified performance and performance, 4G is merely an academic and research and development laboratory effort. We may now access the internet using a variety of technologies, including Wi-Max, Wi-Fi, WAP, GPRS, EDGE, and Wi-Bro in 3G, using our mobile phone to access the internet. Users are stranded when traveling to a location where interoperability between several networks is established when attempting to access the internet via a cell phone using any of the aforementioned technologies. While traveling from a location that supports 4G, users can connect to the network via any of the aforementioned technologies from one location to another The following problems are considered to be fixed in the 4G mobile network:

1. The phone transmits and receives vast volumes of data quickly. The 4G wireless technology has added an IP capability to the mobile phone for better security.

2. With the fourth-generation wireless standard, mobile network users can download at 100 Mbps for mobile access and 1 Gbps for fixed access.

3. The new technology adopted in 4G, OFDMA, replaces the hybrid technology used in 3G that combined CDM A and IS-95. OFDMA is more efficient than TDMA or CDMA in the past.

4. To boost efficiency, OFDMA allocates the channel into a narrow band for data transmission, a distinctive element of fourth-generation wireless technology.

5. The IEEE 802.16e-developed Wireless Mobile Broadband Access (WMBA) standard will serve as the 4G specification. This indicates that the internet is accessible. When downloading data from any website, the execution is being created to avoid call jumble. It will represent a remarkable advancement in 4G wireless technology with a downlink data throughput of 128 Mbps and an uplink data rate of 56 Mbps. The service's limitation is the need for a hotspot for internet connectivity.

6. LTE is intended to work with Microsoft Access' Worldwide Interoperability to integrate a wireless system for the broadband system into 4G mobile phones (WiMAX). WiMAX and LTE differ from one another. The same TCP/IP fundamentals acquired from the IP address computer network architecture. Higher data transfer rates, lower latency, and bandwidth control are all provided. Because CDMA technology is compatible with 4G or LTE, data may be backed up across the two networks.

7. IEEE 802.16m and LTE are the two most important wireless technologies that 3GPP will introduce. One authorization will be issued first, and the other will be considered before becoming a part of the fourth generation wireless system. As of June 2009, IPv6's 4G wireless version is allowed [2].

1.1.7 Fifth Generation Wireless Technology (5G)

The fifth generation, or 5G, of wireless communication standards is scheduled to be put into use by 2020. 5G promises to make wireless networks more accessible to one billion electronic devices by increasing capacity, boosting data transfer rates, and reducing latency. This is one of the technology-related subjects that receives the most attention and promises to make cars, virtual reality (VR), and the Internet of Things more accessible (IoT). For instance, no formal or standard 5G document has been completed by telecom firms or authorities associated with 3GPP, WiMAX, or ITU-R.

The next-generation (5G) wireless technology for mobile devices is meant to be the best available. These days, wired communication is all but useless, and cell phones are used for a range of tasks in addition to transmission. Prior wireless technology facilitated data sharing and phone calls. However, the fifth generation is pushing things even farther and creating a fully mobile experience for people.

1.1.8 Features of 5G

A. Links to field end points at 1 to 10 Gbps.

B. The delay of 1msa.

C. A 1000x bandwidth unit region.

D. A 10-100x network of connected devices.

E. A 99.999 % availability rate.

F. 100% protection.

G. The energy consumption of the system has been reduced by 90%.

The final section of this article provides a look back at current wireless systems and the upcoming generation of wireless communication technologies in the following table. In the years to come, these new technologies will have a long journey, and amazing and exciting features will be created [2].

Table 1 GENERATION OF COMMUNICATION

Generation	**Speed**	**Technology**	**Time period**	**Features**
1G	14.4 Kbps	AMPS, NMT, TACS	1970 –1980	Wireless phones are only utilized for voice during 1G.
2G	9.6/ 14.4 Kbps	TDMA, CDMA	1990 to 2000	Multiplexing allows numerous users to share a single channel, resulting in 2G capabilities. Cellular phones were utilized for data as well as voice during the 2G era.

2.5G	171.2Kbps 20-40Kbps	GPRS	2001-2004	The internet is spreading, and the information becomes moresuitable.Streaming and multimedia services aregrowing.Celltelephones began supporting web browsing, albeit there was only a limited number of mobile phones.
3G	3.1Mbps,500-700 Kbps	CDMA-200 UMTS, EDGE	2004-2005	Multimedia and streaming services are supported. Access and mobility between multiple sorts of devices, such as telephones and

3.5G	14.4Mbps, 1-3 Mbps	HSPA	2006-2010	Increases throughput and speeds to accommodate more info.

4G	100-300 Mbps. 3-5 Mbps 100Mbps(Wi-Fi)	WiMax, LTE, Wi-Fi	Now (Read more on Transitioning to 4G)	4G speeds are further boosted tocomply with the demand for data access used by different services.4G currently supports high definition streaming.New surface HD powered phones.
5G	1-10 GBps	Massive MIMO, Beam forming, mm wave	Soon (probably 2020)	No5Gtechnology is currently in operation. This willgiveconsumers exceptionally high speeds when it is accessible. The usage of availablebandwidth would likewise be efficient.[#].

1.1.9 Global 5G spectrum update

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

Figure 2 Global 5G spectrum [6-7]

1.1.10 The FCC is driving key initiatives to enable 5G

Low-band, mid-band, and high-band frequencies, including mmWave, are all covered.

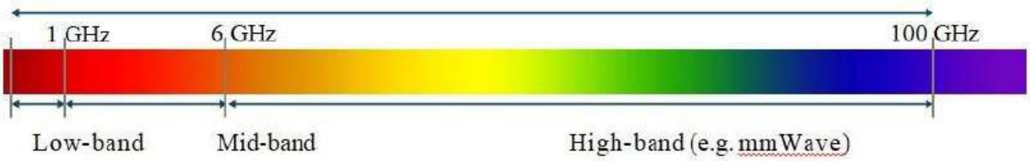


Figure 3 5G Spectrum (10-12)

1.1.11 Low-band

public sale with a reward for media coverage.

1. Following the assignment phase, an auction for a piece of the 600 MHz spectrum was successful and brought in $19.8 billion.

2. Two licensed channels on 70 MHz, with an additional 14 MHz for unlicensed use.

3. 5G and spectrum access are occurring at the same time.

1.1.12 Mid-band

Residents of Broadband Services

a. The initialization of the 3-layer PAL1, GAA2 sharing spectrum in the 150 MHz band.

b. In order to construct the best 5G, the FCC published PAL instructions in 2017.

c. The CBRS Alliance was formally launched to create an ecosystem based on LTE.

d. The inquiry at 3.7-4.2 and 5.9-7.1 GHz was reported to the FCC. (#)

1.1.13 High-band

December 2016 and December 2, 2017 for Frontier Spectrum

1. Available in a number of mmWave bands at 11 GHz.
2. Shared or unlicensed music makes up 70% of new band releases.
3. As a result, it was agreed that the FCC requested comments on the other IMT-2020 branded Spectrum nomination.
4. With the addition of 24.25-24.45, 24.75-25.25, and 42-42.5 GHz. (#)

1.1.14 High-band: Spectrum Frontiers ruling for 5G

More bandwidths require the use of the unlicensed and conventional spectrum. Broadcasting licenses

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

Shared and unlicensed Spectrum

1. 37 GHz–37.6 GHz
2. 64 GHz- 71 GHz [10-12]

1.2 4G Global Spectrum

Over 1,000 band combinations now supported for LTE U.S. / Canada

- 600/700/850 MHz (FDD)
- 1700/1900 MHz (FDD)
- 2300/2600 MHz (FDD/TDD)
- 2500 MHz (TDD)

Europe

- 450/800/900 MHz (FDD)
- 1800/2100 MHz (FDD)
- 2600 MHz (FDD/TDD)

India

- 800/1800/2100 MHz (FDD)
- 1900/2300/2500/2600 MHz (TDD)
- 850/1800 MHz (FDD)
- 2300 MHz (TDD)

South Korea

- o 850/900 MHz (FDD)
- o 1800/2100/2600 MHz (FDD)

Japan

- o 700/850/900 MHz (FDD)
- o 1500/1800/2100 MHz (FDD)
- 2500/3500 MHz (TDD)

China

o 700/850/900 MHz (FDD)

o 1800/2100/2600 MHz (FDD)

o 2300 MHz (TDD)

Australia

o 700 MHz (FDD)

o 1700/1800/1900 MHz (FDD)

o 2600 MHz (FDD/TDD)

Latin America

- 800/1800 MHz (FDD)
- 2300 MHz (TDD)
- 2600 MHz (FDD/TDD)

MENA

- 700/850/900 MHz (FDD)
- 1800/2100/2600 MHz (FDD) [3].

1.3 5G Global Spectrum

Top 10 countries with the most widespread 5G in 2022.A VIAVI Solutions report from 2021 indicated that there were 1.662 cities globally with access to 5G,a rise of more than 20% over the course of the year [4].

- South Korea

As of September 2020, the nation had well over 9 million 5G subscriptions, and by 2025, that number is predicted to rise to 40 million.

- The United States

According to the Cellular Telecommunication Industry Association (CTIA), the rapid adoption of 5G technology might lead to investment of US$275 billion and economic growth of US$500 billion [4].

•The United Kingdom. ...
Back in 2019, 5G 5G networks were being commercialised by UK mobile operators, despite the growth in adoption due to the availability of 5G handsets.

• Spain
90% of the population will have access to 5G by 2022, according to Spanish multinational telecommunications major Telefónica.

• Canada
Although 5G is still a relatively new technology in Canada,telcos are nevertheless working to expand their networks as quickly as they can.

The nation's mobile download speeds have historically been in the top ten in the world,but the new 5G technology has enhanced the network's speed by 205% over its forerunner, 4G.

• Australia
Telstra, the country's largest telecom provider, has set up more than 2000 5G base stations, which cover 41% of the population.The telco also plans to reach 75% of the population in order to offer 5G services throughout Australia.

• Italian operator Wind Tre has started operations in 59 regions and eight regional capitals, while Vodafone's 5G services already cover 90% of Mian.

• Finland
Elisa, a Finnish telecom operator, has a 100-location 5G network that almost 50% of the population of the nation. By the end of 2020, more than 1.8 million Finnish homes have access to high-speed 5G technology thanks to 3000 mobile network carriers scattered over 109 municipalities.

- Saudi Arabia

Saudi Arabia is actually a frontrunner in 5G, thus its inclusion on this list may come as a surprise. By 2030, the nation anticipates a market of $45 billion for new IoT devices powered by 5G. Saudi Telecom now boasts the most extensive 5G coverage, investing US$12 billion in improving digital infrastructure in partnership with private businesses and operating at a median speed of 370.12 Mbps.

- China

The nation has produced 128 million 5th-generation phones, erected 961,000 5G base stations, connected 365 5G terminals, and shipped 5G devices.

