BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATION ENGINEERING

Bandwidth Enhancement of a Microstrip Patch Antenna for 5G Applications

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CANDIDATES DECLARATION

It is clearly stated that this thesis has not been submitted to any other institution for the award of a degree or diploma, and it contains no unlawful statements.

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DEDICATION

This research honors all of our great instructors, parents, and well-wishers.

CERTIFICATE OF APPROVAL

Md. Salauddin, bearing ID No: T173016, Amin Hasan Mahmud, bearing ID No: T173018, and Abir Roy, bearing ID No: T173025, submitted a thesis to International Islamic University Chittagong's (IIUC) Department of Electronic and Telecommunication Engineering (ETE) entitled "Bandwidth Enhancement of a Microstrip Patch Antenna for 5G Applications," which was approved as suitable for partial fulfillment of the requirements.

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Abstract

The main disadvantage of a Microstrip Patch antenna is its narrow bandwidth. This research aims to improve the bandwidth of a microstrip patch antenna (MPA) for 5G applications. A variety of factors such as substrate element, substrate height, feeding method, and so on, which have an impact on the antenna's performance. If those parameters are chosen correctly, the 5G application requirements will be met. This work defined MPA's expanded bandwidth, which will be favorable for 5G applications. The insertion gap concept is used to extend the bandwidth of a microstrip patch antenna in this research. It would also be possible to attain a bandwidth that matches the demands and expectations of 5G applications by adjusting the size of the insertion gap. Finally, a single microstrip patch antenna operating at 28 GHz with a center frequency of 28.075 GHz has been designed. The suggested antenna's gain, bandwidth, return loss, VSWR, directivity, and efficiency are 5.83 dB, 928 MHz, -41.282 dB, 1.017, 7.67 dBi, and 66.7 percent respectively.

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LIST OF SYMBOLS

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	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 Wireless Communication Evolution (0G-5G)

The process of communicating without the use of cables is known as wireless communication. It communicates with each other using a variety of frequencies and bandwidth. The message signal is sent across a free and available bandwidth by the sender. To receive the message signal, the receiver tunes to that specific bandwidth. In mobile wireless communication, the mobile service provider assigns a specific frequency to each mobile station from a range of frequencies. Mobile station users are now using this frequency to send and receive message signals. In 1973, Motorola unveiled the first portable mobile phone. In 1979, NTT launched Japan's first commercial automated cellular network. In 1981, Denmark, Finland, Norway, and Sweden launched the Nordic Mobile Telephone (NMT) system [1]. Following the advent of wireless communication, Mobile Wireless Communication entered the communication market with the debut of 0G, which uses the Push to Talk Technique. In the future, there will be 1G networks that will only be used for voice calls. 2G was a reimagining of 1G that included digital technology as well as the ability to send messages. 3G offered a broad platform for accessing high-speed internet services. 4G was introduced as a more advanced version of 3G, with increased bandwidth and capacity, as well as quality of service (QoS). 5G doubles the bandwidth of 4G and enables real-time wireless Internet access (WWWW). [2]

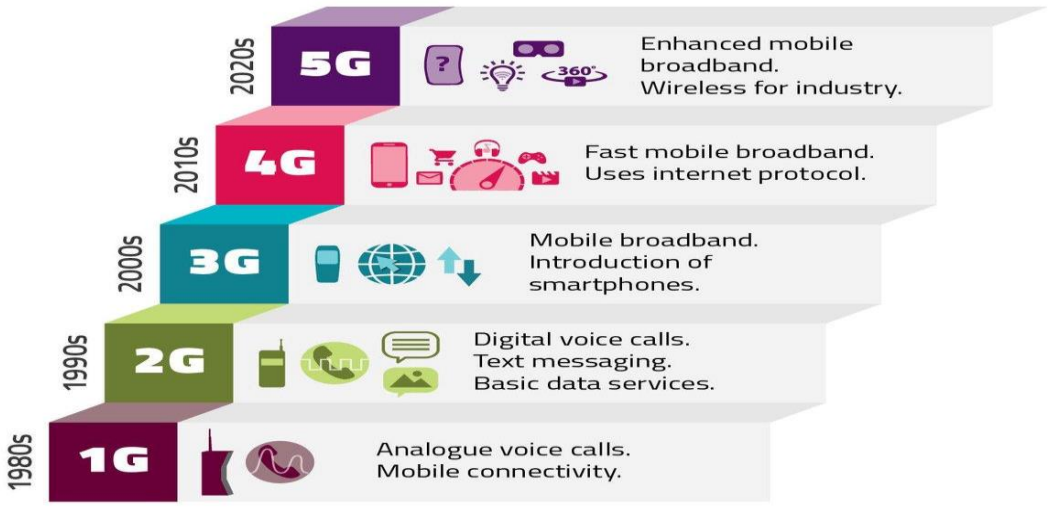

Figure 1.1: Communication evolution/improvement [50]

1.2 Wireless Communication's Zero Generation (0G)

Before the cell phone 0G refers to mobile telephony technology, such as radiotelephones that some people had in their cars before cell phones. Wireless mobile systems predate modern cellular mobile telephone technology.

- ✓ PTT (Push to Talk), sometimes known as "Press to Transmit," is a means of communicating via half-duplex communication lines like two-way radio that was used in 0G systems. As soon as the receiver was taken out of the cradle.
- ✓ IMTS (Improved Mobile Telephone Service) devices emitted a dial tone, giving them the appearance of landline phones rather than cellular handsets.
- ✓ AMTS (Advanced Mobile Telephone System) uses 900 MHz frequencies and eliminates all of the issues that IMTS presents.
- ✓ MTD (Mobile telephony system D) was a fixed wireless service that provided high-speed internet access without the use of a telephone line. It provides an internet connection that is "always on." [3]

1.3 Wireless Communication 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 finished in the early 1990s. In 1979, Nippon Telephone and Telegraph (NTT), based in Tokyo, Japan, introduced the world's first cellular system. In the 1980s, Nordic Mobile Telephone (NMT) and (TACS) 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 the Advanced Mobile Phone System (AMPS) technology. The AMPS system was frequency modulated and used frequency division multiple access with a data rate of 30 kHz and a waveband of 824–894 MHz (FDMA). [4]

1.3.1 Basic features of 1G

- ✓ Allows voice calls
- ✓ speed of 2.4 kbps.
- ✓ Use a signal that is analog.
- ✓ Voice quality is poor.
- ✓ Battery life is poor.
- ✓ The phone is of a large size.

- ✓ Capacity is limited.
- ✓ The accuracy of handoffs is low.
- ✓ Insufficient privacy.
- ✓ The spectrum efficiency was given at a relatively low level.

1.4 Wireless Communication Second Generation (2G)

The second generation of mobile telephony, launched towards the end of the 1980s, is known as 2G. The Global System for Mobile Communication (GSMC), sometimes referred to as 2G, is a new digital technology created by the Global System for Mobile Communication (GSMC) (GSM). GSM technology was designed with digital signals in mind. It offers low-speed SMS and MMS delivery (in kbps). It operates at a frequency of 30 to 200 kHz. Following 2G, 2.5G systems, such as GPRS, CDMA, and EDGE, to offer data speeds of up to 144 kbps, employ the packet-switched and circuit-switched domains.

1.4.1 Basic features of 2G

- ✓ It has a data speed of up to 64kbps
- ✓ Offers services like SMS, MMS (Multimedia Messages), and image messages.
- ✓ 2G is incapable of handling sophisticated data such as movies.
- ✓ To make mobile phones work, 2G requires powerful digital signals.
- ✓ 2G is incapable of handling sophisticated data such as movies.
- ✓ To make mobile phones work, 2G requires powerful digital signals. [4]

1.4.2 GPRS (General Packet Radio Service) 2.5G

2.5G stands for "second and half generation," and it is a mobile wireless technology created between the second and third generations. The term "second and half generation" refers to the "General Packet Radio Services." GPRS data rates range from 56 to 115 kilobits per second during peak hours. AMMS, WAP, and internet services such as email and access to the World Wide Web are all included (WWWW). In traditional circuit switching, data communication is measured in minutes of connection time, but data transfer in GPRS is measured in gigabytes of traffic exchanged [11].

1.5 Wireless Communication Third Generation (3G)

The third generation is abbreviated as 3G. It was created in 2000 and is based on the ITU's (International Telecommunication Union) standard family. The primary goal of 3G technology was to provide fast data transport. It makes use of a Wide Band Wireless Network to improve clarity. It also provides television and video access, as well as Global Roaming services. It operates at 2100MHz and has a bandwidth of 15-20 MHz, making it ideal for high-speed internet and video calling.

1.5.1 Basic features of 3G

- ✓ It has a speed of up to 2 Mbps.
- ✓ For adapting web-based programs and audio/video files, high bandwidth and data transmission speeds are required.
- ✓ It also allows for speedier communication.
- ✓ Allow for the sending and receipt of huge email.
- ✓ It has improved security, teleconferences, and 3D gaming capabilities.

1.6 Wireless Communication Fourth Generation (4G)

4G is an abbreviation for fourth generation, and it offers download speeds of up to 100 Mbps. 4G combines the advantages of 3G with the addition of Multi-Media, allowing users to watch television shows with greater clarity and transport data more quickly than previous generations. Long Term Evolution (LTE) is a component of 4G technology. [5]

4G is being developed to meet the quality of service (QoS) and rate requirements of future applications including MMS, wireless broadband access, basic data and voice services, and other bandwidth-intensive services. [6]

1.6.1 Basic features of 4G

- ✓ It provides high-quality streaming video and speeds ranging from 10Mbps to 1Gbps.
- ✓ It's a cross between Wi-Max and Wi-Fi.
- ✓ It has an extremely high degree of protection.
- ✓ It consumes more battery power.

- ✓ It is challenging to implement.
- ✓ It necessitates the use of complex hardware. [7]

1.6.2 Extension of 4G LTE as 4.5G

The features of 4.5G wireless technology are as follows. It refers to services that aren't part of the standard mobile broadband network. It is a 4G LTE extension that provides download speeds of up to 300 Mbps. It is more important in emerging IoT markets.

- ✓ It's the advancement of mobile broadband data rates on paired and unpaired spectrum, which allows for efficient IoT connectivity.
- ✓ It is necessary for mission-critical public safety.
- ✓ It allows for LTE broadcasting.
- ✓ LTE Advanced Pro 3GPP is the industry standard.
- ✓ Peak Downlink Data Rates: 1 Mbps (LTE-M), 170 Kbps (NB-IoT)
- ✓ Peak data rates (uplink): 1 megabit per second (LTE-M), 250 kilobits per second (LTE-A) (NB-IoT).
- ✓ In LTE-M, 1.08 Mbps (1.4 MHz carrier BW) is used, while in NB-IoT, 180 KHz (200 KHz carrier BW) is used. [14]

1.7 Fifth Generation of Wireless Communication (5G)

The Fifth Generation (sometimes known as 5G) began in late 2010. Increased connection and coverage are among the advantages of 5G technology. The globe wireless World Wide Web is the primary emphasis of 5G. (WWWW). Customers may expect ultra-fast internet and multimedia experiences thanks to 5G's superior technologies. Supercharged 5G networks emerge from LTE advanced networks. To achieve a higher data rate, 5G technology employs millimeter waves and an unlicensed channel for data transmission. [8]

1.7.1 Basic features of 5G

- ✓ It strongly backs the WWWW (Wireless World Wide Web).
- ✓ It has a high capacity as well as a high speed.
- ✓ It can broadcast enormous amounts of data at a rate of Gbps.
- ✓ Provides superior multi-media services, newspapers, and HD clarity for watching TV shows.

- ✓ It transmits data more quickly than the preceding generation.
- ✓ Large phone memory, audio/video clarity, calling speed, interactive multimedia, voice, streaming video, and other features
- ✓ It expanded the amount of multimedia services offered.
- ✓ Low price per bit.
- ✓ It drains more power from the battery.
- ✓ It is challenging to implement.
- ✓ It necessitates the use of complex hardware. [9]

Table 1.1: Comparison between different generation of wireless communication technologies [10]

Generation → Features↓	**0G**	**1G**	**2G**	**3G**	**4G**	**5G**
Year	1960-1970	1970-1980	1980-1990	1990-2000	2000-2010	2015-onwards
Switching	Circuit	Circuit	Circuit and packet	Except for an air interface packet circuit.	Packet	Packet
Speed	Below 1kbps	2.4kbps	64kbps	2Mbps	200Mbps-1Gbps	1Gbps and higher
Technology	PTT, MTS, IMTS, AMTS	Analog Cellular	Digital Cellular	Broadband CDMA, IP	Unified IP & seamless LAN, WAN, WLAN, and PAN connectivity	4G+ WWWW
Services	Pre-cellular systems	Voice only	Digital voice and short messaging, packetized data	High-definition audio, video, and data are all integrated.	Wearable devices, dynamic information access	Wearable gadgets with AI capabilities, dynamic information access
Multiplexing	FDMA	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Core Network	PSTN	PSTN	PSTN	Packet Network	Internet	Internet

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

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

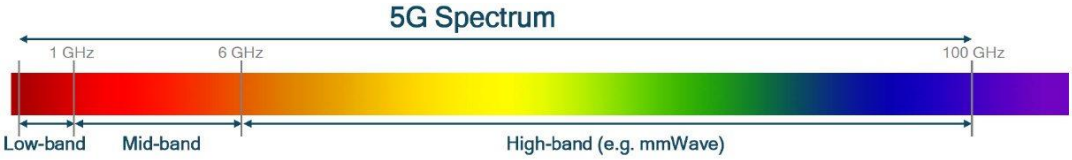

Figure 1.2: Spectrum for 5G

1.8.1 Low-band

Public auction with a Broadcast Incentive

- ✓ After the assignment phase, a portion of the 600 MHz spectrum was successfully auctioned, resulting in a profit of $19.8 billion.
- ✓ A total of 70 MHz of licensed spectrum is divided into two channels, with an extra 14 MHz available for unlicensed usage.
- ✓ The availability of spectrum matches to 5G [12-13].

1.8.2 Mid-band

Broadband Radio for Residents

- ✓ Launching a 150 MHz spectrum in the 3.5 GHz range with incumbents PAL1, GAA2 on a three-layer sharing basis.
- ✓ In 2017, the FCC issued PAL instructions to make them 5G-ready.
- ✓ The CBRS Alliance was formed to promote an ecosystem centered on LTE.
- ✓ The FCC has received inquiries regarding the frequencies of 3.7-4.2 GHz and 5.9-7.1 GHz. [12-13].

1.8.3 High-band

In 2016, the Spectrum Frontiers Court issued a ruling, then in 2017, the Court issued a second ruling.

- ✓ Several millimeter Wave bands are opening up around 11 GHz.
- ✓ Approximately 70% of newly released bands are shared or unlicensed. always in agreement.
- ✓ The FCC has urged that another nominated spectrum branded for IMT-2020 be observed.
- ✓ Consider adding 24.25-24.45 GHz, 24.75-25.25 GHz, and 42-42.5 GHz to your

spectrum. [12-13].

1.8.4 High-band: governing spectrum frontiers for 5G millimeter Wave bands

The shared and unlicensed spectrum are crucial for more bands.

