BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATIONS ENGINEERING

Design and Simulation of a Dual Band MIMO Antenna for 4G & 5G Applications in 5G Smartphone

Supervised by

Md. Mostafa Amir Faisal

Assistant Professor

Department of Electronic and Telecommunications Engineering, IIUC

Submitted By

Emel Kanty Shill (T-163013)

Bashir Ahammad Zabir (T-163014)

Rashed Fahim (T-161045)

Department of Electronic and Telecommunications Engineering

International Islamic University Chittagong

Kumira, Sitakunda, Chittagong – 4318

September, 2020

CANDIDATES DECLARATION

It is hereby declared that the work presented in this thesis has not been submitted elsewhere for the award of any degree or diploma, does not contain any unlawful statement.

Emel Kanty Shill

ID T-163013

Bashir Ahammad Zabir

ID T-163014

Rashed Fahim

ID T-161045

DEDICATION

This thesis work is devoted to all of our honorable teachers and parents.

CERTIFICATE OF APPROVAL

The thesis entitled as "**Design and Simulation of a Dual Band MIMO Antenna for 4G & 5G Applications in 5G Smartphone**" submitted by Emel Kanty Shill, bearing ID No: T-163013 , Bashir Ahammad Zabir bearing ID No: T-163014, & Rashed Fahim bearing ID No -T161045 to the Department of Electronics and Telecommunications Engineering (ETE) of International Islamic University Chittagong (IIUC) has been accepted as satisfactory for the limited contentment of the necessities for the Degree of Bachelor in Electronic and Telecommunications Engineering and accepted as to its style and contents for the examination held on 05-09-2021.

Approved by

Md. Mostafa Amir Faisal

Supervisor

Assistant Professor

Department of Electronic and Telecommunications Engineering

Faculty of Science and Engineering

International Islamic University Chittagong

Kumira, Sitakunda, Chattogram -4318

Acknowledgements

Within Allah's name, the supremely tolerant, very forgiving. All praise and grandeur go to Allah (SWT) for blessing us with opportunities to thrive and showering us with His compassion and guidance throughout our lives. And may Allah's peace and blessings be upon Prophet Muhammad (pbuh), a source of inspiration and guidance in our lives. We thank our thesis supervisor, Md. Mostafa Amir Faisal, for his initiative in this field of research, valuable guidance, and encouragement throughout the research period, as well as Engr. Syed Zahidur Rashid, Head of the Department of Electronic and Telecommunications Engineering, IIUC, for their support and encouragement. We also want to convey our gratitude to him for providing us with best facilities in the department and his timely suggestions. We also appreciate Md. Mostafa Amir Faisal, our thesis convener, for his commitment and sacrifice. We, too, offer our heartfelt gratitude to all of our teachers for their tireless efforts during our academic careers. And we remember our guardians for their role in our lives up to this point. We also like to thank our friends and well-wishers for their participation in the fulfillment of this proposed task, whether explicitly or implicitly.

Abstract

MIMO stands for Multiple-In Multiple-Out, and it refers to the fact that when a packet enters the channel, it is sent through multiple antennas, and when it exits the channel, it is received through multiple antennas. This suggested antenna is made up of four single antennas in order to build a Dual Band MIMO Antenna. This antenna, which is perpendicular to the system circuit board's edge, may be used with the popular full-screen mobile phone. According to simulation findings, the modulus' reflection coefficient is less than -10 dB, indicating that it will satisfy the anticipated future of 5G applications. It will satisfy the 5G application's anticipated future. To test the aforementioned characteristics, single antennas are constructed on 3.3-3.6 GHz and 4.8-5.5 GHz using antenna modeling software. The scope and applicability of design criteria for 5G antenna needs were defined in this article.

Contents

1st Chapter. Introduction

Since the early 1970s, the mobile wireless industry has been developing, revolutionizing, and evolving. The cellular communication sector has grown at a breakneck pace since the mid-nineties. When the cellular thought was initially actualized within the 1960s and 1970s, no one might have anticipated how far reaching remote communication networks would gotten to be. Mobile cellular subscriptions are growing at a rate of 40% per year, and by the end of 2010, there will be four times as many as conventional telephone lines. The fast increase of cellular telephone customers throughout the world has shown beyond a shadow of a doubt that wireless communications is a reliable and viable voice and data delivery system. Because of cellular widespread popularity, other wireless systems and standards have been developed for a variety of different forms of telecommunication traffic in addition to mobile voice telephone calls.