Insisting that 28 GHz frequencies be used to make 5G bands accessible to the general public, the United States has taken the lead globally in this effort. The two nations that have offered this to the mainstream market most recently are South Korea and Japan.

A variety of factors affect how effectively your 5G phone can utilize 5G networks, with South Korea, Sweden, the UAE, Norway, and Qatar topping the ranks for 5G performance. Cellular networks are 5G are a broadband technology that has received the most attention in the last ten years [5].

1.4 Antenna Basics

A unique type of transducer, an antenna transforms radio-frequency (RF) energies into electrical energies or the other way around. The two main types are the transmitting antenna, which produces a radio-frequency field while being supplied electrical energy from the equipment, and the receiving antenna, which absorbs RF energy and supplies alternating current to the apparatus. The microstrip patch antenna is the most used antenna in wireless applications, and patch antennas from Microstrip are primarily exclusively sensitive to microwave frequencies [6].

1.4.1 Frequency

In the traditional definition, frequency refers to how frequently an event occurs through time. The amount of events that take place at a specific time is fundamentally what is meant by the term frequency. The frequency is known as the frequency of a repetition signal with a specific duration, according to the accepted definition (1 second). The periodic signal repeats every 'T' seconds, or named period. All that periodic signal frequency is is time's antithesis (T). In engineering, frequency is used to quantify the frequency of oscillating and vibrational phenomena like waves, sound, mechanical vibrations, and light. The international system's "Hertz" unit of frequency is named after the German physicist (Hz). A repeating event or signal that occurs once per second is indicated by one hertz.

1.4.2 Bandwidth

In communication systems, bandwidth is the ability of a wired or wireless communications system link to deliver the most data possible via a computer network or internet connection in a predetermined amount of time, often one second. The frequency range that an antenna can effectively transmit or receive energy is referred to as its bandwidth. When picking an antenna, bandwidth is typically one of the most crucial determining variables. For instance, several antenna types have extremely small bandwidths and cannot be used for wideband operation.

1.4.3 Input Impedance

The antenna input impedance is defined as the voltage-to-current ratio at an antenna entrance terminal. The antenna resonance is expressed by this crucial antenna characteristic. The input impedance is divided into two parts: the real and the imagined. the appropriate section of The antenna power that is either absorbed or subtracted from the radiation is represented by impedance. The imaginary part of the input impedance, or the reflected power, is the power held in the near field of the antenna. A resonant antenna is one with a real input impedance of zero and no imaginary impedance. The antenna input impedance is determined by the size and length of the antenna. Radius Radius and Rhombic Osmic losses are included in the fundamental component of impedance, marked as Z, and the reactive part, denoted as X, is indicated as Impedance with a sincere interest.

1.4.4 Impedance Matching

The approximate resistance value of a transmitter is said to be resistance matching when it is sufficient to, or the other way around to, the approximate value of a receiver impedance, according to the standard definition. Impedance matching between the antenna and the circuit is necessary for wireless transmission. According to the theory, the impedances of the antenna, transmission line, and circuitry must all be compatible to conduct the greatest power transfer between an antenna and the recipient or broadcaster. Tuning or correlating to the antenna with a number of circuits are terms used to describe the antenna impedance approach. VSWR is a measure of the match quality, and bandwidth is the frequency range where the antenna impedance is close to 50 ohms for a given VSWR. Matching Is Required:Over a narrow frequency range, a resonant device gives off better output. If their impedances match, antennas are deep devices with superior production.

1. The power from the source will successfully be provided to the feed line if the impedance of the feed line and the source are the same.

2. The feed line’s power will successfully transfer to the antenna if the impedance of the antenna matches that of the feed line.

3. When using a receiving antenna, the input impedance of the receiver amplifier circuit should match the antenna's impedance.

4. For a transmitter antenna, the input impedance of the antenna should be compatible with the output impedance of the transmitter amplifier and the transmission line impedance.

1.4.5 Directivity and Gain

When referring to an antenna's ability to transmit energy in a certain direction or to receive energy more effectively from a given focus, the term "directivity" is used. And gain is often described as the ratio of the energy produced by a hypothetical lossless isotropic antenna that is equally sensitive to signals from all directions to the power provided by a far-field source on the antenna's beam axis. Gain and directivity are mutually exclusive. The relationship between a light bulb and a spotlight is explained by the higher directivity phenomena. In certain ways, a 100-watt light is brighter than a 100-watt light bulb. In other others, it is less bright. One could claim that the lightbulb is more The sunlight acts as a highly directed antenna and is more tiny and "directive" than a light bulb. Gain is the practical value of the guide, and an increase in mathematics is equivalent to an improvement in efficiency and direction. The relationships between revenue and directivity are contained in a new metric (), known as an antenna efficiency [6].

1.4.6 Radiation Pattern

The directional (angular) dependence of the radio wave intensity on the antenna is referred to as the radiation pattern in the antenna design (also known as the antenna or a distant field pattern). The relative field strengths that are radiated from the antenna in various directions at a constant distance are known as the radiation pattern. The radiation pattern describes the relative strength of the field that is radiated from the antenna in various directions over a continuous length. Since the receiving characteristics of the antenna are also stated, the radiation pattern is also a "speed pattern". Although the radiation model is three-dimensional, it can be challenging to depict the 3D radiation pattern in a meaningful way.

It takes time to measure a three-dimensional radiation pattern. Measured radiation patterns are frequently a trick in a 3D pattern that appears quickly. a paper or screen with a two-dimensional radiation pattern. These dimensions are shown in polar or rectangular shapes [6].

1.4.7 Voltage Standing Wave Ratio (VSWR)

The voltage standing wave ratio (VSWR) gauges how effectively radio-frequency power is transmitted down a transmission line from a power source to a load. The standing wave ratio is, in other words, the ratio of the most astonishing power to the lowest power in a wave that can be measured (SWR). In terms of voltage, the voltage-to-incident voltage ratio is known as VSWR. The VSWR is a constant, accurate, and positive antenna number. Less VSWR means that more energy is sent to the antenna, which increases power. The minimum VSWR is 1. The ideal antenna in this case does not reflect power [7].

1.4.8 Return Loss (RL)

The proportion of radio waves that arrive at the antenna input that are rejected as opposed to accepted waves is known as the return loss of an antenna. Compared to a short circuit, it is measured in decibels (dB) (100 per cent rejection). Another method for showing an antenna/feedline mismatch is return loss (RL). In comparison to the power delivered into the antenna by the transmission line, the antenna-based power is an algorithmic connection expressed in decibels (dB). The RL and VSWR are intimately connected. The majority of the time S11 is the specified antenna parameter. S11 is just a return loss, nothing more (RL). If S11 = 0 dB, no power is radiated and all power is reflected from the antenna. When 3 dB of power is applied to the antenna, the reflected power is -3 dB if S11 = -6 dB. An RL or S11 of less than or equal to -9.5 dB corresponds to a VSWR of less than or equal to 2.

In this thesis, an RL of -10 dB is deemed acceptable [7].

1.4.9 Polarization

The wave's antenna-emitting electrical field controls the polarization of the antenna. The strength and phase of the electric field have a direct impact on the antenna polarization. If the electric field components' magnitude and stage are both equal, the antenna is linearly polarized. When the volumes are the same but the phases are 90 degrees different, the antenna is circularly polarized.

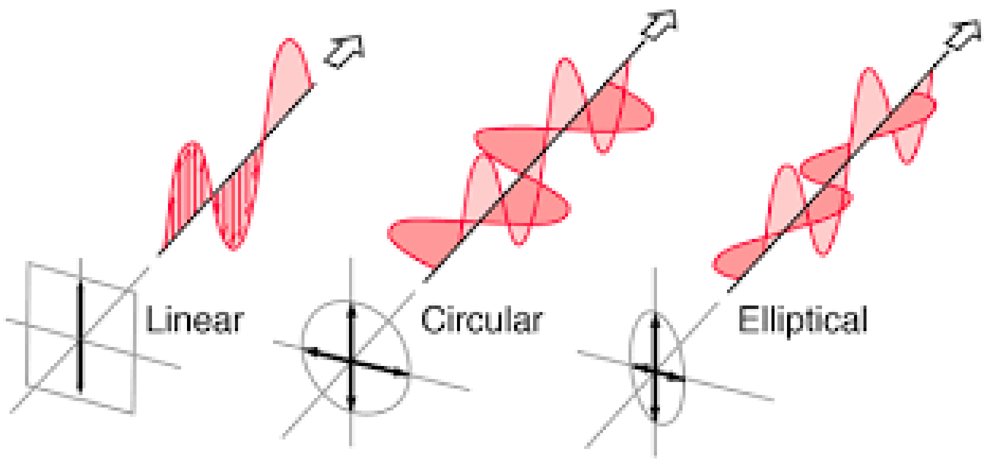


Figure 4 Polarization linear,Circular,Elliptical [8].

To enable communication between two linearly polarized antennas, the electrical fields they are planning must be in alignment. However, a circularly polarized antenna can make a connection with each linear antenna regardless of its direction. A linear antenna is more effective when orientation is insensitive to the circular antenna because all of the power is pointed in one direction rather than being distributed between two. Depending on the application, the antenna is either circular or linear; ideally, the tag antenna should be circularly polarized to allow reading from any orientation [8].

1.5 Micro strip Antenna

A micro strip patch antenna, as depicted in Figure 3, consists of a patch of radiation on one side of the dielectric substrate and a grounded surface on the other. The patch can be produced in any shape and is typically composed of conductive metals like copper or gold. The radiating patch and feed lines are typically photo-etched onto the dielectric substrate.

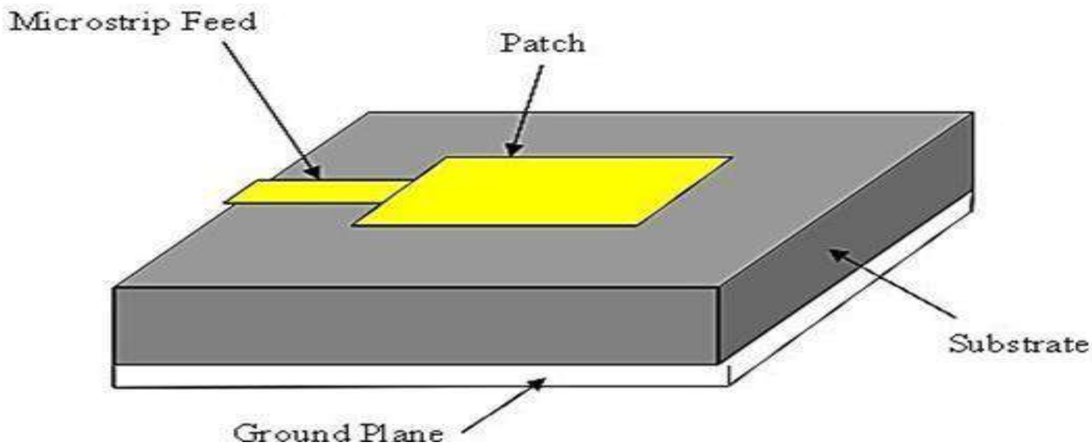


Figure 5 Structure of a micro strip patch antenna [8].