Licensed Spectrum

- A frequency range of 27.5 GHz to 28.35 GHz
- A frequency range of 37.6 GHz – 38.6 GHz
- A frequency range of 38.6 GHz - 40 GHz

Shared and unlicensed spectrum

- Frequency range of 37 GHz– 37.6 GHz
- Frequency range of 64 GHz- 71 GHz. [12-13]

1.8.5 Spectrum of 5G in Europe

Concentrate on the 3.4–3.8 GHz frequency and the 26 GHz spectrum (24.25-27.5 GHz). The European Commission's RSC, CEPT, and major European Member States are pursuing regulatory steps to hasten the deployment of 5G across the EU.

- ✓ The 3.4-3.8 GHz and 26 GHz bands have well-run supervisory activities, with auctions planned in 2017-2018.
- ✓ In March 2017, the government released its 5G strategy for the United Kingdom.
- ✓ In 2017–2018, Ofcom intended to auction a 150 MHz channel in the 3.4 GHz–3.6 GHz band and a 110 MHz channel in the 3.6 GHz–3.8 GHz band. In 2018–2019, Ofcom planned to auction a 150 MHz channel in the 3.4 GHz–3.6 GHz band.
- ✓ Ofcom has introduced a work platform on 26 GHz band accessibility for timely 5G organization.
- ✓ In 2018, the Italian government plans to sell 700 MHz, 3.6 GHz–3.8 GHz, and 26.5 GHz–27.5 GHz frequencies.
- ✓ Ireland's government has successfully auctioned 350 MHz of radio spectrum for 5G connectivity.
- ✓ In response to market demands and operator needs, the Spanish government granted license for the 3.6 GHz-3.8 GHz spectrum in 2018.

- ✓ Spain is concentrating on the 26 GHz spectrum. In 2018, at least 1.4 GHz bandwidth will be available.

Other nations, like as Austria, Belgium, and Switzerland, are planning spectrum releases in the 2018-2019 timeframe. [12-13]

1.9 Antenna Basics

An antenna is a transducer that transforms radio-frequency (RF) energy into electrical energy or the other way around. The receiving antenna, which catches RF energy and supplies alternating current to the equipment, and the transmitting antenna, which takes electrical energy from the equipment and generates a radio-frequency field, are the two basic types. The microstrip patch antenna is the most popular form of antenna used in wireless applications. The microwave frequency range is where microstrip patch antennas are most helpful.

1.9.1 Frequency

In the ordinary sense, frequency refers to the frequency with which a particular event occurs during a given time period. Essentially, the number of times an event occurs in a certain period of time is referred to as frequency. "The number of recurrences of a signal over a specific time period (1 second) is known as frequency," according to the standard definition. Every 'T' second, or time interval, a periodic signal repeats itself. The frequency of a periodic signal is the inverse of the time period (T). Frequency diagrams are shown in Figures 1.3 and 1.4. Frequency is a term used in engineering to describe the rate at which oscillatory and vibratory events, radio waves, audio transmissions (sound), mechanical vibrations, and light are all examples of electromagnetic waves. Heinrich Hertz, a German physicist, gave the SI (International System) unit of frequency the name hertz (Hz). A hertz is a unit of measurement that indicates how many times an event or signal occurs every second.

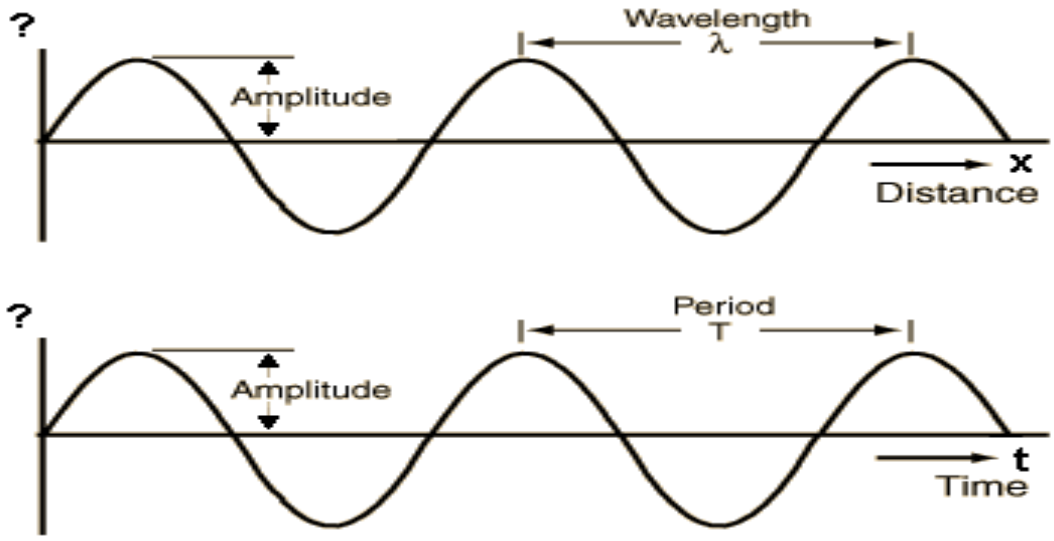

Figure 1.3: Diagram of wave frequency

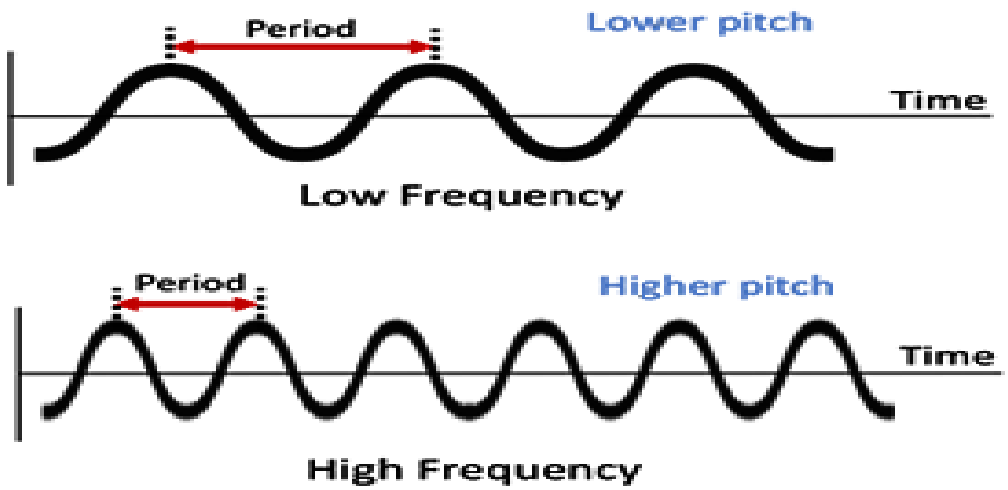

Figure 1.4: Diagram of low and high frequencies

1.9.2 Bandwidth

The ability of a wired or wireless communications system link to transport the greatest amount of data from one place to another over a computer network or internet connection in a given length of time, generally one second, is known as bandwidth in communication systems. The bandwidth of an antenna refers to the frequency ranges over which it can effectively produce or receive energy. In most cases, bandwidth is one of the most important factors to consider when selecting an antenna. For example, several antenna types have extremely narrow bandwidths and cannot be utilized in wideband mode. A bandwidth diagram is shown in Figure 1.5.

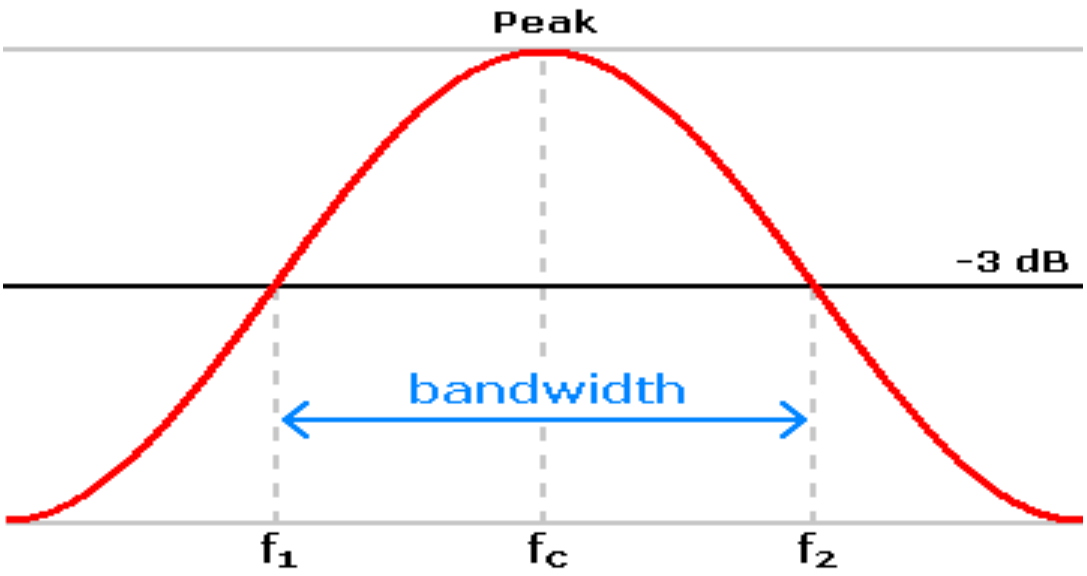

Figure 1.5: Diagram of Bandwidth

1.9.3 Input Impedance

The voltage to current ratio at the antenna input terminals determines the input impedance of the antenna. It is a fundamental antenna property that expresses the antenna's resonance. Real and imaginary input impedance are the two forms of input impedance. The real component of the input impedance represents the power radiated or absorbed within the antenna. The imaginary component of the input impedance, referred to as reflected power, represents the power stored in the antenna's near field. The real and imaginary input impedances of a resonant antenna are both zero. The length and size of an antenna determine its input impedance. Z stands for impedance, which is divided into two parts: a real component that comprises the antenna's radiation resistance Rrad and ohmic losses Rohmic, and a reactive portion that includes the antenna's radiation resistance Rrad and ohmic losses Rohmic portion X [13].

1.9.4 Impedance Matching

The standard definition states: "impedance matching" is "the approximate value of a transmitter's impedance equaling the approximate value of a receiver's impedance, or vice versa." Impedance matching between the antenna and the electronics is required for wireless transmission. When the antenna's impedance is low, maximum power transmission occurs between the antenna and the receiver or transmitter, transmission

line, and electronics are all equal, according to theory. Tuning or matching the antenna is the process of impedance matching the antenna with the electronics over a frequency range. VSWR refers to the frequency range where the antenna impedance is close to 50 Ohms for a given VSWR, and bandwidth refers to the frequency range where the antenna impedance is close to 50 Ohms for a given VSWR. A resonant device produces better output over a narrow frequency range. Antennas are resonant devices that produce better results when their impedances are matched. As shown below, impedance matching is required.

- ✓ The power from the source will be successfully provided to the feedline if the feedline impedance matches the source impedance.
- ✓ The power from the feedline will be successfully transmitted to the antenna if the antenna impedance matches the feedline impedance.
- ✓ The output impedance of a receiving antenna should match the receiver amplifier circuit's input impedance.
- ✓ The input impedance of a transmitter antenna should match the output impedance of the transmitter amplifier, as well as the impedance of the transmission cable [15].

1.9.5 Directivity and Gain

When transmitting, an antenna's directivity refers to its ability to emit energy in a certain direction or to receive energy more effectively from a specific direction when receiving. And gain is usually defined as the difference between the power produced by a far-field source on the antenna's beam axis and the power produced by a lossless isotropic antenna that is equally sensitive in all directions. Gain and directivity are inversely related. When comparing a light bulb to a spotlight, the phenomenon of improved directivity explains the link. In comparison to a 100-watt light bulb, a 100-watt spotlight produces more light in one direction while generating less light in others. The light bulb, in compared to the spotlight, has less "directivity." The spotlight functions similarly to a high-direction antenna. The gain is the directivity's practical value. Gain is the multiplication of directivity and efficiency in mathematics.

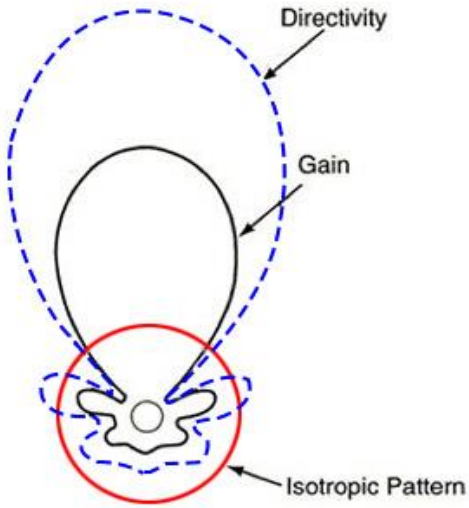

Figure 1.6: Diagram of Directivity and Gain

1.9.6 Radiation Pattern

A "radiation pattern" is the directional (angular) dependency of an antenna's radio wave intensity (also "antenna pattern" or "far field pattern"). At a certain distance from the antenna, the radiation pattern indicates the relative intensity of the radiated field in various directions. Because it depicts the antenna's receiving qualities, the radiation pattern is also known as a "reception pattern." Although the radiation pattern is three-dimensional, it is impossible to depict it in a meaningful way. The radiation pattern is seen in Figure 1.7. Measuring a three-dimensional radiation pattern requires time as well. Radiation patterns are often measured as a two-dimensional slice of a three-dimensional pattern, which may then be shown on a screen or sheet of paper. Pattern measurements can be shown in a rectangular or polar style [13].

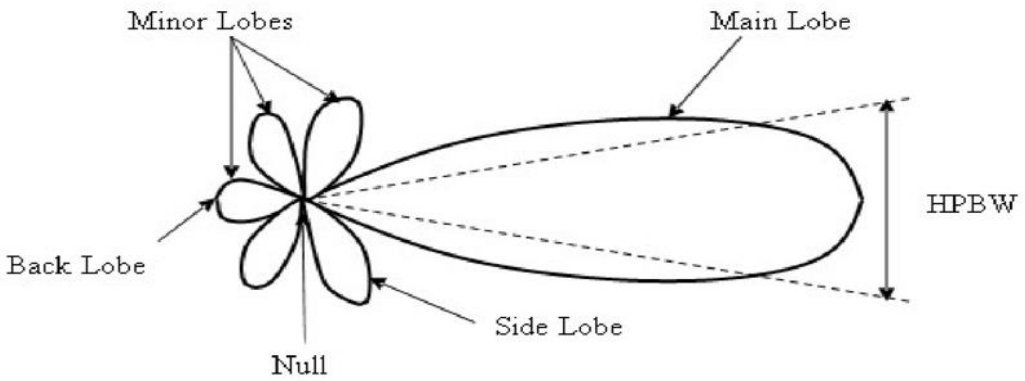

Figure 1.7: Diagram of Radiation pattern

1.9.7 Voltage Standing Wave Ratio (VSWR)

The voltage standing wave ratio (VSWR) is a measurement of how well radio-frequency power is transmitted from a source to a load via a transmission line. In other terms, the highest power to least power ratio in a wave that can be measured is the standing wave ratio (SWR). The voltage ratio of the reflected voltage to the incident voltage is known as the VSWR. The VSWR of an antenna is always true and positive. The better the antenna matches the transmission line and receives more power, the lower the VSWR. A VSWR of more than one is required. No power is reflected from the antenna in this circumstance, which is a perfect situation [13]. Figure 1.8 illustrates the VSWR.