Evolution of cellular mobile communication

Cellular networks and technology have advanced meaningfully since their introduction in the late 1970s, with subsequent generations (2G through 4G) marking key signs in the evolution of mobile communication. Each network generation marked an important landmark in the evolution of mobile data communications, the advantages of which we've detailed below.

1.1 Zero Generation Wireless Technology (0G)

Remote phone begun with 0G, which might have called Zero Era, became accessible after the World War-II. At that time, there were as it were a restricted number of communication channels accessible and portable administrators set up the calls. These mobiles could not bolster the include of handover implies alter of channel frequency while moving. Zero era alludes to the pre-cellular versatile framework within the early 1970's. For example, a few supporters had Radio phones in cars some time recently the presentation of cell phones. Portable radio communication framework delivered cutting edge cellular mobile-telephone technology. These frameworks are called 0G (Zero Era) Frameworks Since they were forerunners of, to begin with, the era of cellular phones. Advances utilized in Zero 2 Era frameworks included Mobile Telephone System (MTS), Push to Talk (PTT), Norwegian Offending Land-Mobil Telephone (OLT), Improved Mobile Telephone Service (IMTS), Advanced Mobile Telephone System (AMTS),), Public Land Mobile Telephony (PLT) and Swedish Mobile Telephony System D (MTD). The clients of the framework were

lumberjacks, development administrators, realtors, and celebrities. The communication framework was utilized for the reason of as it were voice communication.

1.2 First Generation (1G)

First Generation mobile networks first appeared in Japan, the year in 1979, though they were not termed 1G at the time, and then spread to other countries such as the United States in 1980 and the United Kingdom in 198 (1985). 1G networks had such a channel capacity of 30KHz and a speed of 2.4kbps. An analogue technology called Advanced Mobile Phone System (AMPS), which utilized Frequency Division Multiple Access (FDMA) modulation. Only voice conversations were possible on 1G networks, which had challenges with dependability and signal interference, as well as insufficient hacker protection. First Generation system replaced 0G system, whose features includes mobile, radio, telephones and technologies as Advanced Mobile Telephone System (AMTS), Mobile Telephone System (MTS), Push to Talk (PTT) and Improved Mobile Telephone Service (IMTS).

❑ Established in the 1980s and finalized in the early 1990s

❑ Bolstered information exchange speed up to 2.4 kbps

❑ Progress portable phone framework (AMPS) was, to begin with, presented by the USA and is a first-generation versatile system.

❑ It licenses the clients to start voice calls inside as it were one nation

Key features of 1G system-

Key features of First Generation system given below

❑ Frequency 800 MHz & 900 MHz

❑ Bandwidth is 10 MHz, (666 duplex channels through bandwidth of 30 KHz)

❑ Technology is analogue switching

❑ Modulation is Frequency Modulation (FM)

❑ Method of service is only voice

❑ Access technique is Frequency Division Multiple Access (FDMA)

Difficulties of 1G system-

Difficulties of First Generation system given below

- Poor voice quality due to interference
- Poor battery life
- Large sized mobile phones (not convenient to carry)
- Less security (calls could be decoded using an FM demodulator)

1.3 Second Generation (2G)

The 1st Generation network was not perfect, but it kept going until 1991 when it was supplanted by the 2G arrange. This unused versatile network used computerized signals instead of simple, enormously moving forward both security and capacity. 2G systems had transfer speeds extending from 30 to 200 kHz, permitting clients to transmit SMS and MMS messages at unassuming rates of up to 64 kbps. Persistent progressions in GSM innovation come about within the dispatch of 2.5G, which included parcel exchanging within the shape of GPRS as well as EDGE. and when GPRS was discharged in 1997, clients were able to get and send emails whereas on the street

Key features of 2G system

Key features of second-generation system given below,

- Digital system (switching)
- SMS service - possible
- Roaming - possible
- Security - Enhanced
- Voice transmission- Encrypted
- First internet at lower data transmission rate