To make analysis and performance prediction easier, the patch is typically square, rectangular, circular, triangular, elliptical, or another popular shape. For a rectangular patch, the length (L) is typically 0.33330L0.5ти0, where 0 is the wavelength of open space. The patch is selected to minimize t0 (where the patch thickness). Typically, the dielectric substrate rises to a height of h of 0.003 per dielectric substratum = 0.05. The typical range for the substrate dielectric constant (r) is 2.2 m to 12.

Micro strip patch antennas emit due to the fringing fields that exist between the border of the patch and the ground plane. A thick dielectric substrate with a low dielectric constant is good for better antenna performance since it provides better efficiency, a wider bandwidth, and better radiation. A larger antenna is required for such an arrangement, though. It is necessary to build a tiny Micro strip patch antenna because higher dielectric constants have narrower bandwidth and are less effective [5].

1.5.1 Micro strip antenna Feed Techniques

1. Micro strip Line Feed
2. Coaxial/Positron Feed
3. Coupled Aperture Feed
4. Closely Coupled Feeding

1.5.2 Micro strip Line Feeding

A transmission line of this shape is quickly etched to the patch's edge, maintaining the overall level of the structure.

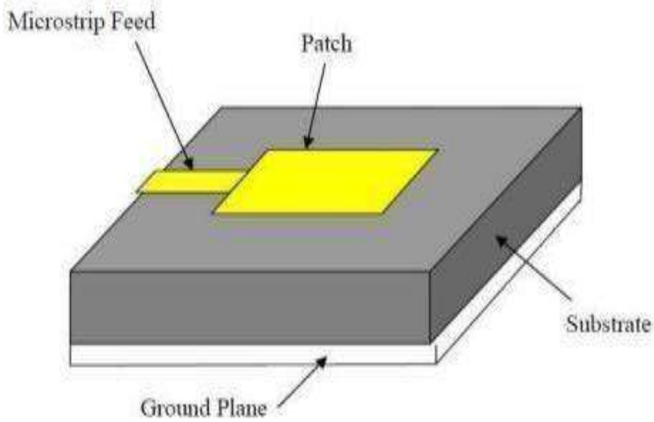


Figure 6 micro strip line feeding [6].

1.5.3 Coaxial / Probe feeding

While the external conductor of the coaxial connector is fastened to the ground level, the inner conductor of the connector traverses the support and is welded to the radiation patch.

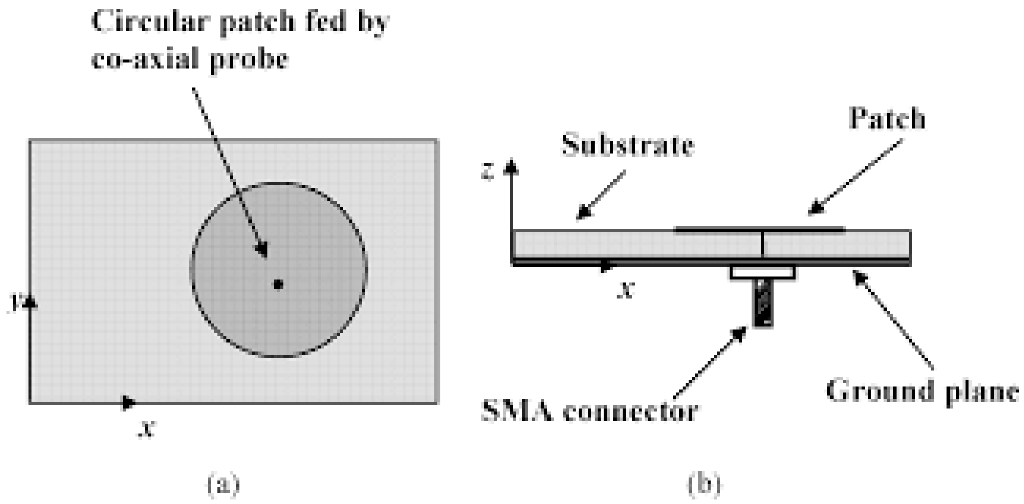


Figure 7 Coaxial /Probe feeding [6].

1.5.4 Aperture Coupled Feed

In this type of feed, the aperture connection is made up of two substrates that are separated by a ground plane. The passage at the base of the lower substratum and the radiating patch divide the ground plane. An electrically tiny hole or slot on the ground floor creates the connection.

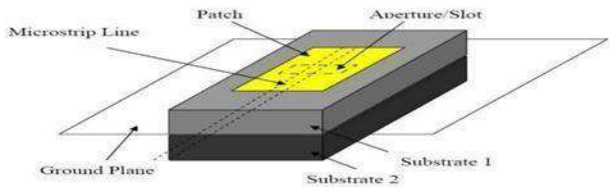


Figure 8 Aperture Coupled Feed [6].

1.5.5 Proximity Coupled Feed

Another name for it is ECMSA Coupled Electromagnetically. Additionally, there are two substrates, the Micro strip feed line is sandwiched between the two substrates, and the radiation patch is located on top of the upper substrate.

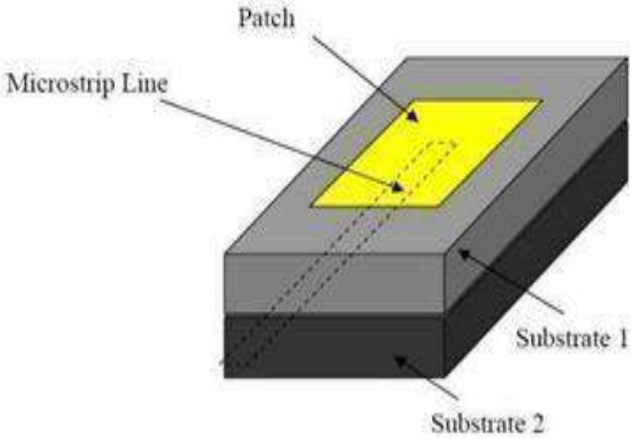


Figure 9 Proximity Coupled Feed [6].

1.5.6 Advantages and Disadvantages

Micro strip patch antennas are becoming more popular in wireless applications due to their low-profile design. They are therefore perfect for built-in antennas in portable wireless devices like cell phones and pagers. Telemetry and communication antennas for missiles must be small, conformal, and often use micro strip patch antennas.The following are a few of the many benefits of the micro strip antenna:

1. Micro strip antennas are lightweight and compact.
2. They may be produced in large quantities by mass production at a reasonable cost.
3. They are low profile and flat, making it simple to adjust them to the surface of the host.
4. Support for both circular and linear polarization.
5. It is easy to combine micro strip antennas and microwave integrated circuits (MICs).
6. They have the ability to use two or three frequencies.
7. They are mechanically durable when mounted on hard surfaces.

The following are some disadvantages of the micro-strip antenna:

1. A micro strip antenna has a finite bandwidth.
2. They are ineffective.
3. They make a negligible benefit.
4. They have issues with extraneous radiation from feeds and junctions.
5. Poor end-fire radiator, with the exception of tapered slot antennas.
6. They have a limited capacity for handling large amounts of electricity.
7. Surface wave stimulation

Micro strip patch antennas have an antenna quality factor that is comparatively high (Q). Q is a measure of an antenna's losses, and a high value corresponds to a narrow bandwidth and low efficiency. To lower Q, the dielectric substrate's thickness might be raised. However, as the layer's thickness increases, a larger percentage of the total power provided by the source is transformed to surface waves. simply because ultimately This surface wave contribution may be viewed as an unintended power loss because it is scattered at the dielectric bends and impairs the antenna's characteristics [8].

1.6 Design Tool

1.6.1 CST Microwave Studio

A top-notch tool for modeling high-frequency structures in three dimensions is CST MICROWAVE STUDIO (CST MWS). Users of CST MWS can quickly and precisely analyze high-frequency elements such antennas, filters, couplers, multi-layer structures, planar structures, and SI and EMC effects. The package contains solvers for the Time Domain and Frequency Domain. CST works with extra solver modules for particular applications. Design choices are improved and time is saved by using specific CAD file importation filters and SPICE parameters extraction. CST provides accurate, effective analytical computing and electromagnetic design technologies. Using our 3D EM simulation application, you may decide how to design and improve devices that work at a wide range of frequencies [9].

1.7 Motivation

Due to its accessibility, versatility, portability, and many other benefits, it has grown in popularity since wireless communication was first developed. Over the past three decades, there has been a considerable increase in the need for mobile connection, data, and traffic. To these requests, the Internet of Things was innovative (IoT). The telecoms sector has grown to meet this expanding need in practically every decade. The adoption of the internet of things, low millisecond latency, 10 Gbps data throughput, and other connection requirements for more than 100 trillion wireless devices by the early 2020s will be made possible by the 5th generation (5G) effect [1]. Due to the fact that high-frequency trajectory loss is one of the main obstacles to the deployment of 5G, we developed an antenna to address this issue [10].

1.8 Essence

A sector that is evolving quickly is telecommunications. A new generation starts to emerge every 10 years or so. The one that interests researchers the most is 5G, which came before it. Technology has moved from Fourth Generation (4G) to Fifth Generation (5G) as a result of the tremendous rise in wireless applications (5G). Next to 4G/IMT-Advanced wireless communication protocols comes 5G. Compared to the present 4G system, 5G can reach higher user density for wireless networks, enabling devices to be more dependable and communicate with other devices and the internet of things (IoT).

We create 5G-compatible antennas even if the use of associate degree antenna wireless connection isn't currently feasible.

The Microstrip Patch Antenna is the most widely used antenna in modern wireless communication because of its unparalleled qualities. Decreased devices are offered because of the smaller size of this type of antenna. Using the Micro strip, the antennas are simple to mount on any PCB. The micro strips can be quickly and easily engraved in a variety of shapes, including rectangular, square, and triangular. Since their manufacturing costs are cheaper, mass production is feasible. Various frequency bands are supported (dual, triple). It is compatible with both circular and linear dual polarization types. It isn't heavy at all.

Sub-6-GHz bands are used by the current 4G network for communication. However, the spectrum resources present in these bands fall short of the 5G requirements [1]. As a result, we must switch from 6-300 GHz up the frequency scale. The FCC has designated 27.5-28.35 GHz for 5G [1], therefore those frequencies are to be used as 5G wireless communications bands, along with the wireless 3.4-3.06 GHz, 5-6 GHz, 24.25-27.5 GHz, and 37-40.5 GHz bands. The design of a high-level 28 GHz micro strip antenna for 5G communication has been the subject of numerous studies. However, as stated by the FCC, certain antennas do not cover the 28 GHz bands. Others cannot be used with 5G mobile phones due of their large sizes. Therefore, it is crucial to construct an antenna that covers the 28 GHz band and is compatible with 5G handsets [11].