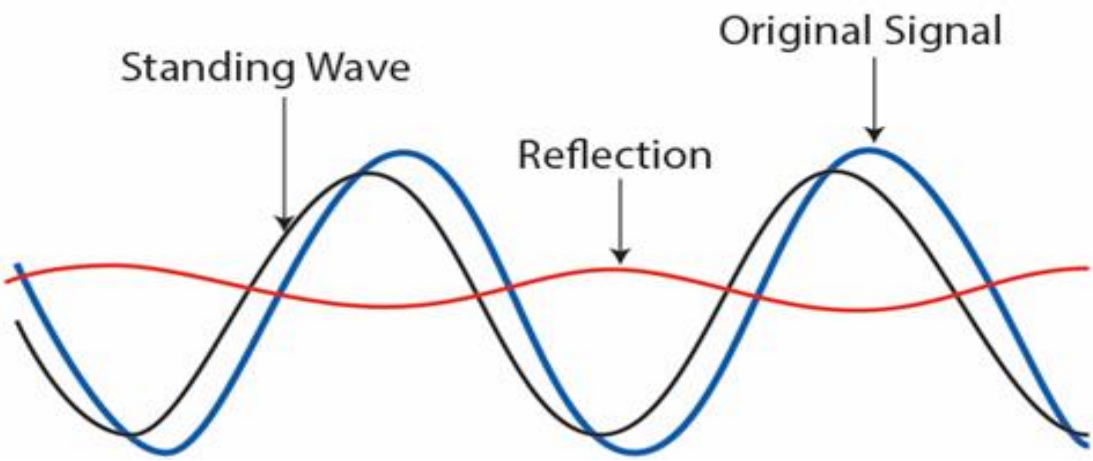

Figure 1.8: Voltage Standing Wave Ratio (VSWR)

1.9.8 Return Loss (RL)

The Return Loss of an antenna is the percentage of radio waves that are rejected against those that are accepted when they arrive at the antenna input. In compared to a short circuit, it's expressed in decibels (dB) (100 percent rejection). The antenna-to-feedline mismatch is often referred to as return loss (RL). It's a dB-measured algorithmic ratio that compares the power reflected by the antenna to the power transmitted into it via the transmission line. The VSWR and the RL are inextricably linked. In fact, S11 is the most commonly stated antenna parameter. S11 is nothing more than a loss of return (RL). No power is emitted if S11 = 0 dB, and all power is reflected off the antenna. If S11 = -6 dB and 3 dB of power is delivered to the antenna, the reflected power is -3 dB. An RL or S11 of less than or equal to -9.5 dB equates to a VSWR of less than or equal to 2. An RL of -10 dB is considered acceptable in this thesis [13].

1.9.9 Polarization

The electric field of the wave generated by the antenna determines the antenna's polarization. The antenna's polarization is determined by the amplitude and phase of the electric field. The antenna is linearly polarized if the magnitudes and phases of the electric field components are equal. The antenna is circularly polarized if the magnitudes are equal but the phases differ by 90 degrees. The projected electric fields of two linearly polarized antennas must be aligned in order to communicate.

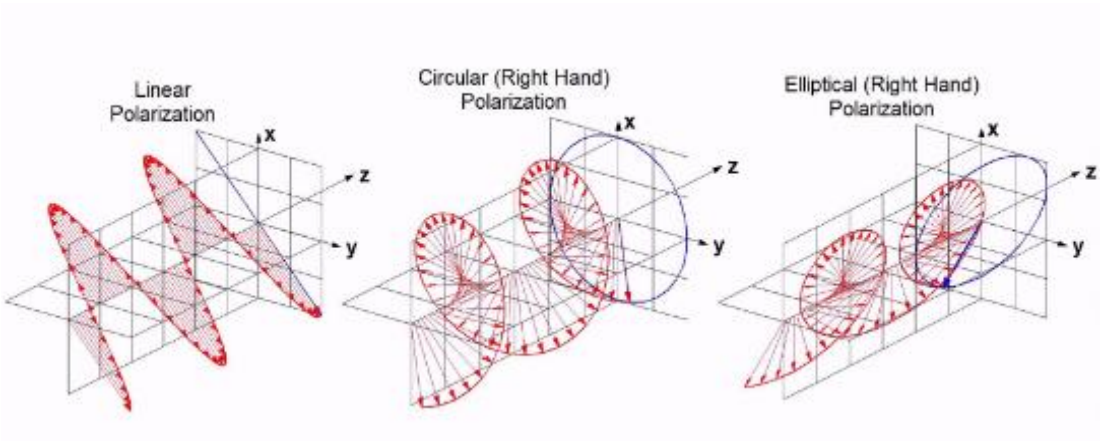

Figure 1.9: Polarization Linear, Circular, Elliptical.

In contrast, a circularly polarized antenna may communicate with any linear antenna, regardless of its orientation. Because all of the radiation is focused in one direction rather than being split between the two components, a linear antenna radiates more power than a circular antenna. A reader antenna can be linear or circular depending on the application, and the tag antenna should preferably be circularly polarized so that it can be read from any angle [16]. Three forms of polarization are depicted in Figure 1.9.

Chapter 2
Microstrip Antenna

2.1 Microstrip Patch Antenna

A microstrip patch antenna is made consisting of a radiating patch on one side of a dielectric substrate and a ground plane on the other, as shown in Figure 2.1. The patch is often constructed of conductive metals like copper or gold, and it may be manufactured in any form. On the dielectric substrate, the radiating patch and feed lines are normally photo etched. The patch is usually square, rectangular, circular, triangular, elliptical, or any other common shape to make analysis and performance prediction easier. The fringing fields between the patch edge and the ground plane cause microstrip patch antennas to emit. Because it provides higher efficiency, a broader bandwidth, and better radiation, a thick dielectric substrate with a low dielectric constant is beneficial for improved antenna performance.

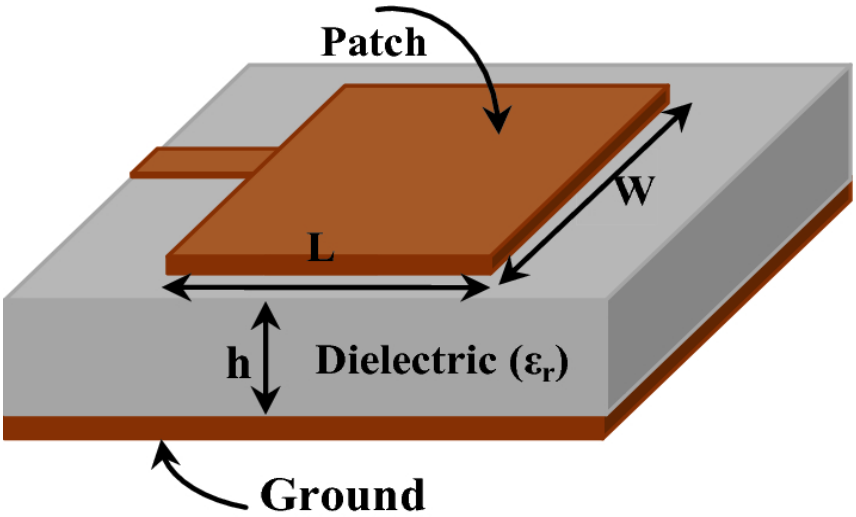

Figure 2.1: Structure of a Microstrip Patch Antenna

Such a configuration, however, demands a larger antenna. Higher dielectric constants are required for a small Microstrip patch antenna, which are less efficient and result in a narrower bandwidth. [16]

2.1.1 Microstrip antenna Feed Techniques

The following are examples of different types of microstrip antenna feed techniques.

- Microstrip Line Feed
- Coaxial / Probe Feed

- Aperture Coupled Feed
- Proximity Coupled Feed

2.1.2 Microstrip Line Feeding

A microstrip transmission line is sliced straight to the patch's border in this method of feeding, maintaining the entire structure in the same plane. The microstrip feed line is shown in Figure 2.2.

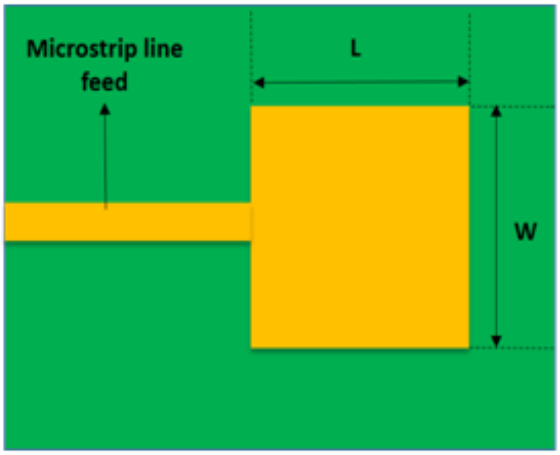

Figure 2.2: Diagram of Microstrip Line Feeding

2.1.3 Coaxial or Probe feeding

The radiating patch is connected to the coaxial connector's inner conductor, which goes through the substrate, while the outside conductor is grounded. Figure 2.3 shows a coaxial feeding system.

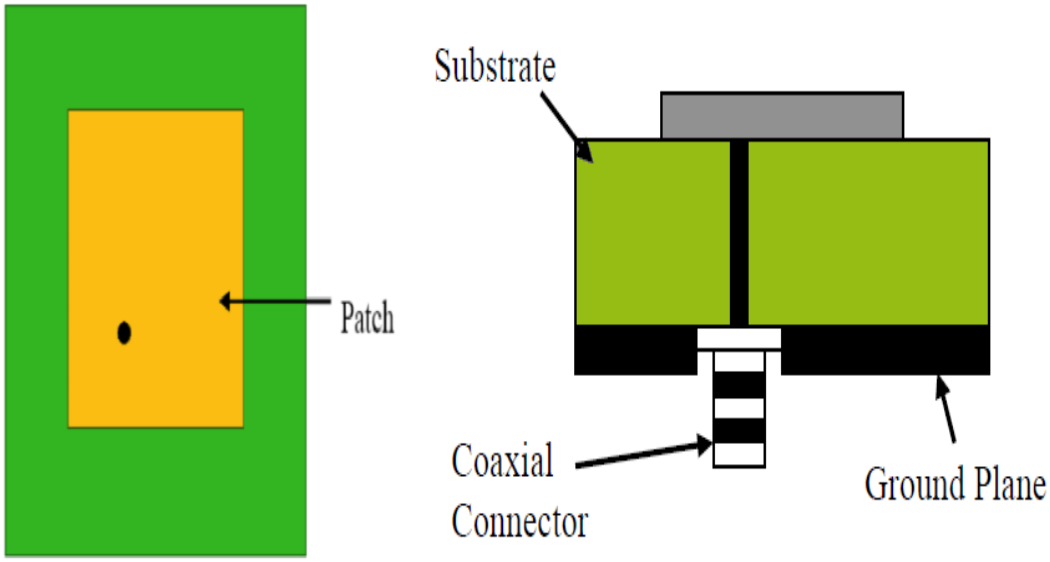

Figure 2.3: Diagram of Coaxial / Probe feeding.

2.1.4 Aperture Coupled Feed

The aperture coupling in this sort of feed is made up of two substrates separated by a ground plane. The radiating patch and microstrip line, which are located at the bottom of the lower substrate, are separated by the ground plane. A small electrically conductive aperture or slit is made in the ground plane to provide coupling. Figure 2.4 depicts an aperture-coupled feed.

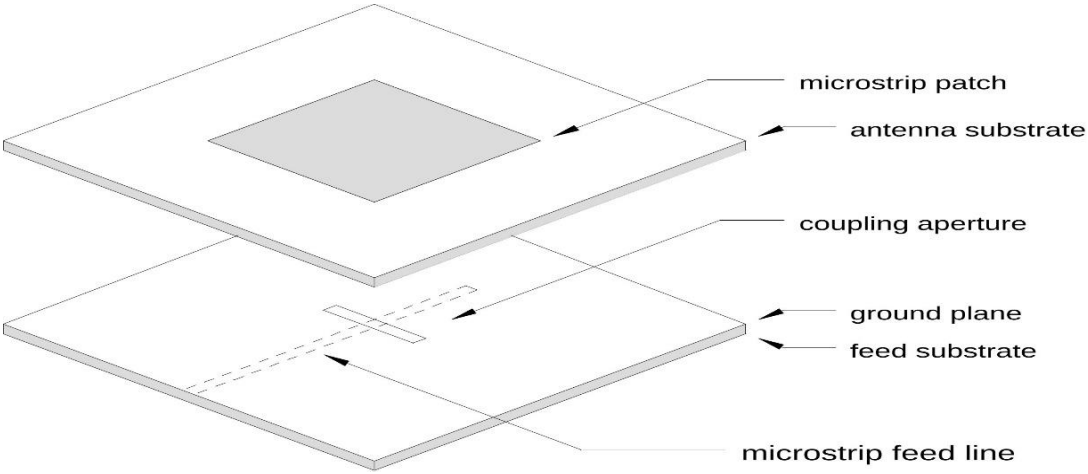

Figure 2.4: Diagram of Aperture-Coupled Feed

2.1.5 Proximity Coupled Feed

Another term for it is Electromagnetically Coupled ECMSA. It is made up of two substrates as well. The radiating patch lies atop the top substrate, with the microstrip feed line sandwiched between two substrates. This is represented in Figure 2.5.

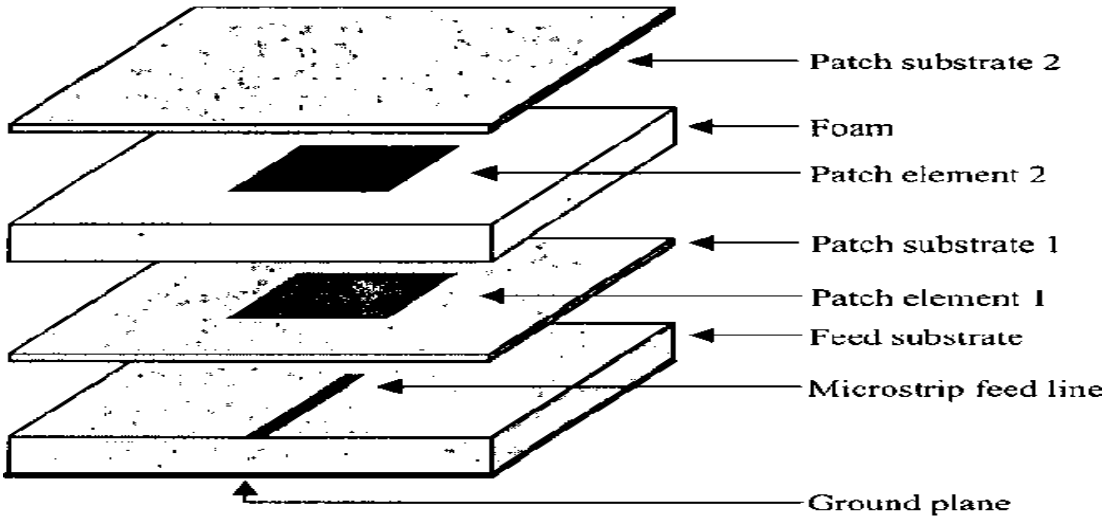

Figure 2.5: Diagram of Proximity-Coupled Feed

2.1.6 Advantages and Disadvantages of Microstrip Antenna

Microstrip patch antennas are becoming more popular in wireless applications due to their low-profile design. As a consequence, built-in antennas in portable wireless devices such as mobile phones and pagers function excellently. Because they must be tiny and conformal, microstrip patch antennas are widely utilized as telemetry and communication antennas on missiles.