Difficulties of 2G system

- Low data transmission rate
- Partial mobility
- Fewer features on mobile devices

1.4 Third Generation (3G)

The make a big appearance of 3G, too known as UMTS in Europe and CDMA 2000 within the Joined together States, within the year 2000 signaled a move within the way portable phones were utilized and seen by the conclusion client, with less accentuation on voice discussions and more on social associations. The major objective of 3G, which was moreover based on GSM, was to supply high-speed information, with the initial 3G innovation permitting information speeds of up to 14Mbps. Clients may conduct video discussions, get to the net, trade records, play online recreations, and indeed observe TV online much appreciated to 3G's capacity to transport bigger sums of information at quicker rates. Whereas 2G networks could download a 3-minute MP3 music in 6-9 minutes, 3G networks would take anything from 11 to 90 seconds to download the same file.

Figure 1: 3G vs 2G Communication

Key features of 3G system-

Key feature of 3G system is given below

- ❑ High data rate
- ❑ Video calling
- ❑ Enhanced security, a greater number of users and coverage
- ❑ Mobile application support
- ❑ MMS support
- ❑ Tracking Location and maps
- ❑ Improved web browsing
- ❑ TV streaming
- ❑ HD quality 3D games.

Difficulties of 3G systems-

Disadvantage of 3G system is written below

- Spectrum licenses are expensive
- Costly structure, apparatuses and application
- Higher bandwidth necessities to support high data rate
- Expensive mobile devices
- Compatibility with older generation second generation system and frequency bands.

1.5 Forth Generation (4G)

The presentation of 4G signaled the starting of the smartphone and hand-held versatile gadget time. 4G is the primary era to utilize Long-Term Evolution (LTE) innovation to attain potential download rates of 10Mbps to 1Gbps, giving conclusion clients with lower inactivity (less buffering), improved voice quality, moment informing and social organizing, high-quality gushing, and quicker download rates. The innovation is being created to oblige the Quality of Benefit (QoS) and rate prerequisites required by applications such as remote broadband get to, Multimedia Messaging Service (MMS), video chat, and others. 4G is additionally the primary IP-based versatile arrange, taking care of voice as fair another benefit. This organize, which may give association for tablets, tablets, and smartphones, ought to be bolstered by all portable gadgets presented after 2013. Clients may appreciate lower inactivity (less buffering), more prominent call quality, fast get to to moment informing and social media, high-quality spilling,

4 Cell Phone Generations Compared

	Standards	Technology	SMS	Voice Switching	Data Switching	Data Rates
1G	AMPS, TACS	Analog	No	Circuit	Circuit	N/A
2G	GSM, CDMA, EDGE, GPRS	Digital	Yes	Circuit	Circuit	236.8 kbps
3G	UTMS, CDMA2000, HSPDA, EVDO	Digital	Yes	Circuit	Packet	384 kbps
4G	LTE Advanced, IEEE 802.16 (WiMax)	Digital	Yes	Packet	Packet	up to 1 Gbps

Figure 2-. 4G cell phone generation compared

Key features of 4G systems

Key feature of 4G system is given below.

- ❑ Much higher data transmission rates up to 1 Gbps
- ❑ Improved security and agility
- ❑ Reduced potential for mission perilous applications
- ❑ HD video streaming and gaming
- ❑ Voice over LTE network VoLTE

Difficulties of 4G system

Disadvantage of 4G system is given below.

- Expensive equipment and infrastructure
- Costly range (most nations, recurrence groups are is as well expensive)
- High conclusion portable gadgets consistent with 4G innovation required, which is costly.

1.6 Fifth Generation (5G)-

The 5G network is on its way, and the portable industry is very energized around it. Concurring to a few investigators, the network will modify not fair how we utilize our phones, but too how we interface our contraptions to the web. The network's expanded speed and capacity will usher in unused IoT patterns counting connected automobiles, keen cities, and IoT within the domestic and working environment. The yearning standard gives a critical execution advancement over 4G and is designed to meet the wants of the previously mentioned creating applications. Throughputs of up to 10Gbps (100 times quicker than 4G systems) are anticipated to meet the developing request for transmission capacity; latencies of 1mSec (vs. 30-50mSec for 4G) will empower near-real-time reaction rates, and association densities of 1000 gadgets per square kilometer (100 times higher than 4G) will back the developing number of IoT gadgets and sensors.