Chapter 2

2 Literature Review

2.1 Overview of "Release 15 on 5G standards" Update By 3GPP

3GPP (3rd Generation Partnership Project) members meet regularly to team up and formcellular communications standards. Currently 3GPP is defining standards for 5G. The International Telecommunication Union (ITU) has proposed some requirements for 5G that emphasis on accomplishing three key performance indicators (KPIs) [5].

- >10 Gbps peak data rates for the enhanced mobile broadband (eMBB)
- >1M/km^2 connections for massive machine type communications (MMTC)
- <1ms latency for ultra-reliable low-latency communications (URLLC)

Now we show in ***i*** i ***Table 2***, there are some distinguish about LTE and NR

Table 2 DIFFERENCES BETWEEN 4G AND 5G [6].

	LET	NR
Frequency of Operation	Up to 6 GHz	Up to 6 GHz, ~ 28 GHz, ~ 39 GHz, other mm Wavebands (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 CodingControl: 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 ChannelBW

Table 3 frequences I of interest in several locations [6].

NR Operating Band	Uplink (UL) and Downlink (DL) Operating band BS transmit/receiveUE 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

Other bands, such as 24.25 GHz–29.5 GHz, are being keenly studied for use in 5G NR. In Technical Report 38.815 this frequency update is being tracked and actively reported. A better visual outline of the frequencies of interest inseveral locations, taken from that technical report is provided in the following frequency chart.

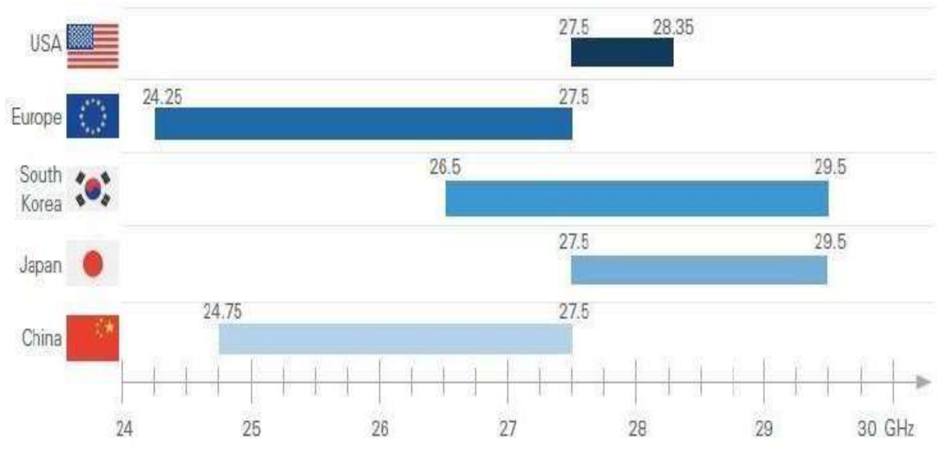


Figure 10 Illocated Frequency Bands In Different Location For 5g [6].

2.2 Paper Review

The investigation into the fifth generation (5G) mobile application with the current antenna will be effective if the works of other researchers that are connected to this thesis, "A novel Dual Band for 5g Antenna SUB-GHz for Wireless Communication," are reviewed in this part. As a result, an antenna with superior performance and simple manufacturing should be designed and simulated.

1. Research on, “A High Gain Microstrip Patch Antenna with Slotted Ground Plane for Sub-6 GHz 5G Communications.”

In this essay, the design of a slotted ground is presented. Fifth generation (5G)sub-6 GHz wireless communications plane microstrip patch antenna. The layout features a T slot on a microstrip patch that is rectangular and has a poor ground structure (DGS). The planned antenna's ground plane is made up : modified C-slot form The altered C slot includes unique the modified C shape is torn at the top and bottom to further improve the performance of the antenna. An illuminating plate is designed with a feature that concentrates the side lobes to make the radiated signal's primary lobe stronger, thereby increasing the proposed antenna's gain. The suggested The antenna is made of FR-4 epoxy, and use the inset feeding method. Plan and simulate are completed utilizing CST Studio Suite. The size of the antenna is a maximum gain and dimensions of 28.03 x 23.45 x 5.35 both 5.49 dB and 7.12 dB of maximum directivity.The proposed antenna uses a bandwidth ranging from 4.8 GHz to 5 GHz is covered by the range of 4.775 GHz to 5.049 GHz.Band of 5G communications at sub-6 GHz [12].

2. Research on, "Ultra-Wideband Patch Antenna for Sub-6 GHz 5G Communications."

Due to its benefits of tiny size, sample-processing method, low cost, and good quality, the Microstrip Patch antenna is one of the most significant members of the antenna family. New antennas are needed for the operating frequency spectrum obtained by the three Chinese operators covering three 5G bands, including 2.515-2.675 GHz, 3.4-3.6 GHz, and 4.8-4.9 GHz, in order to realize true 5G wireless communications. In order to create an ultrawideband (UWB) antenna, the step-impedance resonator (SIR) and ground plane construction are modified in this research. The three 5G bands are covered. From 2.32 GHz to 5.24 GHz, the S11 value is below -10dB, which includes applications for WiFi, Bluetooth, and WLAN. The planned antenna has gains of 2.52 dBi and 3.04 [13].

3. Research on, "Wideband Microstrip Patch Antenna for Sub 6 GHz and 5G Applications."

This research examines a novel microstrip patch antenna shape intended for sub-6 GHz applications, including a 5G one. Using CST Software, the suggested antenna was created and tested for frequencies ranging from 3.5 GHz to 5 GHz. The substrate of the Rogers RT5880 is used in this investigation and has a 2.2 dielectric constant and thickness of 0.254 mm. The proposed antenna feeds from a metallic ground that is quartered.To reduce the antenna impedance mismatch, a microstrip feed line was coupled toa plane. The results of design variation factors like the In this work, the substrate size, patch size, and ground plane size were all measured and analyzed. The ideal antenna setting was dependent on the performance of the return loss antenna. Recently, the finalized antenna's performance was successfully simulated [14].

4. Research on, “A Dual-band Dual Mode Antenna for On/Off-Body Communications.”

In the Industrial Scientific and Medical (ISM) band, a dual mode antenna is presented in this study for use in on and off body wireless communication. The suggested architecture has two distinct ISM band resonances at 2.45 GHz and 5.8 GHz. In the lower frequency band, the antenna radiates omnidirectional, while in the higher frequency band, it radiates directionally. By building a substantial ground plane on the second layer of the substrate, the impact of human tissues on the S11 and bandwidth performance of the antenna is reduced. The antenna is 44mm 44 mm 1.6mm in total. Tissue layers at 2.45 GHz and 5.8 GHz have been used to examine how the antenna affects the human body. The findings demonstrate the suggested antenna's stability in the presence of human tissues and its suitability for both on- and off-body communication [15].

5. Research on, “Design of MIMO WLAN 2.4/5.2/5.8 and 5G SUB-6 GHz antennas for laptop computer applications.”

The paper suggests a concept for MIMO antennas for laptop computers with a broadband impact. Stereoscopic bending-coupled architecture is used in the antenna. The grounded inverted L-shaped arm, two short metal arms, and the feed are what make up the coupledfed antenna. A T-shaped metal strip with multiple arms serves as the isolation mechanism's construction to minimize interference between the two antennas. The design's overall dimensions are 6.2 x 50 x 4.2 mm3. The design antennas and isolation element, which measure (LW) 200 260 mm2, are installed in the top left corner of the system ground. They are composed of 0.8 mm FR-4 substrate. According to the findings, this MIMO antenna design may operate in the WLAN2.4/5.2/5.8GHz (2.4-2.484 GHz; 5.15-5.35 GHz; 5.725-5.825 GHz) and 5G NR SUB-6GHz (3.3-4.2 GHz; 4.8-5 GHz) bands [16].

6. Research on, “A Wideband Dual-Polarized Antenna and its Array with Electrically Downtilt Function for 5G Sub-6 GHz Communication Applications.”

It is suggested to use a wideband dual-polarized antenna for 4G and 5G communication applications.The antenna element has three natural resonant modes that are pushed closer to generate a wide bandwidth. It is made up of a pair of opened-loop dipoles for dual polarization. The feed point's additional U-shaped slots help to match the antenna element's input impedance to 50 Ohm. The manufactured antenna element has a strong port-to-port isolation (>25 dB), a 75.9% (VSWR 2) impedance bandwidth, and operates between 1.8 and 4.0 GHz. Additionally, it achieves a beamwidth of 671 in the H-plane and 68.7 3.3 in the V-plane with 8.5 dBi gain over the supported bands. A six-element dual-polarized array with electrically downtilt is also manufactured and measured using six antenna elements and an RF phase shifting module (RFPSM) based on vector modulators. This results in a peak gain of 16.8 dBi,a beamwidth that is similar to that of a single antenna element in the H- plane, and an electrically downtilt in the V-plane from 0 to 12, which is preferred in communication applications. This antenna array might be applied to future 5G communication systems as well as other things [17].

7. Research on, “A multi-slotted antenna for LTE/5G Sub-6 GHz wireless communication applications.”

In this paper, a low-profile multi-slotted patch antenna for fifth-generation (5G) and long-term evolution (LTE) communication applications is presented. A stepped patch and a ground plane made up the antenna under study. Three slots have been put inside the patch to achieve the needed operating band. The addition of the slots improves the capacitance effect and enables the prototype antenna to operate in the LTE bands of 22/42/43/46 and the N77/N78/N79 for sub-6 GHz 5G wireless communications, with a frequency range of 3.15 to 5.55 GHz (S11 10 dB). An appropriate candidate for wireless fidelity (WiFi), wireless local area network (WLAN), LTE, and sub-6 GHz 5G communication applications, the wideband antenna reported in this study offers omnidirectional steady radiation patterns, good gains, and efficiency with a compact dimension [18].

8. Research on, "A compact double-band planar printed slot antenna for sub-6 GHz 5G wireless applications."

This paper we see sub-6 GHz 5G applications, a planar rectangular slot antenna with dual-band operation and substantially greater peak gain is suggested, built, and manufactured. An inverted stub on the antenna's upper edge is simultaneously driven by a microstrip feed line with a double-folded T-shaped construction. The antenna has a rectangular radiating slot. The constructed design has a small footprint and a radiating part that measures 0.30 by 0.17 0 (where 0 denotes the free-space wavelength) and a profile that measures 0.009 0. With a peak gain of about 7.17 dBi, the measured findings demonstrate the operating frequency ranges of 3.29-3.63 GHz and 4.3-5.2 GHz. The feed patch and the slot provide the higher frequency band, whilst the stub loaded on the slot produces the lower resonant frequency band. The simulated results and the measured results show good agreement. The proposed design is appropriate for applications in the sub-6 GHz band of the International Telecommunication Union [19].