2.1.6.1 Advantages of the microstrip antenna

- ✓ Microstrip antennas are small and light.
- ✓ They can be constructed cheaply, allowing them to be mass-produced in enormous quantities.
- ✓ They feature a low-profile planar design that conforms to the host surface effortlessly.
- ✓ Linear and circular both polarization are supported.
- ✓ Microstrip antennas are simple to include into microwave integrated circuits (MICs).
- ✓ They have the ability to operate on dual and triple frequencies.
- ✓ When installed on stiff surfaces, they are mechanically resilient.

2.1.6.2 Disadvantages of the Microstrip antenna

- ✓ Microstrip antennas have a small bandwidth.
- ✓ Inefficient.
- ✓ Gain is poor.
- ✓ They have an issue with extraneous radiation from feeds and connections.
- ✓ Except for tapered slot antennas, poor end fire radiator.
- ✓ Their ability to handle high amounts of electricity is limited.
- ✓ Excitation by surface waves.

The antenna quality factor of microstrip patch antennas is quite high (Q). A high Q denotes a restricted bandwidth and low efficiency, while a low Q indicates a big bandwidth and low efficiency. The thickness of the dielectric substrate can be increased to lower Q. A surface wave is created by an increasing proportion of the source's total power. Because it is eventually diffused at the dielectric bends and causes deterioration of characteristics, this surface wave contribution may be regarded an

undesired power loss. [16]

2.2 Design Tool

This section contains a collection of design tool characteristics.

2.2.1 CST Microwave Studio

CST MICROWAVE STUDIO (CST MWS) is an advanced modeling tool for three-dimensional high-frequency structures. CST MWS allows users to investigate high-frequency components such as antennas, filters, couplers, planar and multi-layer structures, as well as SI and EMC effects, rapidly and precisely. Both time-domain and frequency-domain solutions are included in the program. Filters for importing certain CAD files and extracting SPICE parameters increase design possibilities while saving time. For electromagnetic design and analysis, CST offers precise, cost-effective computational solutions.

2.2 Motivation

Wireless communication has risen in popularity since its introduction because to its low cost, flexibility, portability, and other benefits. As a result, there has been a rapid increase in the need for mobile connections, data rates. During the previous three decades, there has been a significant increase in mobile data traffic. The Internet of Things (IoT) has once again broadened the scope of these needs. The telecommunications industry has produced new generations of standards practically every decade to suit this expanding demand. They have resulted in the fifth generation (5G), which will be implemented in the early 2020s in order to accomplish the goals of connecting more than 100 billion wireless devices, millisecond latency, 10 Gbps data throughput, and the internet of things [38]. Path-loss at high frequencies is one of the key difficulties for 5G deployment, thus we designed an antenna that can manage it.

2.3 Essence

Telecommunications is a rapidly evolving industry. Every ten years, a new generation emerges. 5G is the preceding technology, and it is the one that researchers are most interested in. As a consequence of the massive increase in wireless applications,

technology has progressed from Fourth Generation (4G) to Fifth Generation (5G) (5G). After 4G/IMT-Advanced, 5G is the next wireless communication standard. 5G will be more competent than current 4G, allowing for higher wireless network density, device-to-device ultra-reliability, large-machine networking, and the Internet of Things (IoT). We must create 5G compatible antennas since wireless communication is impossible without the use of an antenna. Because of its unrivaled features, the microstrip patch antenna is the most widely used antenna in today's wireless communication. Because of its lower size, this antenna can accommodate smaller end devices. Any PCB may simply be etched with microstrip antennas. Microstrip patches are easy to etch and come in a variety of forms, including rectangular, square, and triangular patches. They have a lower cost of production and can thus be bulk manufactured. They can operate in a range of frequency bands (dual, triple). They accept both linear and circular polarization. They're not overly heavy. The current 4G network uses sub-6-GHz channels to communicate. However, the available spectrum in these bands is insufficient to satisfy the expectations of 5G [38]. As a result, higher frequency bands ranging from 6 to 300 GHz will be required. As a result, the Federal Communications Commission [39] has designated the 3.4-3.6 GHz, 5-6 GHz, 24.25-27.5 GHz, 37-40.5 GHz, and 66-76 GHz bands for 5G wireless communication, as well as the 3.4-3.6 GHz, 5-6 GHz, 24.25-27.5 GHz, 37-40.5 GHz, and 66-76 GHz bands for 5G wireless communication. At 28 GHz [40] and 38 GHz, several experiments have been undertaken to produce high gain microstrip patch antennas for 5G communication. However, some of those antennas do not cover the whole 28 GHz and 38 GHz bands, as required by the FCC, while others are too large to be compatible with 5G mobile phones. As a result, it's critical to build an antenna that can span the 28 GHz and 38 GHz bands while yet being compatible with 5G devices.

Chapter 3
Literature Review

3.1 Paper Review

This section will examine the work of other researchers pertinent to this thesis, "Bandwidth Enhancement of a Microstrip Patch Antenna for 5G Applications," which will be a critical component of research for fifth-generation (5G) applications utilizing the present antenna. As a result, a better-performing, easier-to-manufacture antenna was designed and simulated.

1. Research Paper on “Dual-band Microstrip Antennas for 5G and Short-Range Applications”

In this paper, dual-band monopole antennas with a rectangular ring shape were built. A Rogers RT/duroid 5880 dielectric substrate was used to construct the antenna. Variations in the diameters of the ring antennas and the ground are used to conduct a parameter analysis. It was shown that single-band, dual-band, and wideband characteristics may be created by changing the ground diameters. With a ground size of D = 38 mm, two resonances at 3.19 GHz and 4.63 GHz with bandwidths of 240 MHz and 322 MHz were found. The resonance frequencies were found to be 3.17 GHz and 4.67 GHz, respectively, with bandwidths of 550 MHz and 190 MHz, using a VNA. This paper is meant to function between the frequencies of 3.2 and 4.6 GHz. Short-range devices utilize frequencies between 3.1 and 3.3 GHz, whereas radiolocation services use bands between 3.1 and 3.3 GHz. Furthermore, the frequency ranges 4.4 GHz–4.5 GHz and 4.5 GHz–4.8 GHz are being investigated as prospective 5G competitors. [17]

2. Research Paper on “Broadband Microstrip Antenna for 5G Wireless Systems Operating at 28 GHz”

This paper presents a new broadband microstrip antenna design approach for 5G systems. The proposed antenna works in the LMDS (Local Multipoint Distribution Service) frequency range and has a core operational frequency of 28 GHz. The antenna was created with the intention of operating in the 28 GHz range, which is one of the frequency bands expected to be used in 5G systems. The antenna model must also take

into account a compact antenna size and the greatest achievable bandwidth. The antenna design approach has been tweaked to make it smaller and lighter, allowing it to be used in mobile terminals and facilitating integration with electronic equipment. Using the FEKO program, the antenna's size and attributes were calculated, simulated, and optimized. The antenna has a small footprint, measuring 6.2 x 8.4 x 1.57 mm. The antenna was made out of Rogers RT Duroid 5880 material, which has a dielectric coefficient of 2.2 and a thickness of 1.57 mm. The antenna shown in this article features a low reflection coefficient of 22.51 dB, strong energy gains of 3.6 dBi, a wide working range of 5.57 GHz (19.89 percent), and great energy efficiency. [18]

3. Research paper on “Bandwidth Enhancement of Rectangular Patch Microstrip Antenna”

The bandwidth (BW) of microstrip antennas is typically in the 1% to 5% range. To attain a low Q, a broadband antenna must have the following antenna geometry considerations: first, a thicker substrate or lower dielectric permittivity; second, feed impedance must be matched; third, patch geometry optimization; and lastly, suppression of surface waves in a thick substrate. In this work, the third and fourth parameters are used to improve bandwidth. The antenna is a rectangular patch antenna with dimensions of 40x40x1.575 mm3 and a permittivity of 4.4 constructed of FR-4 substrate. To improve the BW, the patch antenna is fan-shaped rather than rectangular. The simulated result shows a significant increase in band width. In terms of bandwidth, the suggested antenna outperforms the usual rectangular patch microstrip antenna. The suggested antenna offers a much greater bandwidth than the typical rectangular patch microstrip antenna, according to simulation results. The radiation pattern remains unchanged and omnidirectional. The innovative antenna has the potential to operate in the microwave frequency band C. [19]

4. Research Paper on “Bandwidth Enhancement in Multipatch Microstrip Antenna Array”

For microwave frequency, a microstrip patch antenna was employed in this study. The program was used to investigate the impact of the top patch, especially the fluctuation of VSWR as a function of two parameters: the distance between the two patches and the higher patch's size. A built array of two multipatch microstrip antennas with a

resonance frequency of 5.2 GHz has a return loss S11 of roughly 29 dB, a gain level of approximately 10.683 dB, and a bandwidth enhancement of around 23.07 percent, according to modeling and experiment data. The goal of this project is to show how a multilayer multipatch microstrip antenna may improve bandwidth and directivity. A multipatch microstrip antenna array with a bandwidth of 29.61 percent and directivity of 11.4703dB was used to build a highly directional antenna. [20]

5. Research Paper "Gain and Bandwidth Enhancement in Compact Microstrip Antenna"

This research study proposes a novel compact microstrip patch antenna in a stacked configuration. In terms of return loss, gain, and bandwidth, the antenna's attributes are tested and compared to those of a standard microstrip patch. With superstrate loading, the new suggested design reduces patch size by 66.34 percent while dramatically enhancing gain and bandwidth. A revolutionary small microstrip antenna in stacked configuration is developed for WLAN applications. The stacked arrangement boosts the antenna's gain and bandwidth in the intended band of interest. With a gain of 4dBi and a band width of 91 MHz, the suggested architecture achieves a size reduction of 53%. The IE3D Commercial simulator's Genetic Algorithm optimizer is used to improve the performance of the recommended antenna. [21]

6. Research Paper on "Increasing Microstrip Patch Antenna Bandwidth by Inserting Ground Slots"

The bandwidth of the microstrip patch antenna was increased in this study by making use of a high number of slots in the ground plane. This method is used to achieve a large number of bands and a broad band response. The simulated findings demonstrate a significant increase in antenna bandwidth while maintaining the same antenna gain and directivity. The new antenna has a bandwidth of 540 MHz, compared to 47 MHz for the conventional antenna. We were successful in increasing bandwidth by 18%. The addition of vertical slots to the ground plane resulted in an antenna configuration that was more omnidirectional and covered more ground. This antenna is suitable for cognitive radio applications. The proposed design has been successfully implemented for rectangular patch antennas and can be applied to other patch antenna types as well. This antenna was constructed on a FR-4 substrate. This antenna's measurements are

59 mm and 79 mm. The height is 1.6 mm and the dielectric constant is 4.4. In the ground plane, they inserted up to 15 1mm wide slots. The gap between the slots is 3 millimeters. They examined two distinct designs. The slots of the initial design ran parallel to the feeding line. The feeding line was horizontally aligned with the slots in the second one. The main goal of this study is to construct and duplicate MPAs that may be used in a variety of applications. The antenna bandwidth has been enhanced by 18%. All of the models were created using the HFSS simulator. [22]

7. Research Paper on “Design of a wideband microstrip antenna”

The fabrication of a single-layer wideband microstrip antenna is described in this study. The antenna is a parasitic patched gap-coupled microstrip antenna. The wideband nature of gap-coupled microstrip antennas is clear. A parasitic element is joined to the radiating patch in the present gap-coupled antenna arrangement. The size of the feed strip, the distance between the feed strip and the radiating patch, the distance between the radiating patch and the parasite patch, and the dimensions of the parasitic patch are all carefully determined. At the center frequency of 8.2 GHz, this antenna design produced a 44 percent 1:2 VSWR impedance bandwidth. Between simulated and measured findings, there are strong relationships. It is possible to communicate with UWB radios with this antenna. UWB systems are based on impulse radio, which broadcasts data at extraordinarily high data rates using energy pulses rather than a narrow-band frequency carrier. In the frequency range of 6.4 GHz to 10 GHz, a 3.6 GHz bandwidth was attained, which is 44 percent of the center frequency. [23]

8. Research Paper on “Novel Design of Microstrip Antenna with Improved Bandwidth”

This study proposes a one-of-a-kind broadband patch antenna design. The suggested antenna's broadband feature is obtained by meticulously calculating the size and placements of the slots and notch on the radiating patch. The suggested antenna's bandwidth is determined to be 30.5 percent, or around 430 MHz, with an operational frequency range of 1.56 GHz to 2.12 GHz. Antenna properties for various inclination degrees are investigated, as well as their impact on bandwidths. The antenna has a maximum gain of 9.86 dBi and a broadside radiation pattern in the direction of maximum radiation over the entire operating band. To achieve the desired

performance, the recommended antenna construction is conceived, fabricated, and tested. The simulated and experimental findings are compared and found to be reasonably close. The fundamental drawback of traditional microstrip patch antennas is their limited bandwidth, which severely restricts their use. As a result, scientists, researchers, and designers began working hard to boost patch antenna bandwidth. Different shapes and sizes of slots and notches can be loaded on the patch or on the ground plane to increase bandwidth. Other bandwidth improvement methods are available, but this technology makes it easy to manufacture, load, and boost bandwidth without adding to the structure's bulk. Several papers for wireless applications, including U-slot loaded rectangular microstrip antennas, L-shaped slot loaded rectangular microstrip antennas, stepped U-slot loaded rectangular microstrip antennas, half stepped U-slot loaded compact shorted square microstrip antennas, and edge center-shorted square microstrip antennas with stepped slots, have been published as a result, with bandwidths of 17.4 percent, 14.6 percent, 14.3 percent, and 2 percent, respectively The compact broadband slotted rectangular microstrip antenna had a bandwidth of 26.7 percent, while the W-shaped patch antenna had a bandwidth of 36.7 percent, the M-slot folded patch antenna had a bandwidth of 21.17 percent, the E-H shaped microstrip patch antenna had a bandwidth of 30 percent, and the V-slot corner notch loaded microstrip patch antenna had a bandwidth of 51 percent. Several different radiating topologies for enhancing the bandwidth of microstrip antennas have also been reported: The bandwidth of the star-shaped patch antenna was 0.84 percent, 24 percent, and 25 percent, respectively; the bandwidth of the C-shaped, E-shaped, and U-slot microstrip patch antennas was 0.84 percent, 24 percent, and 25 percent, respectively; the bandwidth of the plus-shaped and cross-shaped slot-loaded patch antennas was 53 percent and 6.49 percent, respectively; the bandwidth of the multi-slotted patch antenna was 27.62 percent. An antenna radiating structure for generating increased bandwidth that may be employed in wireless applications has been devised based on the previously stated publications. [24]

9. Research Paper on “Study on Bandwidth Enhancement Techniques of Microstrip Antenna”

In this study, they introduced a novel triangular UWB microstrip antenna with an ultra-wide bandwidth (UWB) of more than 8 GHz. This optimal antenna design gives

sufficient gain over the whole UWB band. To develop band-notched UWB, the researchers significantly shortened the ground plane (defected ground), cut slits in the triangle radiating patch, and employed different substrate materials. A small coplanar triangular microstrip antenna with an 8.3 GHz UWB has been built. In the WiMAX and WLAN frequency ranges, the same antenna with a faulty ground also provides notches coplanar fed triangular patch with a slot and slits coplanar fed triangular patch with a slot and slits coplanar fed triangular patch with a slot and slits coplanar fed triangular patch with a slot and slits coplanar fed triangular patch with a slot and slits coplanar fed. Across all pass bands, the antenna delivers a steady and high average gain. The UWB curve moves to higher frequency values when the substrate's dielectric constant drops. The primary radiator is a 50 coplanar feed line-fed triangular patch printed on FR4 with a dielectric constant of 4.4 and a height of 1.6 mm. From 2.8 to 10 GHz, the antenna delivers 7.2 GHz UWB with average directivity and gain of 5 and 3 dBi, respectively, with an average directivity of 5. A 50 coplanar feed line feeds the antenna, which is fabricated on a FR4 substrate. The addition of the slot and slits to the triangle resonator enhances the top frequency bound, resulting in a total bandwidth of 8.3 GHz, according to the modeling results. The overall bandwidth improved by roughly 1.1 GHz and the return loss (S1,1) was considerably decreased when compared to the original suggested antenna with greater antenna strength and directivity. [25]