9. Research on, "Compact sub-6 GHz 5G-multiple-input-multiple-output antenna system with enhanced isolation."

In this paper they analysis for upcoming sub- 6 GHz 5G applications, a small two-element multiple-input multiple-output (MIMO) antenna system with better impedance matching and isolation is given. On a common rectangular ground, the two identical tapered microstrip line-fed modified rhombus radiating elements are positioned in the same orientation at a small substrate area of 0.24 0.42 (where 0 at 3.6 GHz). To obtain better impedance bandwidth and isolation, a modified T-shaped ground stub is sandwiched between two radiating elements. The center of each radiating element was further attached to a split U-shaped stub to reach the desired resonant frequency of 3.6 GHz. The suggested antenna provides isolation of more than 20 dB between a pair of components and spans a 3.34 to 3.87 GHz (530 MHz) operating bandwith a 10 dB gain [20].

10. Research on, "Design and Characterization of a Slot based Patch Antenna for Sub-6 GHz 5G Applications."

This paper they design a dual-band microstrip patch antenna's design, manufacture, and characterisation are all covered in this article. Both 3 GHz and 3.3 GHz, which are viable bands for sub-6 GHz 5G applications, are the operating frequencies of the antenna. The antenna design and manufacturing are done on a Rogers 5880 substrate with a permittivity of 2.2 and a thickness of 1.57 millimeters (mm). A rectangular patch with three rectangular slots of varying sizes makes up the antenna model. A 50 microstrip line that is 1 mm thick is used to feed the antenna. The antenna is 50 x 30 in total dimension. According to the simulation results, the antenna has return losses of -20.6 dB at 3 GHz and -18.2 dB at 3.3 GHz, and gains of 7.52 dBi at 3 GHz and 5 dBi at 3.3 GHz. Additionally, the antenna's radiation efficiency is 97.6% at 3 GHz and 88.5 % at 3.3 GHz. The findings of the antenna measurements and those of the simulation are in a fair amount of agreement, showing that the antenna gives a gain of 4.7 dBi at 3 GHz and return losses of -22 dB at 3.05 GHz and -16 dB at 3.3 GHz. A parametric analysis, which offers informative suggestions about the antenna design and performance, is also carried out in order to demonstrate the effects of various parameters on the antenna performance.

11. Research on, " A Compact Frequency An Radiation Reconfigurable Antenna For 5G And Multistandard Sub-6 Ghz Wireless Application"

This paper describes a reconfigurable antenna that can change its pattern and operate in three modes across various frequency bands. Four PIN diodes enable frequency and pattern reconfigurability. To execute the antenna's frequency reconfiguration, two diodes are installed specifically in the hexagon's radiating portion. By altering the main lobe beam steering, the other two PIN diodes are coupled with the inverted L-shaped and CPW ground to achieve the pattern reconfiguration. An antenna has been created,evaluated numerically and experimentally, and then it was constructed. The antenna prototype is created using a 1.6 mm (= 4.3) thick FR-4 substrate that is readily available in the marketplace. As a result, the suggested antenna works with numerous 5G sub-

6 GHz bands (3.1 GHz, 4.1 GHz, and 3.8 GHz), WiFi (2.45 GHz), and X-Band satellite applications (7.8 GHz, 9.5 GHz). The outcomes are really encouraging. The proposed (small) antenna prototype can be a potential candidate for future portable devices, sensor networks, and telecommunication applications because it is seen that the measured findings closely match the simulated results [22].

12. Research on, "A Compact Monopole Patch Antenna for Future Sub 6 GHz 5G Wireless Applications."

In this paper they discuss about future Sub 6 GHz 5G wireless communications will use a small printed monopole patch antenna with finite ground, which is presented. The square slotted microstrip patch antenna is a small 30 34 mm2 device. Partial ground plane and stub optimization help to obtain good impedance match across a broad range (3–7 GHz band).Over the whole band, the antenna displays an omnidirectional emission pattern with good gain. proposed antenna is implemented on FR4 laminate, and the proposed design can be applied to future 5G wireless applications for wireless communication between Internet of Things nodes due to the good agreement with simulation findings [23].

13. Research on, "A low-profile rectangular slot antenna for sub-6 GHz 5G wireless applications."

In this paper they design, a brand-new planar rectangular slot antenna for a sub-6 GHz 5G wireless application is proposed. The suggested design is compatible with LTE Band 42, WiMAX, and 5G at sub-6 GHz. The antenna has an inverted stub, an E-shaped, rectangular radiating slot, a circular parasitic element on its upper side, and a microstrip feed line with a two-folded T-shaped design that simultaneously activates both of these elements. Its dimensions are 32.4 27.9 1.6 mm3, and it has outstanding impedance matching and reflection coefficient properties. The resonant frequency is 3.5 GHz, with a peak gain of almost 4.2 dB, and the reflection coefficient (S11) is found to be 26.5 dB. The suggested antenna offers a total bandwidth of 19 MHz and an efficiency of 82% over the whole frequency range.The suggested antenna is a desirable option for sub-6 GHz 5G wireless applications, to sum up [24].

14. Research on, “A low-profile compact UWB antenna array for sub-6 GHz MIMO applications in 5G metal-frame smartphones.”

In This paper they introduces a low-profile compact sub-6 GHz fifth generation (5G) metal-frame smartphone application-specific ultra wideband (UWB) multiple input multiple output (MIMO) array antenna system. Each component of the array antenna system is made up of a metal frame, a number of slots and slits, a thin rectangular slot in the ground plane, and an E-shaped monopole antenna element that is fed by a microstrip line. Each component is small and only takes up an area of 11.4 x 8.4 mm2 (0.125 x 0.092 x 0, where x0 is the wavelength of free space at 3.3 GHz), with a metal frame height of 6 mm. The 3.3-6 GHz band (|S11| 6 dB), which is UWB for future 5G mobile terminals, is where the MIMO system canoperate. The MIMO antenna system has a prototype that has been built and tested. Despite being printed on a high-loss FR-4 substrate, the proposed MIMO antenna has good return loss, transmission coefficient (over 12.8 dB), adequate radiation efficiencies (over 50%), envelope correlation coefficient (below 0.06), and ergodic channel capacity (between 35 and 40 bps/Hz) acrossthe working band. Additionally, the MIMO array system can continue to function well in the presence of a human hand, a big display, and a battery. Good qualities are offered by the MIMO antenna for application in 5G communications [25].

15. Research on, “Design of Patch Antenna for 5G Communication at 6 GHz (WRC-23) With WLAN Application.”

In this paper they work on the most recent band added under WRC-23 for the improvement of quality of service for 5G connectivity is 6 GHz. We suggested a microstrip patch antenna with dimensions of 26241.6mm3 and FR4 (r = 4.4) as the substrate. Basically, more spectrums have been introduced for a variety of applications employing 5G technology to improve data rate. The need of one frequency band with a 6 GHz operating frequency is met by our suggested antenna. The maximal gain is 3 dB, and the reflection coefficient |S11| is -21.16 dB. WLAN applications are also accepted for a different frequency at 5 GHz. With a peak gain of 2.86 dB, the reflection coefficient |S11| is -35.47 dB. At 6 GHz, the received bandwidth is 500 MHz, while at 5 GHz, it is 400 MHz. On HFSS software, we constructed and tested the proposed antenna. Along with WLAN operations, this antenna is a strong option for 5G applications [28].

2.3 Summary

Designing 5G antennas Sub-6 for wireless communication at millimeter wave bands like 2.5 GHz, 6.1 GHz, and others has been the subject of numerous studies. According to the most recent studies, the millimeter wave band between 2.5 and 6.1 GHz is the most promising and significant choice for wireless communication because so many studies have been conducted that cover this frequency range. Again, designing antennas with high gain to overcome severe path-loss, sufficient miniatureness to be able to integrate in mobile phones, efficient and easier to fabricate as well, is the most difficult task in 5G deployment.

2.4 Objective

- Design a nobel for 5G Antenna sub-6 for wireless communication .
- To improve gain and also improve performance of parameters.
- To achieve better Efficiency.

Chapter 3

3 Methodology

3.1 Methodology

Methodology is the formal, theoretical examination of the practices employed in a subject of study. It comprises a theoretical analysis of a collection of approaches and beliefs pertinent to a particular subject of study. Standards, theoretical models, phases, and quantitative or qualitative research techniques are frequently included in it [29].

3.2 Research Design

The framework developed to find answers to the research questions is known as research design. The design of the research activity outlines the research topic, dependent and independent variables, experimental design, and, when applicable, data collection techniques and a plan for statistical analysis. This study's research design included- o A study of the transition between 4G and 5G. o Antenna requirements research for 4G and 5G. o Learn about wireless communication systems and Sub-6. o Read up on dual-band 5G antennas and tiny strip antenna literature.

o Micro strip antenna design study process.

o Practice designing antennas in CST Microwave Studio. o Calculate the parameters required to design an antenna. o Put the procedure into action.

3.3 Pilot Study

Before beginning a larger research effort, a pilot study, pilot project, pilot test, or pilot experiment is carried out to improve the study design and assess feasibility, time, cost, and unfavorable events. It is completed before the anticipated research. The goals of the study are frequently followed when conducting pilot studies. While a pilot study cannot completely prevent systemic mistakes or unforeseen problems, When conducting original research, it can greatly cut down on the number of errors that waste time and effort.

Importance

- To evaluate the protocol and research method.
- To classify important variables and decide how to functionalize each one.
- To create or assess the efficiency of research tools and methodologies.
- To assess statistical parameters for upcoming research

3.4 Software

A potent tool for simulating high-frequency components in three dimensions is the Microwave Studio for Computer Simulation (CST MWS). High frequency (HF) devices such filters, couplers, antennas, single and multi-layer structures, as well as SI and EMC effects, may all be quickly and accurately analyzed using CST MWS. CST MWS is the preferred option in R&D departments that are heavily focused on technology due to its unmatched performance. The simple-to-use CST MWS tool offers immediate insight into the EM behavior of highfrequency systems.

3.5 Design procedure

Step 1: Equation-based antenna design, which is a method for producing MPAs, is used to create a single element rectangular micro strip patch antenna (MPA) that operates in the

2.5GHz range.

Step2: Save the structure and simulate the designed antenna in step two.

Step 3: Save the outcome if the antenna satisfies the requirements.

Step 4: Improve the performance of the developed Micro strip patch antenna.Create a rectangular slot antenna array in step 5 to add another 6.1 GHz resonance.Save the structure and simulate the designed antenna in step six.

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

Step 8: Improve the performance of the designed antenna.

Step 9: Save the outcome if the antenna satisfies the requirements.

Step 10: Compare your results to those of other antennas.

3.5.1 Flow Diagram

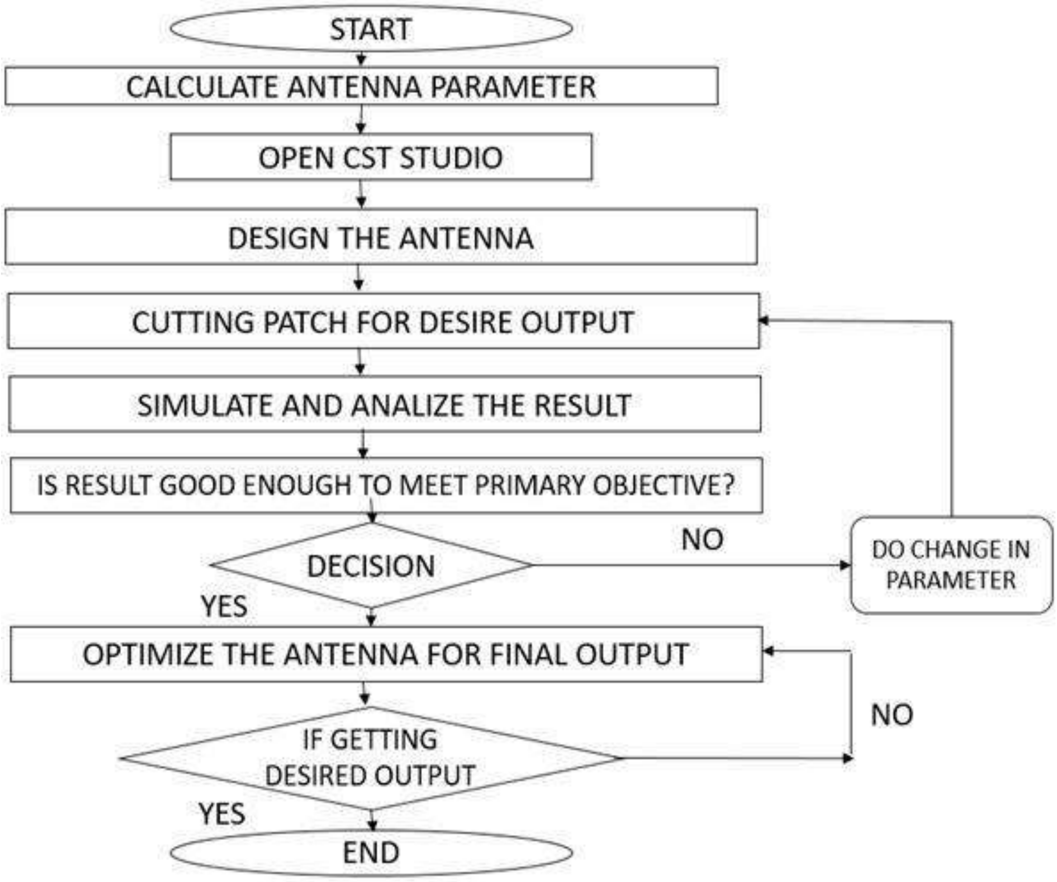


Figure 11 Flow design of the research work

3.5.2 Antenna Design by Equation

Choosing a suitable dielectric substrate with the necessary thickness is the first step in antenna design (h). Dielectrics enhance mechanical and electrical stability. They help to produce displacement current, which (according to Ampere's Law) produces a time-varying magnetic field, and are used to reduce the size of the antenna. This time-varying magnetic field can produce a time-varying electric field, according to Faraday's law, which creates a propagating electromagnetic field. In this approach, a substrate can enhance the radiating properties of the antenna. The features of some typical dielectric substrates are listed below.

Table 4 LIST OF ALL SUBSTRATES

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

The substrates in the table above have quite high dielectric constants, which suggests a significant loss for high gain antenna design. In order to produce a high-gain antenna for this study, a foam material with a dielectric constant close to 1 was selected. The material for the ground and micro strip line should then be chosen. In this situation, we have three choices: copper, silver, or gold. Silver has a better conductivity than the other metals. However, compared to the other two metals, copper is both much more difficult and less expensive.

Consequently, copper is frequently employed.

Equations (1) through (5) have been utilized to determine the antenna length and width *[27]*.

Patch width is given by,

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\in_r+1}} ------------------------------------(1)$$

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

$\in r$ is the dielectric constant of substrate.

2. For determine the actual length L, two parameters such as effective dielectric constant and extension of length have to be calculated. Firstly, the effective dielectric constant is calculated using below equation (2).

$\in_r + 1 \in_r - 1 \quad 10Hs$

$$\in eff = \frac{\quad}{2} + \frac{\quad}{2}\left(1 + \frac{\quad}{w}\right) ----------------------(2)$$

Where

Hs is the substrate's height.

w is the patch's 2 width. Second, the following equation is used to determine the extension of length (3).

$(\varepsilon reff + 0.3)(WHs + 0.264)$

$\Delta L = 0.412\ h$______________________________−−−−−−−−−−−−−(3)

$(\varepsilon reff - 0.258)(WHs + 0.8)$

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

Leff

$= \frac{}{\sqrt{\epsilon ff}}$ -- (4)

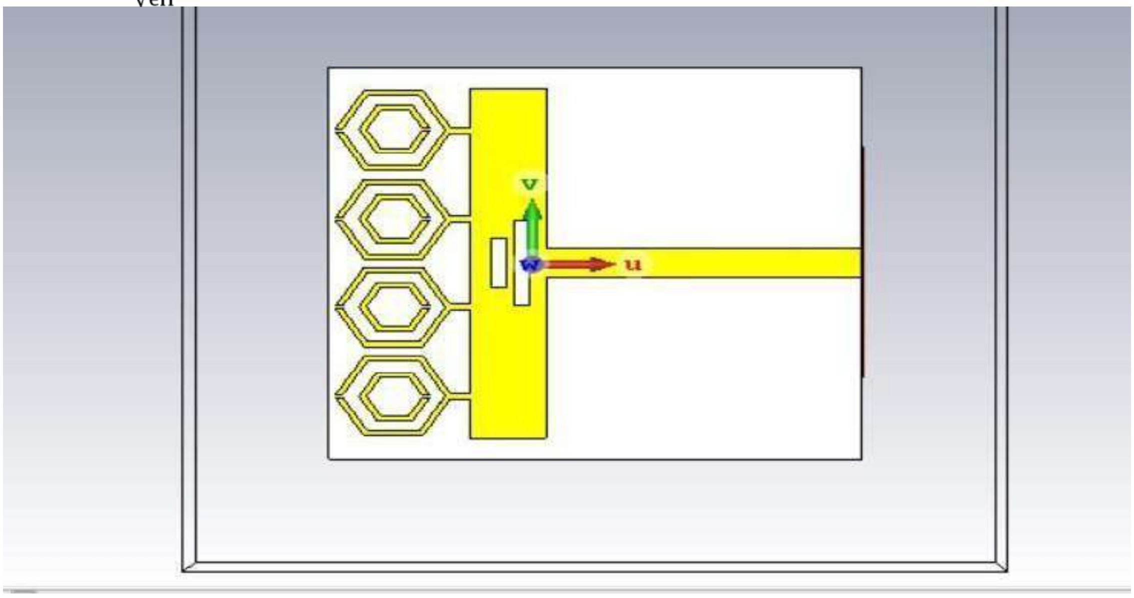


Figure 12 antenna design by equation

Parameter	**Value**
Frequency (fr)	2.34 & 2.44 GHz
Substrate thickness (h)	2.1 mm
Dielectric Constant (€r)	4.3 mm
Length (L)	54.60 mm
Width (W)	58 mm

3.5.3 Optimization Through Optimizer in CST MWS

The geometric design of the single element antenna must be optimized once it has been produced using the formula to maximize antenna gain. The optimizer offers a number of algorithms to pick from. Examples of algorithms include the Trust Region Framework, Genetic Algorithm, Particle Swarm Optimization, and others. One of the methods used in this study is the "Trust Region Framework" since it yields better results faster. Numerous iterations of optimization are performed to get greater antenna gain than traditional single element antennas.

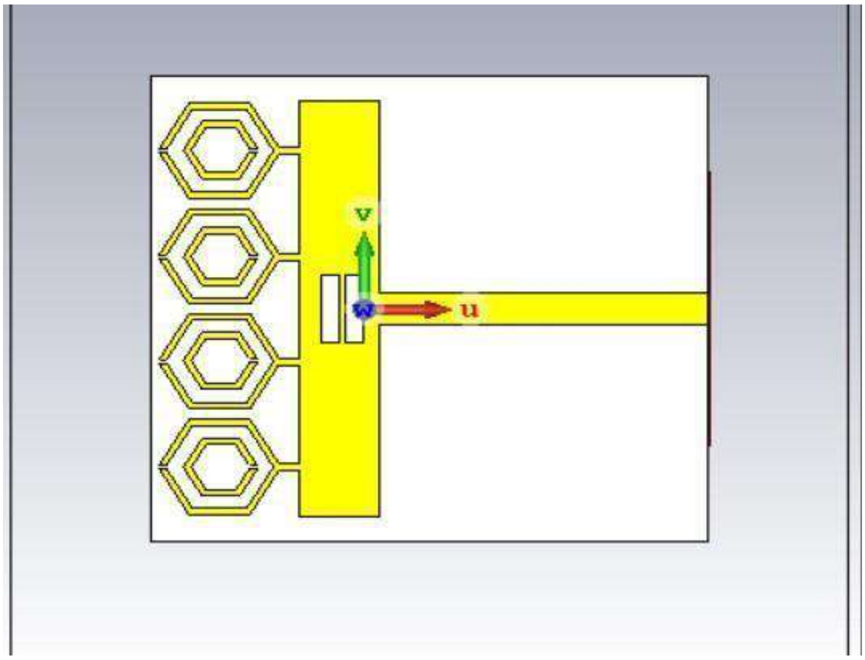


Figure 13 optimized design by CST

Table 5 OPTIMISED SINGLE ELEMENT ANTENNA PARAMETERS

Parameter	Value
Frequency (fr)	2.5 GHz
Substrate thickness (h)	2.1 mm
Dielectric Constant (€r)	4.3 mm
Length (L)	54.60 mm
Width (W)	56 mm

Chapter 4

4 Simulation and Result Analysis

This chapter, we show results that are obtained after performing simulation of the designed antenna are presented and analyzed.

4.1 Simulation Result of Single Optimizing

This section is divided into three parts and the result analysis and discussion are primarily illustrated on three antenna design parameters. In order to conduct this research, seven outcome indicators were tracked. By looking at the antenna result parameters and the final antenna constructed using those design parameters, the final antenna design parameters are chosen.

4.1.1 Return Loss Plot before Optimisation

In this design, the result return loss before optimization in his design appears unfeasible for operating in the intended band, and optimization is the only answer here.