10. Research Paper on “A Novel Design for Millimeter Wave Microstrip Antenna with Bandwidth Enhancement”

To increase bandwidth, an unique microstrip antenna with two rectangular slots is developed. To increase bandwidth, two rectangular slots are given a new resonant frequency near the core frequency. An imperialist competition method is also used to improve patch settings that influence bandwidth (ICA). The planned antenna's bandwidth is eventually raised to 2.26GHz (27.48GHz to 29.74GHz), which is 1.46GHz wider than the original antenna, according to simulation data. Meanwhile, the suggested antenna maintains a consistent gain of 7.1 to 7.65dBi across the operating spectrum. Over the frequency band of 27.5–29.5GHz, N sites are picked at equal intervals. The antenna bandwidth has been extended to 2GHz when S11 at these N sites is less than -10dB, indicating that the bandwidth has been increased. [26]

11. Research Paper on “An Integrated Antenna System for 4G and Millimeter-Wave 5G Future Handheld Devices “

This paper addresses an integrated antenna system for millimeter-wave Fourth Generation (4G) and Fifth Generation (5G) wireless applications and portable devices with Defected Ground Structure (DGS). The suggested design is based on a 0.508 mm thick Rogers RT/Duroid 5880 substrate with overall dimensions of 110 mm x 75 mm. Researchers are working harder to create 5G wireless networks for mobile and wide-band wireless communication. Millimeter-wave radios have emerged as a major solution for 5G low-latency, multi-Gbps wireless networks in recent years. With measured bandwidths of 160 and 450 MHz, the 4G antenna array covers the twin sub-6 GHz frequency bands centered at 3.8 GHz and 5.5 GHz. In contrast, the 5G antenna array covers mm-wave frequency bands of 26/28 GHz with a 4.9 GHz broad bandwidth. [27]

12. Research Paper on “A Flexible Directional Antenna for 5G Millimeter -wave Applications”

In this study, a unique flexible antenna is suggested. The antenna is a microstrip antenna with dimensions of 12.25mm x 7.45mm x 0.07mm printed on a Rogers 5880 substrate. The simulated bandwidth ranges from 24.6-24.7GHz. With a maximum strength of 6.16 dBi, the antenna features a directed pattern. The purpose of this study is to develop a flexible antenna with a working direction pattern of 24 GHz. The recommended antenna is a rectangular patch antenna with a directed pattern that is powered by a 50 microstrip line. To increase antenna bandwidth, a step-shaped feeding line and slots carved on the patch are used. The antenna substrate is a Rogers 5880 substrate with a relative dielectric constant of 2.2 and a thickness of 70 m. [28]

13. Research Paper on “Ultra-wideband Microstrip Array Antenna for 5G Millimeter-wave Applications”

Using a graded line cut and a U-slot combination, this research proposes a design for a 5G millimeter-wave ultra-wideband microstrip array antenna. To improve bandwidth performance, the suggested design employs a proximity coupling feeding mechanism. To estimate the bandwidth augmentation, the recommended antenna bandwidth performance is compared to that of a standard antenna array design. Numerical and

modeling results reveal a considerable improvement in bandwidth performance when compared to earlier designs. The recommended antenna has a gain of 8.71 dB and works at 28 GHz with a bandwidth of 4.47 GHz. These findings show that the recommended antenna design is suitable for millimeter-wave 5G applications. They improved the bandwidth and gain performance of a microstrip antenna for 5G millimeter-wave applications using a mix of U-slot methods and a stepped line cut approach. A stepped line cut technique is used to aid in the development of a slot antenna. The slot antenna has the benefit of being able to produce two-way radiation patterns with a wider bandwidth. When slots are added to an antenna, they can generate a coupling effect that affects the Q factor, which is inversely proportional to the antenna's bandwidth. [29]

14. Research Paper on “Compact and Wide Bandwidth Microstrip Patch Antenna for 5G Millimeter Wave Technology: Design and Analysis”

According to the study's findings, fifth-generation (5G) technology will concentrate on improving fourth-generation (4G) technology by resolving 4G shortcomings such as limited bandwidth and data transfer rate. A microstrip patch antenna has been suggested for 5G millimeter wave technology. It was created a microstrip patch antenna with a high bandwidth millimeter wave, compact dimensions, consistent radiation patterns, and much higher gain. In this study, a FR-4 substrate with a dielectric constant of 4.3, a thickness of 1.6 mm, and a loss tangent of 0.025 was employed. The proposed antenna has a high bandwidth of 14.674 GHz, a reflection coefficient of -40.14 dB, a voltage standing wave ratio (VSWR) of 1.1098 dB, a maximum gain of 5.29 dB, and a high directivity of 7.465 dBi. This study's antennas were effective in meeting the demands for increased gain and larger bandwidth in 5G applications, notably at 28 GHz. The obtained bandwidth ranged from 21.227 GHz to 35.874 GHz, demonstrating the utility and adaptability of the suggested antenna. The measured bandwidth was 52.4 percent, with a maximum gain of 5.29 dB and a directivity of 7.465 dBi. Furthermore, the antenna's bandwidth performance in this investigation was shown to be adequate for broadband applications and capable of transmitting high-quality data. In contrast, the planned antenna efficiency was 60.6 percent. [30]

15. Research Paper on “Highly Efficient 2x2 Antenna Array at 28 GHz and 38 GHz for 5G Applications”

Wireless technology is evolving from 4G to 5G to meet significant demands such as more capacity, higher data rates, ultra-low latency, and reduced route loss. 5G technology, among other things, can address the challenge posed by 4G by providing access to more than 100 billion wireless devices, millisecond latency, and data speed of 10 Gbps. According to a reputable source, practically all countries will have 5G connectivity by 2021. The goal of this project is to build an efficient 2x2 antenna array at 28 and 38 GHz in order to meet 5G specifications. Previous research found that the antennas did a terrible job of covering 5G requirements. A 2x2 antenna array was built in this study at both 28GHz and 38GHz. Both antenna designs make use of foam as a substrate element, with a Hs = 0.5mm substrate height and a quarter-wave feeding mechanism. Bandwidth, return loss, realized gain, VSWR, and antenna efficiency at 28GHz are 61.19 dB, 15.4 dB, 1.001, and 97.97 percent, respectively, and 52.28 dB, 13.8 dB, 1.005, and 97.97 percent at 2.49GHz. When the recommended antenna array was compared to the previous work, it was revealed that the recommended antenna array more efficiently satisfied all of the requirements. The antenna array has a bandwidth of 1.3 GHz and 2.54 GHz in frequency bands 28 GHz and 38 GHz, respectively. At 28 GHz and 38 GHz, the antenna array achieves realized gains of 15.3 dB and 13.6 dB, respectively. [31]

16. Research Paper on “Optimization of Design Parameters of Microstrip Patch Antenna at 28 GHz and 38 GHz for 5G Application”.

The fact that 5G antenna design is a vital and difficult problem right now inspired this effort. 5G antenna designers at 28 GHz and 38 GHz are struggling to meet 5G specifications. The following literature review adequately addresses this problem. A single element MPA has a return loss and gain of 15.5 dB and 6.9 dB, respectively, at 38 GHz, and a return loss and gain of -12 dB and 7.4 dB, respectively, at 54 GHz. The return loss was close to -10dB, indicating that this antenna is inefficient. The tri-band MPA was created with 5G in mind. The bandwidth of this antenna was 900 MHz at 28 GHz and 480 MHz at 38 GHz. Furthermore, a gain of 7.02dB was obtained at 28 GHz, while a gain of 5.05dB was obtained at 38 GHz. Given that the standard for 5G channel bandwidth is 1 GHz, it is challenging to fill the channel bandwidth with such capacity.

Furthermore, the increase is less than what is required for basic 5G. It has been constructed a one-of-a-kind multiband MPA with bandwidths of 5.5 GHz at 37 GHz and 8.67 GHz at 54 GHz. Because the expanded bandwidth consumes more battery power than the actual 5G antenna, this antenna receives greater bandwidth, resulting in a total waste of working frequency. Furthermore, at 37 GHz, the gain is 5.5 dB and at 54 GHz, it is 6 dB, which does not match 5G requirements. The substrate for a single-element high-gain antenna has been built using air. Despite the fact that the final parameters fulfilled the 5G standard, this antenna is built on an air substrate, which is quite difficult to implement in practice. The following design elements have an impact on antenna performance: substrate element, substrate height, and feeding technique. The 5G requirements will not be satisfied if these are not appropriately elected. This research identified the optimal value of substrate element, substrate height, and feeding mechanism as design features for manufacturing MPA at 28 and 38 GHz that meet 5G specifications. Furthermore, the performance of antennas created with these three design parameter values is compared. [32]

17. Research Paper on “Analytical Review of Bandwidth Enhancement Techniques of Microstrip Patch Antenna”

The biggest issue is a lack of bandwidth. As a result, antenna designers are focusing their efforts on tiny broadband antennas. Several technologies, including literal analysis, have been used to increase the MPA's bandwidth over the last decade. The goal of this study is to compare and contrast several techniques to increasing bandwidth, the slot technique, air gap technique, multiple radiating element technique, parasitic patch technique, multiple feeding technique, and proximity couple technique are only a few examples. The increasing data rates in wireless devices necessitate the usage of broadband antennas. We also exhibited the 5G wireless communication technology, which uses a wider spectrum of frequencies. As a result, antenna designers are focusing their efforts on developing miniature broadband antennas. The MPA appealed to the designer due to its small size, low profile, low cost, and great dependability. Due to single resonance radiation, microstrip patch antennas have a limited bandwidth. A microstrip patch antenna generally has a bandwidth of less than 5%. As the number of slots increases, the radiation efficiency and directivity of a slot antenna technology decreases. [33]

18. Research Paper on “Design of 2x2 Microstrip Patch Antenna Array at 28 GHz for Millimeter Wave Communication”

Due to several limits in 4G, such as lower bandwidth, higher latency, and more route loss, wireless technology is being developed to 5G. By offering millisecond latency, 10 Gbps data capacity, and connection with 100 billion wireless devices, 5G wireless technology can transcend the constraints of 4G. The goal of the research is to create a cost-effective 2x2 antenna array that fulfills 5G specifications. The primary purpose of this project is to build a functional antenna array. [34]

19. Research Paper on “Design and Analysis of a 28 GHz Microstrip Patch Antenna for 5G Communication Systems”

The design and performance of a 28GHz microstrip patch antenna (MSPA) for fifth-generation (5G) communication systems are described in this research. According to modeling data, the beam gain is 7.587 dBi, the directivity is 7.509 dBi, the radiation efficiency is 98.214 percent, and the bandwidth is 1.046 GHz. The MSPA will operate at 28GHz and is constructed on a FR-4 substrate with a loss tangent of 0.0025, a r of 4.4, and a radiating copper metal thickness of 0.035 mm. The MSPA has a 1.046 GHz bandwidth, a VSWR of 1.023, a -38.86 dB return loss, a gain of 7.587 dBi, and a radiation efficiency of 98.214 percent. Inset-feed impedance matching methods, quarter-wavelength impedance transformers, and antenna size optimization were applied to achieve our target. [35]

20. Research Paper on “A 28 GHz Rectangular Microstrip Patch Antenna for 5G Applications”

The recommended antenna has a -13.48 dB return loss, an 847 MHz bandwidth, a gain of 6.63 dB, and a 70.18 percent efficiency. To match the radiating patch with the 50 microstrip feedline, an inset feed transmission line approach is adopted. As the mobile industry transitions to millimeter-wave spectrum, carriers are anticipated to take use of the 28, 38, and 73 GHz bands that will become accessible for future technologies. [36]

21. Research Paper o “Microstrip Patch Antennas with Multiple Parasitic Patches and Shorting Vias for Bandwidth Enhancement”

To increase bandwidth, two new microstrip patch antennas with numerous parasitic

patches and shorting vias have been suggested. Two extra resonances can be formed by adding numerous parasitic patches to the typical triangle patch antenna, resulting in a broader antenna bandwidth. This antenna was also built and tested, and its measured 10-dB impedance bandwidth between 5.5 and 6.55 GHz is 17.4 percent. To construct three resonances, this article first develops a one-of-a-kind microstrip patch antenna with many parasitic patches. Two more resonances may be achieved when parasitic patches are inserted into the construction of the proposed antenna, considerably expanding the bandwidth. The influence of dimension factors on antenna performance was evaluated using a parametric approach. Two shorting vias are then added to the previously stated antenna, allowing the input impedance to be decreased at defined frequency ranges and, as a result, the bandwidth to be extended even further. Two examples of the recommended antennas were constructed and tested to validate the design concepts. The impedance bandwidths of these two antennas with S11 0 dB extend from 5.46 to 6.27 GHz (13.8%) and 5.5 to 6.55 GHz (17.4%), respectively, according to the data. They're both capable of putting up a fantastic long field. [37]

22. Research Paper on “Design a Single Band Microstrip Patch Antenna at 60 GHz Millimeter Wave for 5G Application”

This suggested article discusses a single-band slotted microstrip patch antenna for 5G wireless applications. The suggested antenna has a basic design, is inexpensive, and is small in size. Because of its small size, the antenna can only function on a single frequency band. Due to the elimination of the H and E slots, the impedance bandwidth has risen. The central frequency is 59.93GHz, with a bandwidth of 4.028 GHz and frequencies ranging from 57.981GHz to 62.009GHz in this design. Microstrip patch antennas with a gain of up to 5.42 dB are recommended for millimeter wave wireless applications. [51]

23. Research Paper on “28 GHz Microstrip Patch Antennas for Future 5G”

This research presents the structural design of a microstrip patch antenna array operating at the core frequency of the 28 GHz waveband. Each of the four components in the patch antenna array has a rectangular patch and uniform dispersion. Its dimensions are 26.51 x 20.37 mm, and its frequency is 28 GHz. The inset feed method is used to match the radiating patch with the 50 microstrip feedline. The proposed 2x2

antenna array outperforms the current CRLH TL CPW antenna, which has a gain of 2.99 dB, a wideband antenna with a gain of 7.1 dB, and a broadband elliptical-shaped slot antenna with a gain of 3.7 dB by up to 8.393 dB. As a consequence, the directivity of 10.13 dB and efficiency of the candidate are greater than the directivity and efficiency of 80 percent of the candidates considered for 5G wireless networks and applications. This paper proposes a simple printed patch antenna array. With four components in an array, the antenna, which utilises microstrip technology, was designed for 28 GHz operation. Impedance and phase matching processes were designed using a quarter-wavelength transformer and transmission line. Antennas with single and four elements in an array were examined using electromagnetic analysis software. The findings show that at 28 GHz, an antenna gain of 8.393 dB was achieved. At 400 MHz, the bandwidth was attained. [52]

24. Research Paper on "Dual-band Microstrip Antennas for 5G and Short-Range Applications"

For this project, dual-band monopole antennas with a rectangular ring form were created. Rogers RT/duroid 5880 dielectric substrate was used to construct the observed antenna. A parameter study is carried out using variations in the size of the ring antennas and the ground. It was shown that single-band, dual-band, and wideband characteristics could be achieved by altering the ground diameters. Two resonances were discovered at 3.19 GHz and 4.63 GHz, with bandwidths of 240 MHz and 322 MHz, respectively, for a ground size of D = 38 mm. The resonance frequencies were found to be 3.17 GHz and 4.67 GHz, respectively, with bandwidths of 550 MHz and 190 MHz, using a VNA. This study created monopole antennas with a rectangular ring construction. Single-band, broadband, and dual-band features originate from changes in ground dimensions. For single and dual-band features, it was determined to build identical circuits. Measurements were used to verify the simulations. [53]

25. Research Paper on "Microstrip Patch Antenna at 28 GHz for 5G Applications"

This research discusses the design and simulation of a 28 GHz microstrip patch antenna for 5G communication. With a center frequency of 27.91 GHz, a maximum reflection coefficient of –12.59 dB, a very broad bandwidth of 582 MHz, and a high gain of 6.69 dB, the antenna works in the Local Multipoint Distribution Service band.

The transmission line of the antenna is an inset feed. The substrate was Rogers RT Duroid 5880, which has a dielectric constant of 2.2 and a height of 0.254 mm. The antenna dimensions were established, and the simulated results were shown and analyzed using HFSS. A rectangular microstrip patch antenna in the LMDS band is proposed in this study for 5G wireless communication. The antenna has a -12.59 dB return loss and resonates at 27.91 GHz. The antenna has a gain of 6.69 dB and an omnidirectional emission pattern. The antenna may be fitted into devices with little space. The antenna that has been designed has the potential to be used in future 5G wireless devices. [54]

26. Research Paper on “Single Feed Compact Millimeter Wave Antenna for Future 5G Applications”

In this electronic article, we will explore the design and numerical modeling of a small single-layer millimeter wave antenna for future fifth generation (5G) applications activated by a microstrip line. Its design is based on a rectangular patch on a dielectric substrate with variable geometries of notches. There are two resonance frequencies in the proposed antenna: 28.00 GHz and 38.00 GHz. The antenna may provide two bandwidths of roughly 921 MHz (3.29 percent) centered at 28.01 GHz and 1.0451 GHz (3.72 percent) centered at 38.03 GHz, according to the numerical solution of the Maxwell equations using the finite element technique (FEM) ,(fr) 1 = 28.01 GHz has a reflection coefficient of -23.8112 dB and (fr) 2 = 38.03 GHz has a reflection coefficient of -17.0898 dB. The antenna's gain varies between 8.0527 dB in the lower band to 8.2869 dB in the upper band. [55]

27. Research Paper on “Dual-band Microstrip Patch Antenna Array for 5G Mobile Communications”

This paper presents the design of an 8-element microstrip patch antenna (MPA) array for dual-band 5G communications. At 28, the proposed antenna array is rather tiny, measuring 1616 mm. The dual-band response is achieved by etching an inverted U-shaped slot in the primary radiator. The results indicate that the proposed array has the potential to induce resonance in the relevant frequency regions. In addition, the proposed antenna array generates omnidirectional radiation and has a gain that is suitable for both frequency ranges. Radiation parameters of the proposed antenna at

27.3 and 39.75 GHz and the antenna generates omnidirectional radiation in both the E- and H-planes, which is discovered. In addition, the ideal bands' gain is 5.42 and 6.25 dBi, respectively. [56]

28. Research Paper on “Millimeter wave microstrip patch antenna for 5G mobile communication”

A microstrip patch antenna for future 5G communication technology with centered frequencies of 38GHz and 54GHz, bandwidths of 1.94GHz and 2GHz, and a low-cost substrate and small-sized patch perfectly suited for shrunk devices is described in this paper. It consists of a Rogers RT5880 (lossy) substrate, a PEC patch, and a PEC ground with a dielectric constant of 2.2, a loss tangent of 0.0013, and a standard thickness of 0.508mm. A 6 mm x 6.25 mm substrate and a patch 2 mm × 2 mm patch are employed. A microstrip is employed. The technique of line feeding is used. Using tapered line feeding, an array with four components spaced four millimeters apart might yield a 12 dB gain for mobile data applications on millimeter wave frequencies of 38.6GHz, 47.7GHz, and 54.3GHz, with bandwidths of 3.5GHz, 2.5GHz, and 1.3GHz, respectively. The total dimensions of the antenna are 6mm6.25mm0.578mm. The recommended antenna design is simulated using CST Microwave Studio. [57]

29. Research Paper on “28 GHz printed antenna for 5G communication with improved gain using array”

A simple rectangular microstrip feed antenna for 5G communication is created in this work. The dimensions of the recommended structure are 7.9 x 14.71 x 1.6 mm, and the substrate is FR-4. The antenna's operating frequency range is 27.67 GHz to 28.31 GHz. The reflection coefficient exceeds -14 decibels. The proposed structure is shown to be the optimum alternative for 5G communication using simulated s11, VSWR, surface current, and radiation pattern data. In addition, the radiation pattern is reliable in the operational band. Three stages of evolution are included in the suggested framework. All structures for the 28 GHz 5G communication frequency are built on a FR4 substrate. It operates between 27.58 GHz and 28.53 GHz and has a maximum gain of 7.2 dBi in the working spectrum. The suggested structure has a low profile and can easily be installed on MMIC devices, making it more suitable for 5G communication. [58]

30. Research Paper on “Design and simulation of a rectangular patch microstrip antenna for the frequency of 28 GHz in 5G technology”

The development of tiny antennas for a wireless communication device operating at a frequency of 28 GHz using microstrip technology is shown in this paper. For antenna design, the inset feed approach is utilized, with a change in the length of the transmission line on the side of the patch gap. The CST software tool is used in the antenna design process, which is a moment or simulation process. In the simulation phase, the Taconic TLY-5 material substrates were used to facilitate antenna design. This paper discusses some of the simulation results for antenna parameter values such as bandwidth, VSWR, radiation pattern, beam width, and polarization. Bandwidth refers to the frequency ranges of a frequency spectrum area that signify low to high frequency restrictions. The simulation depicts the bandwidth gained from trials with different gap widths. The experimental results with a 0.70 mm gap were effective in running at a resonance frequency of 28 GHz. For this gap distance, the bandwidth of return loss less than 10 dB achieved is 463MHz. It shows a graph of the SWR's frequency value after simulation. For resonance frequencies of 28 GHz, the minimum VSWR value is 1.08. [59]

3.2 Summary

Microstrip patch antennas for 5G communication have been developed in millimeter wave bands such as 28 GHz, 38 GHz, and others, according to study. The millimeter waves bands of 28 GHz and 38 GHz, according to current research, are the most promising and crucial prospects for 5G wireless communication, with major study done in this frequency band. Again, the most difficult task in deploying 5G is developing an antenna with high gain to compensate for significant route loss, is small enough to put in a phone, is efficient, and is simple to manufacture.

3.3 Objectives

- ✓ A single microstrip patch antenna was constructed and simulated to increase bandwidth for 5g applications.
- ✓ Designing the antenna by changing different dimension and defining a best antenna with enhanced bandwidth for 5g applications.

- ✓ Designing antenna for 5g applications based on different dimension such as insertion gap, patch width, patch length etc.
- ✓ Finally, choose the most effective antenna.
- ✓ To design and simulate a microstrip patch antenna for 5G applications that has better antenna properties, particularly in terms of bandwidth.
- ✓ To increase the performance of microstrip patch antennas.
- ✓ In comparison to existing microstrip patch antennas operating at 28 GHz.

Chapter 4
Methodology

4.1 Methodology

The structured, theoretical analysis of the procedures utilized in a field of study is known as methodology. It entails a theoretical assessment of a collection of methodologies and doctrines relevant to a certain field of study. Standards, theoretical models, phases, and quantitative or qualitative research techniques are common concepts [41]. A technique is an organized set of actions or approaches. This term can relate to practices that are typical in an industry or scientific discipline, such as the research methods employed in a particular study. A methodology, on the other hand, differs from a technique in that it does not strive to deliver solutions. A methodology, on the other hand, is concerned with theoretical reinforcement to establish whether approach or set of procedures is feasible in a certain situation.

4.2 Research Design

The research design refers to the framework that has been built to gather responses to the study questions. The study topic, dependent and independent variables, experimental design, and, if relevant, data collecting techniques and a statistical analysis strategy are all part of the research activity design. The study's research design was as follows:

- An investigation of the growth of 5G technology.
- An examination of the antenna needs for 5G networks.
- Select the 5G millimeter wave band.
- Examine the literature on microstrip antennas and 5G antennas in use today.
- Designing a microstrip antenna is a method that has to be studied.
- In the CST Microwave Studio, you can learn how to design antennas.
- Calculate the parameters needed to create an antenna.
- Determine the ideal dimension values for various parameters like insertion gap, patch length, patch width, and so on.
- Find the optimum design for high-bandwidth 5G applications.
- Decide on your feeding method.

- Carry out the procedure.

4.3 Pilot Study

A pilot study, also known as a pilot project, pilot test, or pilot experiment, is a small-scale preparatory study carried out to assess feasibility, time, cost, and negative events, as well as to enhance the study design before undertaking full-scale research. It was completed ahead of time for the research. Pilot studies are commonly conducted in order to achieve the study's goals. While a pilot study cannot eliminate all systemic flaws or unanticipated issues, it may significantly minimize the number of errors that waste time and effort during the research process.

Pilot Research and Its Importance:

- To put the study procedure and/or protocol to the test.
- To classify variables of importance and determine how each should be functionalized.
- The purpose of this project is to design or test the effectiveness of research equipment and methodologies.
- To assess statistical factors in preparation for future research.

4.4 Software

The Technology for Computer Simulation Microwave Studio (CST MWS), as shown in figure 4.1, is a sophisticated tool for modeling high-frequency components in three dimensions. CST MWS analyzes high-frequency (HF) devices such as filters, couplers, antennas, single and multi-layer structures, as well as SI and EMC effects, quickly and accurately. According to the Computer Simulation Technology manual, CST operates by discretizing Maxwell's integral equation. It is also stated that CST Microwave Studio employs central finite difference techniques to compute time derivatives. CST is said to work utilizing the FDTD approach in several guides. The unrivaled performance of CST MWS makes it the obvious choice for technology-driven R&D departments. CST MWS is a simple-to-use tool that gives rapid insight into high-frequency designs' EM behavior [42].

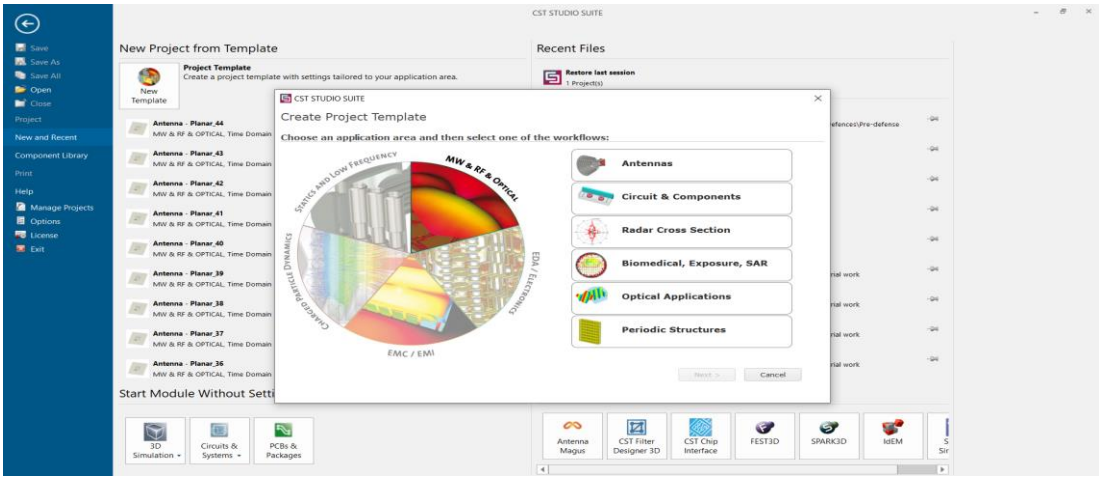

Figure 4.1: Starting view of CST studio suite application

4.5 Design procedure

Step 1: Design a microstrip patch antenna to enhanced bandwidth for 5g applications.

Step 2: Second, several dimensions are utilized to determine the optimum option based on 5G requirements.

Step 3: Now, depending on the 5G requirement, utilize a feeding approach to obtain a decent outcome.

Step 4: An antenna for 5g applications is designed using a substrate material, a substrate height, and a feeding mechanism with various dimensions.

Step 5: Save the construction and run a simulation of the antenna that have created.

Step 6: If the antenna meets the criteria, save the result.

Step 7: If the outcome isn't satisfactory, optimize the design.

Step 7: Improve the performance of the designed Microstrip patch antenna.

Step 8: Compare your results to those of other antennas.

❖ Figure 4.2 shows a flow chart of the research work.

4.5.1 Antenna Substrate

The initial step in antenna design is to choose a suitable dielectric substrate with the required thickness (h). Electrical and mechanical stability are aided by dielectrics. They are used to lower the antenna's size and help in the formation of displacement current, which, according to Ampere's Law, provides a time-varying magnetic field. According to Faraday's rule, this time-varying magnetic field can create a time-varying

electric field, resulting in a propagating electromagnetic field. A substrate can improve the antenna's radiating qualities in this approach. Table 4.1 includes some common dielectric substrates and their characteristics.

Table 4.1: Substrates List

Name of the Dielectric Material	Dielectric constant
FR-4	4.4
RT Duroid-6002	2.94
RO4730	3
Rogers RO 3200	3.02
Rogers RT Duroid-5880	2.2
Rogers RT Duroid-5870	2.33
Foam	1
TLC-32	4.3
Nylon	3.4
Teflon	2.1

When building high-gain antennas, the dielectric constants of the substrates in the table above are relatively high, suggesting substantial loss. To begin, we picked a substrate material at random, Rogers RT-5880, which has a dielectric constant of about 2.2 and is frequently utilized in MPA designs. The microstrip line and ground material should be chosen after that. We have three possibilities in this situation: copper, silver, or gold. The conductivity of silver is greater than that of other metals. Copper, on the other hand, is far more durable and less expensive than the other two metals. As a result, copper is widely employed.

4.6 Antenna Design by Equation

There are multiple sections to this section on antenna design techniques. To begin, the goal of this episode is to estimate the antenna radiating patch's length and width. The dielectric constant of the substrate (r), the height of the substrate (Hs), and the antenna's resonance frequency must all be considered when designing an antenna radiating patch [43]. Second, a feeding strategy was devised. Inset feeding and quarter-wave transformer feeding are both used to feed this antenna. Finally, a quarter-wave

transformer feeding scheme was implemented.