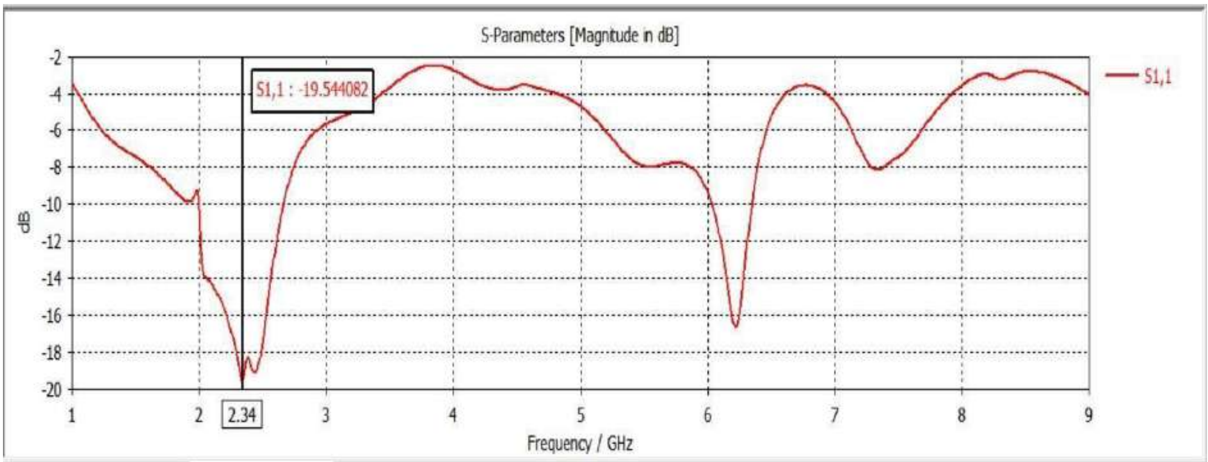
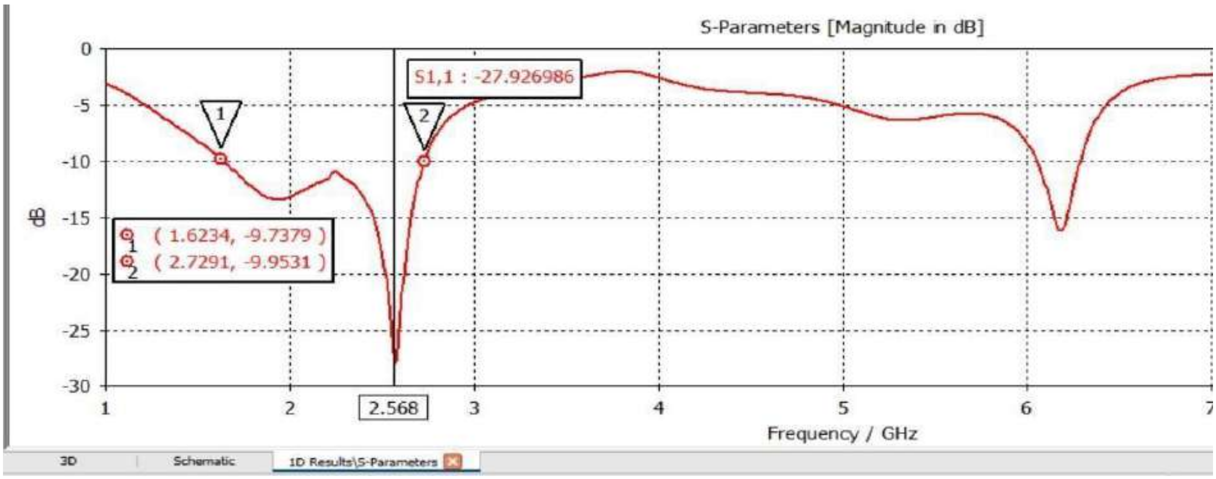


Figure 14 Reflection Coefficient

4.2 Optimised Simulation Results after slotting

4.2.1 Return Loss Plot

The optimized antenna's return loss map is shown below. Right present, the resonance frequency is both 2.5 GHz AND 6.1GHz. Additionally, the optimized antenna's turn loss value is -27.92 dB at 2.5GHz and -16.13 dB at 6.1 GHz, indicating perfect impedance matching. For return Loss at 2.5 & 6.1 GHz is given below,



4.2.2 Return Loss Comparison between after slotting and before slotting

The Comparison between after slotting and before slotting are below:

Before Slotting	After Slotting
At 2.34 GHz & 2.44 GHz return loss are -19.44 dB & -19.061 dB.	At 2.5 GHz return loss are -27.92 dB.

4.2.3 2D Radiation Pattern

In antenna design, the directional dependence of the antenna's radio wave intensity is referred to as a "radiation pattern." According to the 2D radiation pattern of a single element antenna, the designed antenna has a good radiation pattern and a constrained beam width. A microstrip patch antenna radiates in a half-circular pattern, and we can see that ours fits the standard, which is also nearly half-circular, precisely.

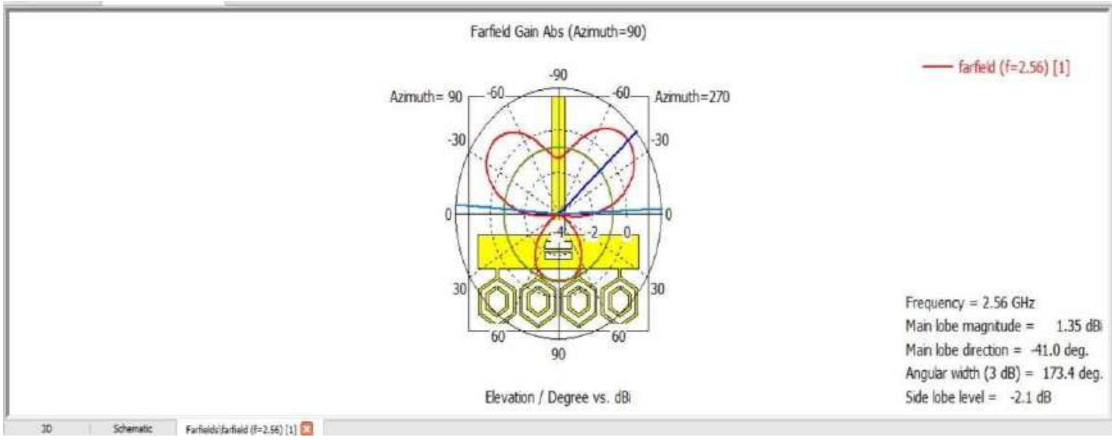


Figure 15 2D Radiation Pattern at 2.5 GHz

4.2.4 3D Radiation Pattern

A 3-dimensional representation of an antenna's power radiation pattern in the surrounding area is called a 3D radiation pattern. This pattern is typically used to gather data from an antenna at a suitable distance, or the far-field. Simply put, it is the amount of energy an isotropic antenna (a hypothetical antenna that radiates equally in all directions) emits in a specific direction. A good antenna should retain its 3D radiation pattern across the operating frequency range, just like it does for the 2D radiation pattern. It is easier to determine the power given in a single direction from a 3D radiation pattern. Below, at 2.5 and 6.1GHz, is the antenna's 3D radiation pattern.

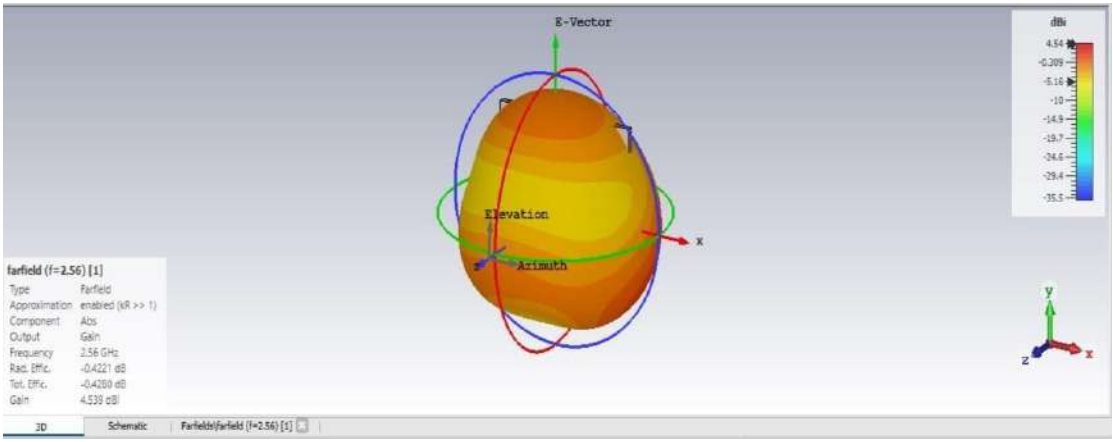


Figure 16 3D Radiation Pattern at 2.5 GHz

4.2.5 Efficiency

The ratio of the aperture's effective area to its actual physical size is known as antenna efficiency. Below is a graph illustrating an antenna's antenna efficiency. It details the proportion of the actual aperture area that is used to collect radio frequency (RF) radiation. The antenna met the requirement for antenna efficiency.

Figure 20 below illustrates that the antenna efficiency is 87% for 2.5 GHz and 62% for 6.1 GHz, respectively.

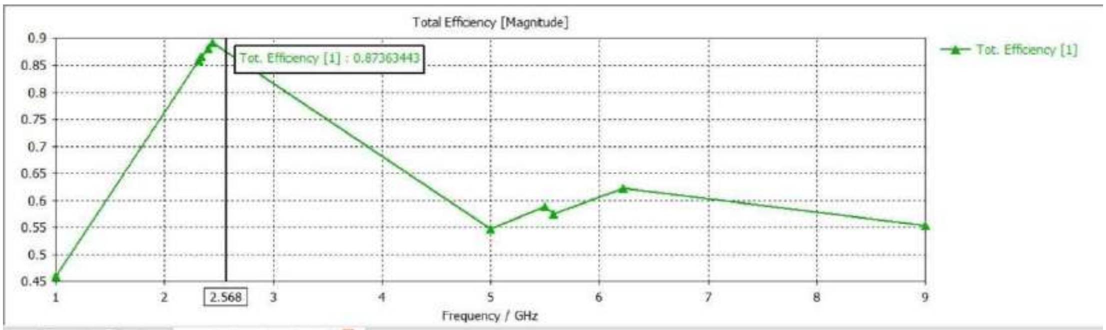


Figure 17 Antenna Efficiency of patch

Antenna **4.2.6 Radiation Efficiency**

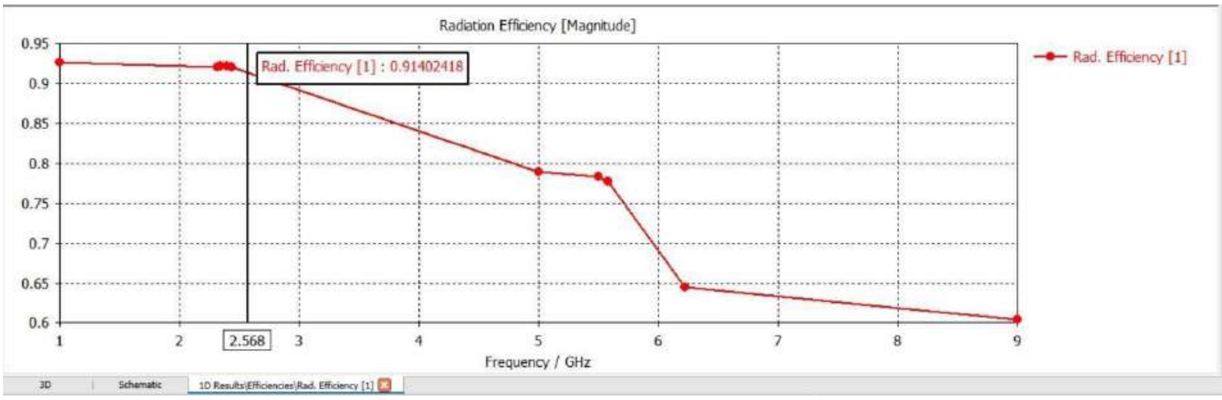


Figure 18 Radiation Efficiency of Patch Antenna

The antenna met the required radiation efficiency. Figure 4.9 below illustrates that for frequencies of 2.5 GHz and 6.1 GHz, respectively, the radiation efficiency is 91% and 65%.