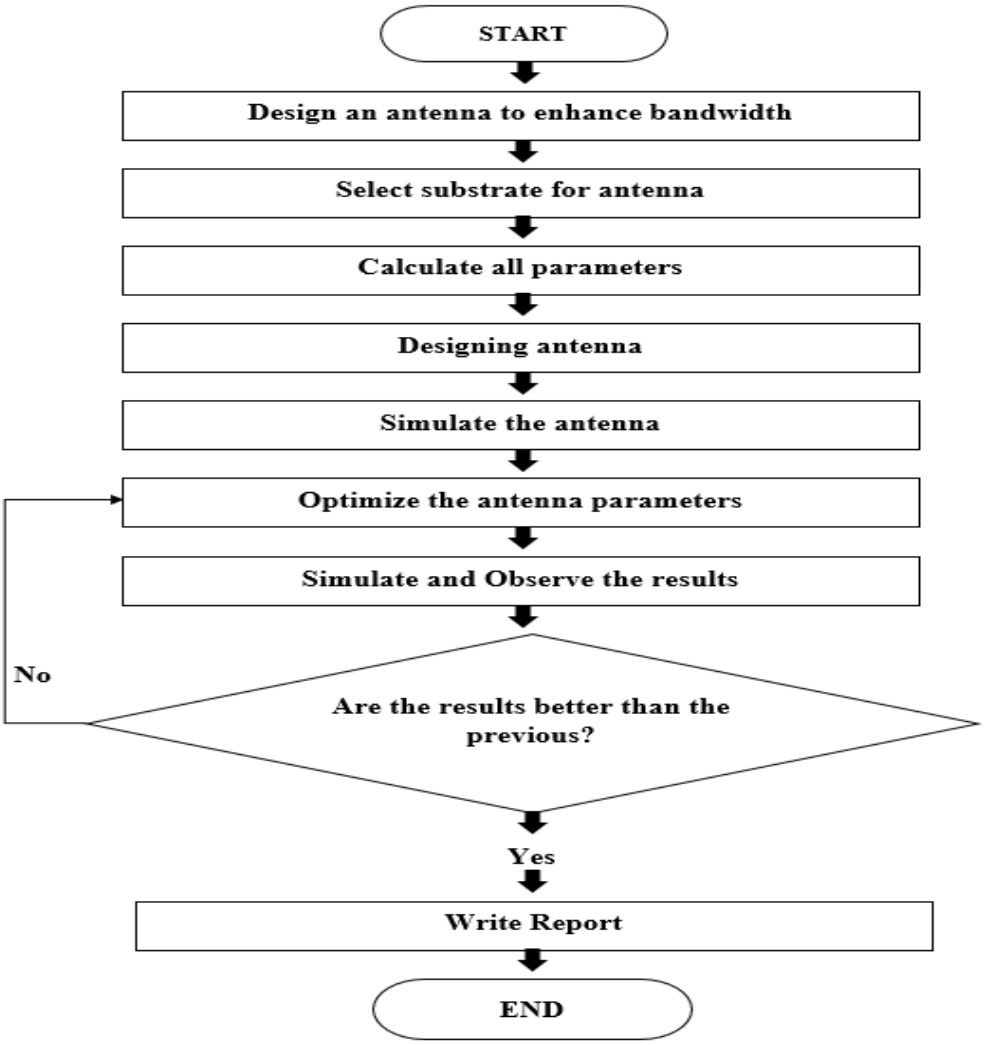

Figure 4.2: Flow Chart of the Research work

4.6.1 Radiating patch

1. Width design is crucial for a proper radiator design and achieving the requisite resonance frequency of operation. As a consequence, using the equation below, the width may be calculated (1).

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \text{ ----------(i)}$$

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. In order to calculate the actual length of L, two parameters must be determined: the effective dielectric constant and the length extension. To begin, the effective dielectric constant is determined using the equation below (2).

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(1 + \frac{10Hs}{w}\right) \text{----------(ii)}$$

Where,

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

3. Second, the length extension is calculated using the equation below (3).

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

4. Finally, the equation below determines the actual length L. (4).

$$L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{eff}}} \text{----------(iv)}$$

4.6.2 Feed-line

1. Microstrip inset feed is the process of feeding the radiating patch inset to provide proper impedance matching. Inset feed line design is shown in Figure 4.3. The following equation is used to calculate the inset feed location (5).

$$x_o = \frac{L}{\pi}\cos -1\sqrt{\frac{Z_o}{Z_1}} \text{----------(v)}$$

Where,

- Zo=50 Ω is the transmission line impedance.
- Z1 is the characteristic impedance.

The characteristic impedance Z1 is calculated using the formula below (6).

$$Z_{in} = \sqrt{Z_o + Z_1} \text{----------(vi)}$$

Where,

- Zin is the input impedance that can be provided by the calculator in [49] In

addition, the inset feed has two extra parameters: feed width wf and length Lf. Below are the formulas for determining those parameters (numbers (7) and (8).

$$\boldsymbol{W_f = \frac{2Hs}{\pi}\left\{B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B - 1) + 0.39 - \left(\frac{0.61}{\varepsilon_r}\right)\right]\right\}} \text{----------(vii)}$$

$$\boldsymbol{L_f = 3.96 \times W_f} \text{ ----------(viii)}$$

Where,

$$\boldsymbol{B = \frac{377\pi}{2Z_o\sqrt{\epsilon_r}}} \text{ ----------(ix)}$$

2. When impedance matching becomes challenging, the technique of quarter-wave transformer feeding is used. In this example, the center of the radiating patch's width is linked to a feed line, and both must have the same impedance. Finally, a variable width feedline is connected to the first feedline to match the impedance of the 50ohm transmission line. The formula for calculating the width of the first feedline segment (Wf1) and the width of the last feedline section (Wf2) is:

$$\boldsymbol{W_{f1} = W_{f2} = \left(\frac{377}{Z_o\sqrt{\epsilon_r}} - 2\right) + Hs} \text{ ----------(x)}$$

Where,

- $\in r$= Dielectric constant of the substrate element
- Zo= impedance of the feed line

As a result, using the above nine formulas, it is able to create an MPA that perfectly meets the 5G standards. CST microwave studio will next design the antenna based on the calculated antenna parameters.

4.7 Antenna geometry and designed parameters

Three antenna design parameters have been finished in order to determine the antenna design as indicated above. The substrate elements, substrate height, and feeding strategy are all of these things. The geometry of the antenna designed on each parameter is presented in the next section.

4.7.1 Antenna designed with different dimensions

The first step is to choose the dielectric material that will serve as the antenna's substrate. Then, to acquire better results from the proposed antenna, compute several parameters with very good dimensions. As illustrated in figures 4.3 and 4.4, the proposed antenna is built of Rogers RT 5880 as the substrate material and copper conductor material for the patch and ground plane.

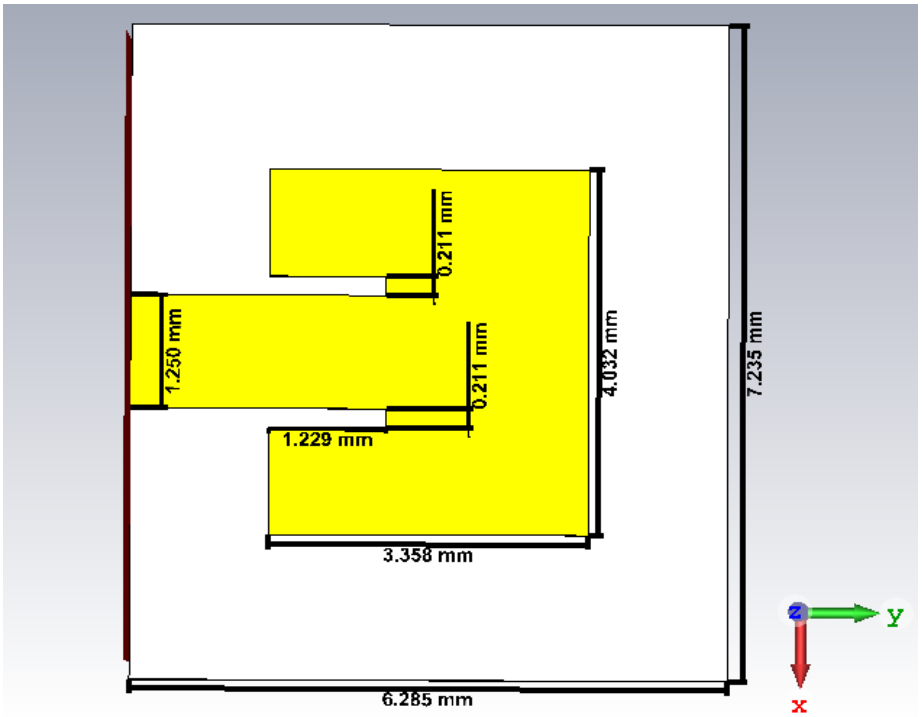

Figure 4.3: Top view of the designed antenna

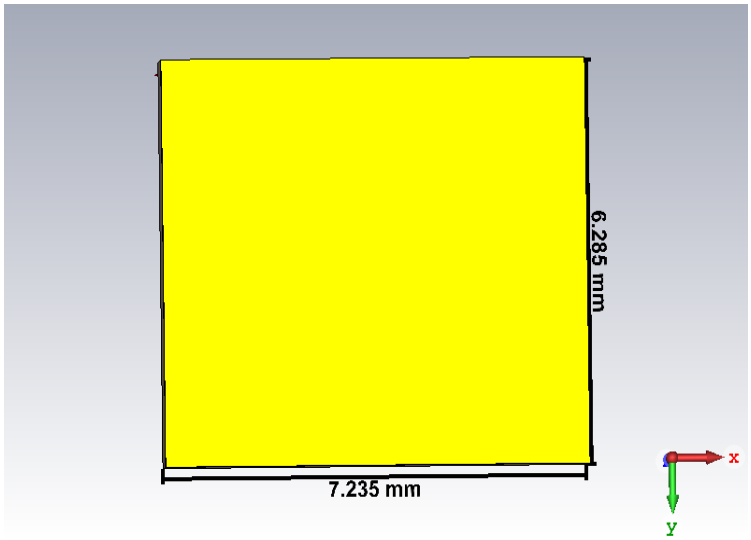

Figure 4.4: Back view of the designed antenna

Table 4.2 computes the recommended antenna design parameters for 28 GHz using the equations provided in the antenna approach section. The substrate height was set to Hs = 0.5 mm. This parameter may change in the future as a result of the analysis.

Table 4.2: Dimensions of antenna design parameter 28 GHz operating frequency

Substrate name	**Patch Length, Lp (mm)**	**Patch Width, Wp (mm)**	**Inset feed, Fi (mm)**	**Insertion Gap, gi (mm)**	**Feed Width, Wf (mm)**	**Feed Length, Lf (mm)**	**Substrate height, hs (mm)**
Rogers RT 5880	4.032	3.358	1.229	0.211	1.250	2.479	0.5

Chapter 5
Simulations and Result's Analysis

The results of a simulation of the planned antenna are presented and discussed in this chapter.

5.1 Simulation Results of the Designed Antenna

This section's investigation and discussion of the findings is mostly focused on various antenna parameter dimensions. This analysis was carried out by keeping track of all of the parameters presented in this study. Those design parameters are then utilized to create the proper antenna, and examining the antenna result parameters determines the final antenna design parameters.

5.1.1 Result analysis of the Designed Antenna

This antenna design parameter is primarily influenced by the changing dimensions of a number of parameters such as insertion gap, patch length, patch width, and so on. The suggested antenna has a resonance frequency of 28.075 GHz and works at 28 GHz. Rogers RT-5880 is the substrate element for this antenna, and it has a dielectric constant of 2.2. Patching, grounding and feeding lines all require copper conductors. For the feed line between patch and supply power, the transmission line microstrip in the antenna design has a typical impedance of 50 ohms. Table 4.2 shows the size of the different antenna parameters. I was able to improve the bandwidth in table 5.1 to 928 MHz using those parameters, which is higher than the earlier work reported in table 5.2. In table 5.1, I obtained improved s1,1 parameter values of-41.282 dB, which is also a better result than the previous studies shown in table 5.2. As indicated in Table 5.2 below, I also got good results in VSWR, or Voltage Standing Wave Ratio, with 1.017, which is better than earlier work. Our efficiency, gain, and directivity results, as shown in table 5.1, were also achieved, though not as well as in prior trials. According to the CST studio suite, the power accepted per port is about 100 percent, as shown in figure 5.8, where the value is 0.4999, which is over 50 percent, because the simulated power is multiplied by 0.5, as shown in figure 5.9. Based on the aforementioned description, we can observe that our maximum outcomes are superior to past results. Figure 5.9 depicts the simulated power, which is considerably superior

to prior study work.

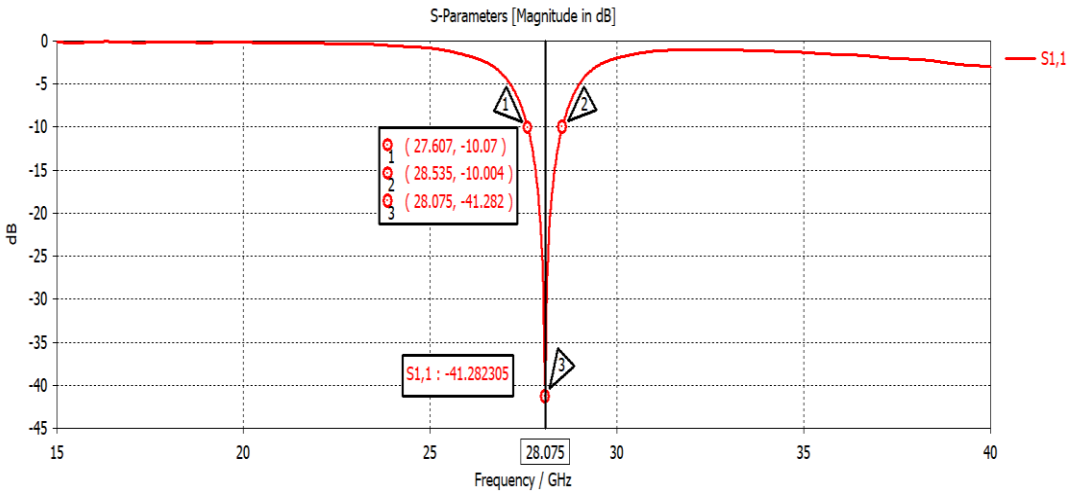

Figure 5.1: The bandwidth and S11 parameter for the proposed antenna

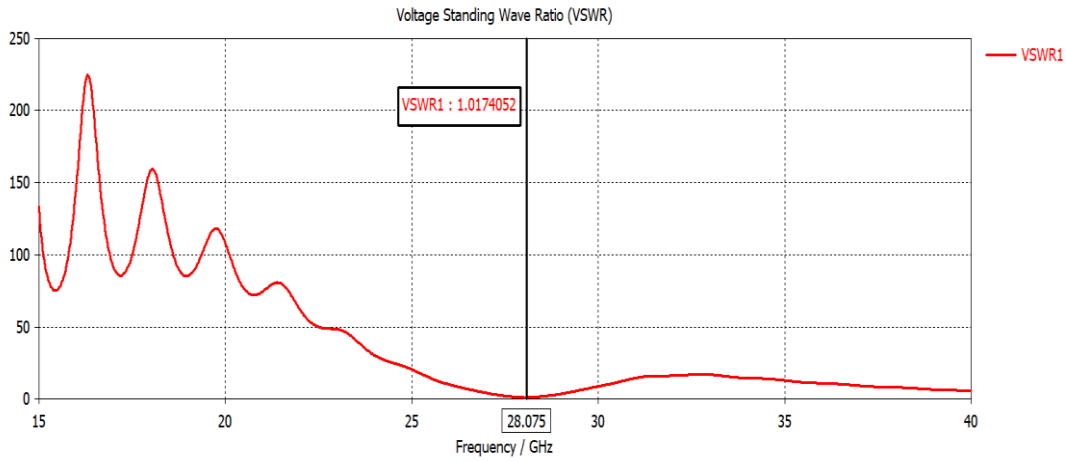

Figure 5.2: The VSWR of the proposed antenna

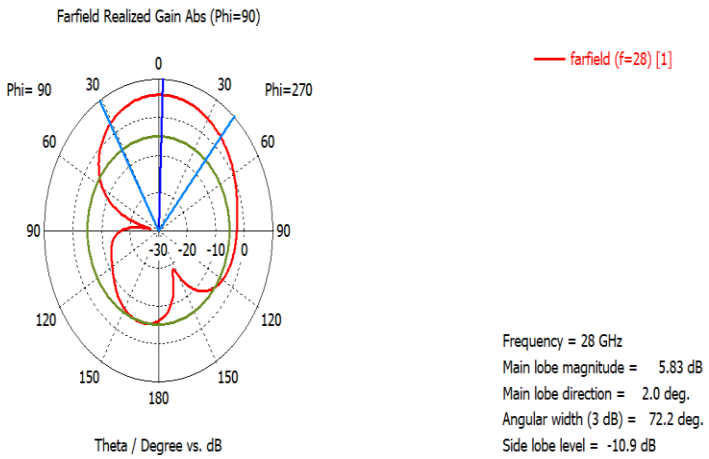

Figure 5.3: Radiation pattern and gain of the proposed antenna in polar view

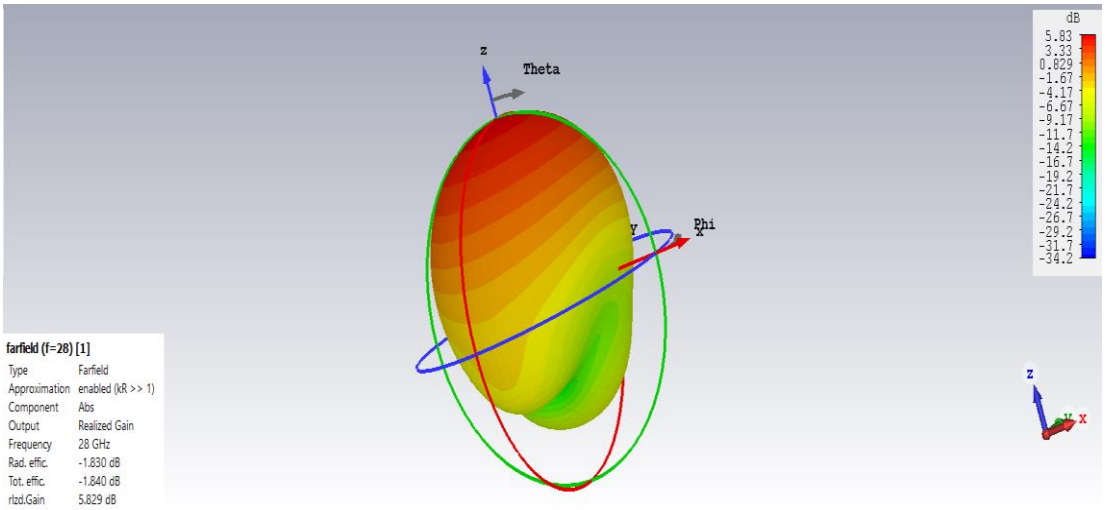

Figure 5.4: Radiation pattern and gain of the proposed antenna in 3D view

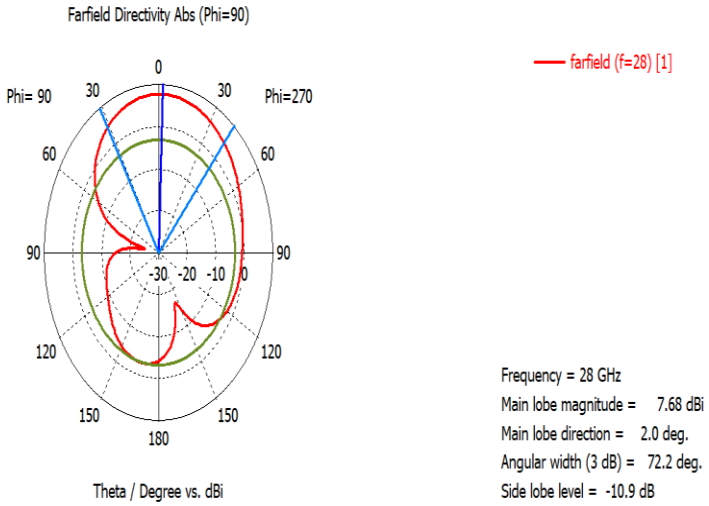

Figure 5.5: Radiation pattern and directivity of the proposed antenna in polar view

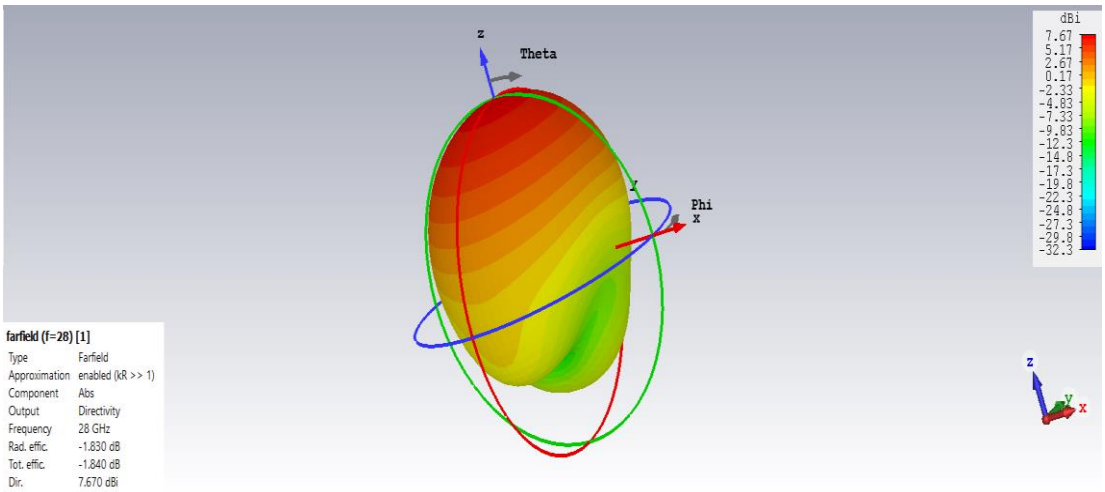

Figure 5.6: Radiation pattern and directivity of the proposed antenna in 3D view

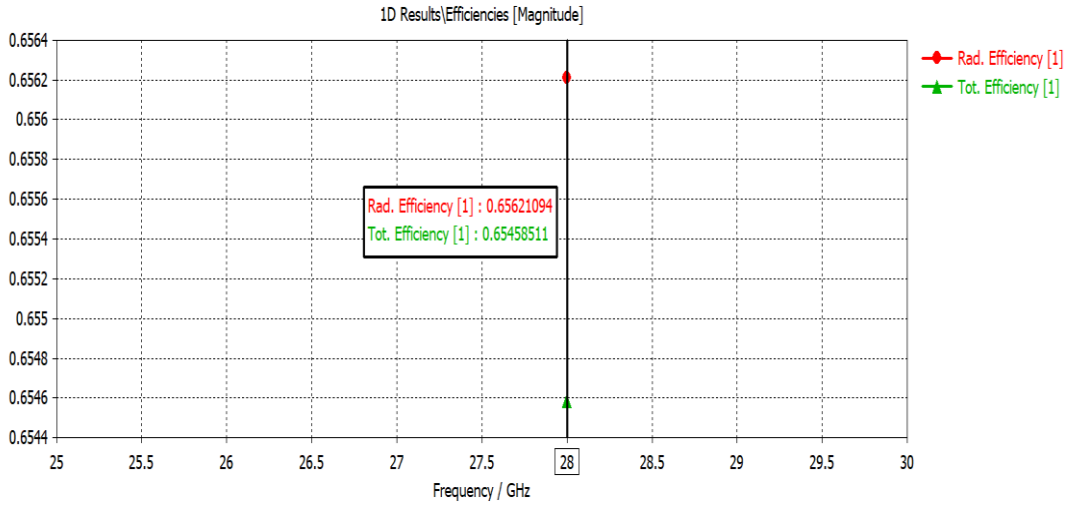

Figure 5.7: Radiation efficiency and total efficiency of the proposed antenna

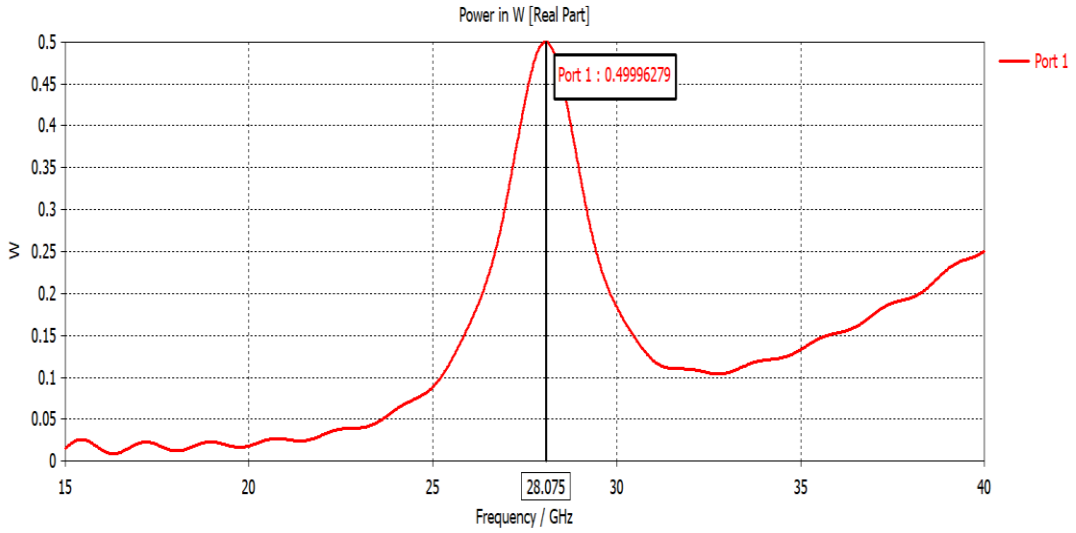

Figure 5.8: Power accepted per port of the proposed antenna

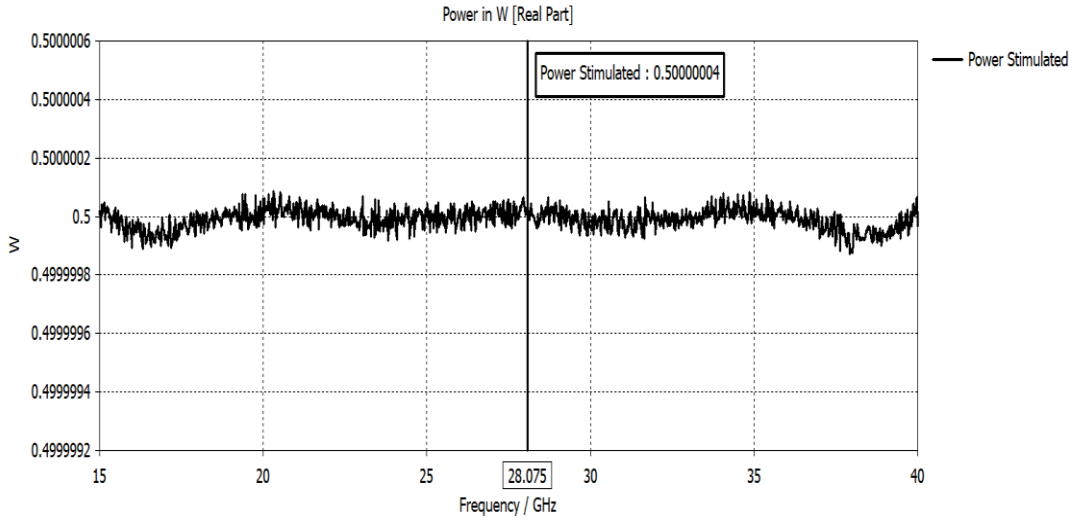

Figure 5.9: Simulated power of the proposed antenna

Table 5.1: Simulated results of antenna parameters for 28 GHz operating frequency

Antenna Parameter	Results/Outputs
Return Loss, S1,1	-41.282 dB
Bandwidth	928 MHz
Gain	5.83 dB
Directivity	7.67 dBi
VSWR	1.017
Efficiency	66.7%
Power Simulated	100 %
Power Accepted	99.99 %

5.2 Comparison with the existing single element MPA

Tables 5.1 and 5.2, which show the simulated results and compare the proposed work to previous work, based on these comparisons, it is clear that the proposed antenna, which was designed by varying dimension of the various parameters, outperformed previous research in terms of meeting 5G specifications.

Table 5.2: Comparison with the existing single element antenna for 28 GHz

Antenna Reference	Years	Bandwidth	VSWR	Return Loss, S1,1 (dB)	Gain (dB)	Directivity (dBi)	Efficiency (%)
[45]	2019	847 MHz	1.537	-13.48	6.63	-	70.18 %
[46]	2018	582 MHz	1.77	-12.59	6.69	-	-
[47]	2018	400 MHz	1.022	-20.53	6.21	8.002	77.72 %
[48]	2020	463 MHz	1.22	-27.98	6.72	-	-
[49]	2020	800 MHz	1.487	-14.15	6.06 (ieee)	7.7	
Proposed antenna	2021	928 MHz	1.017	-41.28	5.83	7.67	66.7 %

Chapter 6
Conclusion

The major purpose of this study was to create a microstrip patch antenna that was 5G compatible. To make this endeavor more effective, we attempted to improve outcomes by changing the parameters dimensions, which will significantly improve the antenna's bandwidth, return loss s11, and VSWR. Following that, a single-element antenna operating at 28GHz was built employing those features, which met 5G criteria and outperformed prior trials. The fact that existing antennas do not meet the exact requirements of 5G was the motive behind this work. So, in order to make this task more efficient, we modified the parameter dimensions and it has a unique influence on the bandwidth of the antenna, return loss and VSWR which were 928 MHz, -41.282 dB and 1.017 respectively and those were far better than the existing works. Finally, a single-element antenna at 28GHz was developed using those characteristics, and the antenna met 5G specifications and outperformed previous efforts.

6.1 Achievements

The main goal of this research was to develop a 5G-compliant microstrip patch antenna design. The issue that existing antennas do not fulfill the exact criteria of 5G was the impetus for this effort. As a result, we attempted to achieve better results by adjusting the parameter dimensions to make this operation more efficient, it has a significant impact on the antenna's bandwidth parameter. In this situation, the substrate used is Rogers RT-5880, which has a height of Hs = 0.5mm. Following that, a single-element antenna at 28GHz was designed using those characteristics, and the antenna met 5G specifications and generated better results than the previous work.

6.2 Limitations

The proposed antenna has concerns with gain, directivity, and efficiency. These parameters are critical for microstrip patch antennas, and we need to improve them to make them more accessible for 5G applications.

6.3 Future Work Field

As we can see from the previous results and simulation discussion, our gain,

directivity, and efficiency were all subpar in contrast to previous studies. As a result, more effort to increase gain, directivity, and efficiency may be conducted. In addition, the planned and simulated antenna should be built in the real world to verify its performance and compare the simulation and measured results.

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