4.3 Final Design Result of Antenna

After antenna optimization, the whole simulation results are tabulated in Table 4.1. The return loss for this antenna is good across the 2.5 GHz.The antenna's VSWR is also less than 1.5.The antenna's gain is quite good in compared to earlier designs. Both at 2.5 GHz, the antenna offers a gain of 4.5+ dBi. The antenna's great directional performance is shown by its directivity, which is approximately 4.5+ dBi. Over the full working band, this single element antenna's radiation efficiency is greater than 85%.

Parameters	Value	Standard
The Frequency inresonance	2.5	As per need
Reflection Coefficient (S11)	-27.92 dB	Less than -10 dB
VSWR	1.083	2-1
Directivity	4.961 dBi	5-8
Total Efficiency	87%	70%
Radiation Efficiency	91%	70%
Gain	4.539 dB	6-9 dBi
Bandwidth	1.1057	1+

4.4 Comparison with the existing 5G antenna for SUB-6

The performance of the designed antenna is compared to recently designed by different in the below:

Reference	Operating Frequency (GHz)	Return Loss	Gain (dBi)	Efficiency
[15]	3.5 & 4.2	-10.34 & 14.28	2.07 & -0.974	78%
[16]	2.6	-29.28	-	Between 60-90%
[17]	4.5	-10	7.17	79.58%
[18]	3.83 & 5.34	-14.10 & -22.75	2.235 & 2.69	74.7% & 79.6%
[19]	3& 3.3	-20.6 & -18.6	7.52 & 5	97.6% & 88%
[20]	3.5	-26.5	4.2	82%
[21]	3.50 & 5.50	-22.27 & -25.64	2.5 & 2.6	-
[22]	5 & 6	-35.47 & -21.16	2.86 & 3	-
Our work	2.56	-27.92	4.539	87%

Chapter 5

5 Conclusion

In this thesis, a dual-band micro strip patch 5G antenna operating at 2.5 GHz is constructed and modelled in CST Microwave Studio for use in 4G and 5G wireless communication. The simulation results for 2.5 GHz are reported for both slotted and non-slotted scenarios.

5.1 Achievements

CST Microwave Studio was used in this thesis project to construct and model the antenna, which is used for wireless communication at frequencies of 2.5 GHz. This micro strip patch antenna has a theta polarized radiation pattern with gains of 4.539 dB, respectively, with reflection coefficients of -27.92 dB (VSWR=1.083).At 2.5 GHz the efficiency is 87%.

5.2 Limitation

In order to make the suggested antenna more useful for usage in mobile phones, beam steering capabilities is not included.

5.3 Future Field of work

The design sub-6 GHz 5G antenna is a good option for future research into 5G because it can be easily deployed and used not only for mobile applications but also for wireless body area networks, the military, health monitoring, aircraft applications, and other areas.

References

[1] Rajiv, “RF page,” RF page, 1 august 2022. [Online]. Available:

https://www.rfpage.com/evolution-of-wireless-technologies-1g-to-5g-inmobile-communication/. [Accessed 14 10 2022].

[2] S. S. S. P. C. B. N., “"Improvement Microstrip Patch,” *"InternationalConference,* pp. .27-30, 2010.

[3] H. .Mehta, “andHardik,"0Gto5GMobile,”

,JournalofBasicandAppliedEngineeringResearc, pp. 56-60, 2014.

[4] .M.M.M.AliandA.Seba, “Sebak,"Directiveantennasforfuture5Gmobilewireless,” *201732ndGeneralAssemblyandScientificSymposium of,* pp. 1-4, 2017.

[5] RuchiVarmaJayantaGhos, “RuchiVarmaJayantaGhosh"DualBandDoubleUslotLoadedAntenna,” *Proc.ofthe2017IEEE,* pp. 5-8, 2017.

[6] P. Bevelacqua, “Antenna Basic,” Antenna-theory.com, 6 decembar 2018.

[Online]. Available: http://www.antenna-theory.com/basics/main.php. [Accessed 14 octobar 2022].

[7] T. .S.Kumar, “AFutureCommunicationTechnology:5G,” *nternationalJournalofFutureGenerationCommunicationandNetworkin,* pp. 303310, 2016.

[8] M. T. A. S. S. A. L. Y. a. M. K. M. S. H. Jaafar, “Improving gain performance by using air substrate at 5.8GHz,” *2012 International Conference on Computer and Communication Engineering (ICCCE), Kuala Lumpur,* pp. 95-98, 2012.

[9] S. B. a. A. S. A. Elfatimi, “Single feed compact millimeter wave antenna for future 5G applications,” *2018 International Conference on Intelligent Systems and Computer Vision (ISCV), Fez,* pp. 1-4, 2018.

[10] M. S. M. N. R. M. T. I. a. M. T. I. S. Das, “Broadband Elliptical Slotted Patch

Antenna for 5G Communications,” *2018 International Conference on Computer, Communication, Chemical, Material and Electronic Engineering (IC4ME2), Rajshahi,,* pp. 1-4, 2018.

[11] M. S. S. a. M. Ikram, “Slot-based connected antenna arrays for 5G mobile terminals,” *2018 International Workshop on Antenna Technology (iWAT), Nanjing,* pp. 1-3, 2018.

[12] T. O. O. a. P. Kumar, “A High Gain Microstrip Patch Antenna with Slotted Ground Plane for Sub-6 GHz 5G Communications,” *2020 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD),* pp. 1-6, 2020.

[13] X. T. e. al, “Ultra-Wideband Patch Antenna for Sub-6 GHz 5G Communications,” *2019 International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM),* pp. 1-3, 2019.

[14] A. J. A. ,. I. I. B. M. ,. Z. Z. ,. N. N. F. B. M. Al-Gburi, “Wideband Microstrip Patch Antenna for Sub 6 GHz and 5G,” *Przegląd Elektrotechniczny,* pp. 26-29, 2021.

[15] K. N. P. Y. A. S. A. G. a. X. J. L. S. Ahmad, “A Dual-band Dual Mode Antenna for On/Off-Body Communications,” *2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI),* pp. 1275-1276, 2021.

[16] G. N. a. N. S. Jyothi Sree, “Spiritual leaf shape compact MIMO patch antenna for 5G lower sub-6 GHz applications" Frequenz,” *https://doi.org/10.1515/freq2022-0047,* 2022.

[17] L. Z. H. Z. Y. L. S. X. a. G. Y. H. Jin, “A Wideband Dual-Polarized Antenna and its Array With Electrically Downtilt Function for 5G Sub-6 GHz Communication Applications,” *IEEE Access,* pp. 7672-7681, 2020.

[18] R. M. A. A. A. A. M. A. R. M. M. .. .. .. I. M. Azim, “A multi-slotted antenna for LTE/5G Sub-6 GHz wireless communication applications,” *nternational Journal of Microwave and Wireless Technologies, 13(5,* pp. 486-496, 2021.

[19] I. S. M. I. &. M. K. Ishteyaq, “A compact double-band planar printed slot antenna for sub-6 GHz 5G wireless applications.,” *International Journal of Microwave and Wireless Technologies,* pp. 479-477, 2021.

[20] M. A. E. H. A. a. H. Y. M. S. A. A. Megahed, “Sub-6 GHz Highly Isolated Wideband MIMO Antenna Arrays,” *in IEEE Access,,* pp. in IEEE Access,, 2022.

[21] A. K. F. T. a. R. K. Q. Amjad, “Design and Characterization of a Slot based Patch Antenna for Sub-6 GHz 5G Applications,” *2019 Second International Conference on Latest trends in Electrical Engineering and Computing Technologies (INTELLECT),* pp. 1-6, 2019.

[22] S. Shakir Ullah, "A Compact Frequency and Radiation Reconfigurable Antenna for," *Wireless Communications and Mobile Computing,* p. 12, 2022.

[23] U. F. e. al, "A Compact Monopole Patch Antenna for Future Sub 6 GHz 5G Wireless Applications," 2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, pp. 1715-1716, 2020.

[24] M. T. I. R. H. Z. M. S. Md Zikrul Bari Chowdhury, "A low-profile rectangular slot antenna for sub-6 GHz 5G wireless applications," *https://doi.org/10.1002/dac.5321,* 2022.

[25] M. M. Fakharian, "A low-profile compact UWB antenna array for sub-6 GHz MIMO applications in 5G metal-frame smartphones," *ttps://doi.org/10.1002/mmce.23320,* 2022.

[26] O. A. S. e. al, "Design of a 3.8-GHz Microstrip Patch Antenna for Sub-6 GHz 5G Applications," *2022 IEEE Nigeria 4th International Conference on Disruptive Technologies for Sustainable Development (NIGERCON),* pp. 1-5, 2022.

[27] K. K. S. D. B. P. a. P. S. P. K. Karthika, "Frequency Reconfigurable Antenna and its Switching Techniques for Wireless Communication Systems," *2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS),* pp. 907-911, 2022.

[28] A. A. a. P. Suraj, "Design of Patch Antenna for 5G Communication at 6 GHz (WRC-23) With WLAN Application," *2021 6th International Conference for Convergence in Technology (I2CT),,* pp. 1-5, 2021.

[29] M. T. A. S. S. A. L. Y. a. M. K. M. S. H. Jaafar, "Improving gain performance by using air substrate at 5.8GHz," *2012 International Conference on Computer and Communication Engineering (ICCCE),* pp. 95-98, 2012.

[30] T. O. O. a. P. Kumar, "A High Gain Microstrip Patch Antenna with Slotted," *2020 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD),,* pp. 1-6, 2020.