Features of 5G

Feature of 5G is given below

- ❑ 1 Gbps to 10 Gbps connections to end points in the field.

- Potential of 1ms
- 1000x bandwidth in per unit area.
- 10x to 100x number of linked devices.
- Availability is 99.999 percent.
- 100 percent coverage.
- 90 percent saving in system energy usage [1].

Figure 3: Examples of 5G Use Cases

1.7 Antenna Basics

An antenna could be a devoted transducer that changes radio-frequency (RF) areas into electrical vitality or vice-versa. There are two essential sorts: the getting radio wire, that captures RF vitality and delivers substituting current to the equipment, conjointly the transmitting radio wire, that's encouraged with electrical vitality from the gear and produces radio-frequency field. In remote applications, the preeminent common assortment of antennas is that the microstrip fixes radio wire, utilized for remote communications. Microstrip fix radio wires are ordinarily sensible exclusively at microwave frequencies.

1.7.1 Frequency

In typical sense, frequency implies how as often as possible happens a specific occasion in a specific period. Fundamentally, frequency alludes to the number of events of an occasion in a positive time. From the ordinary definition, “The number of repeats of a flag over a characterized time period (1 moment), is known as frequency. Intermittent flag rehashes itself after each ‘T’ moment called time period. Frequency of periodic flag is only the reverse of a time period (T).

Below Figure appears frequency chart. In building wording, frequency is utilized to distinguish the rate of oscillatory and vibratory events, for case radio waves, sound flag (sound), mechanical vibrations, and light. The SI (Universal Framework) unit of frequency which is entitled by the German physicist Heinrich Hertz is hertz (Hz). One hertz indicates that an occasion or flag rehashes once per moment.

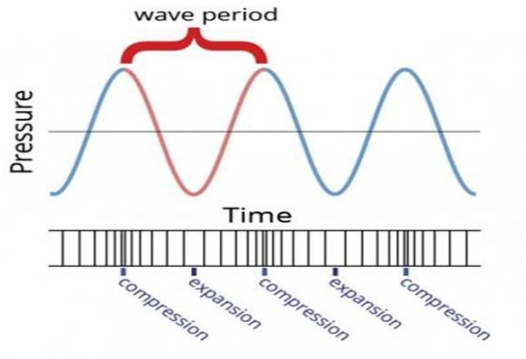

Figure 4- Frequency diagram

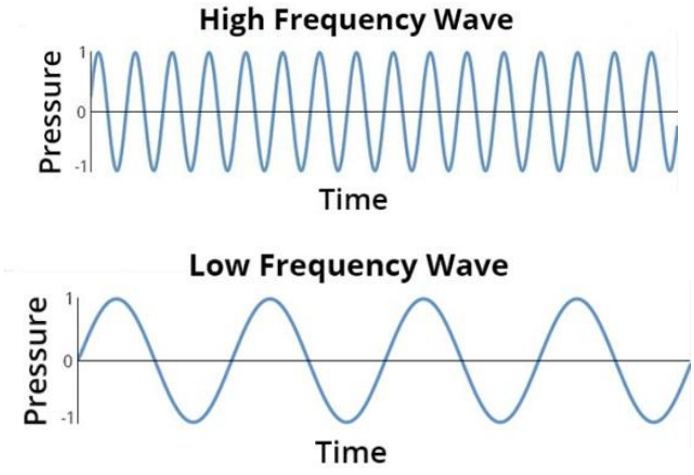

Figure 5- High frequency and Low frequency diagram

1.7.2 Bandwidth

In communication systems, bandwidth is characterized as the capacity of a wired or farther communications system interface to transmit the most prominent entirety of data from one point to another over a computer orchestrate or web affiliation in a given whole of time, customarily in one minute. Within the case of radio wire, exchange speed implies the degree of repeat over which the getting wire can fittingly radiate or get essentialness. Habitually,

exchange speed is one of the preeminent needed choosing parameters utilized to select upon a getting wire. For events, various accepting wire sorts have especially limit exchange speeds and cannot be utilized for wideband operation. shows up transfer speed within the chart figure underneath.

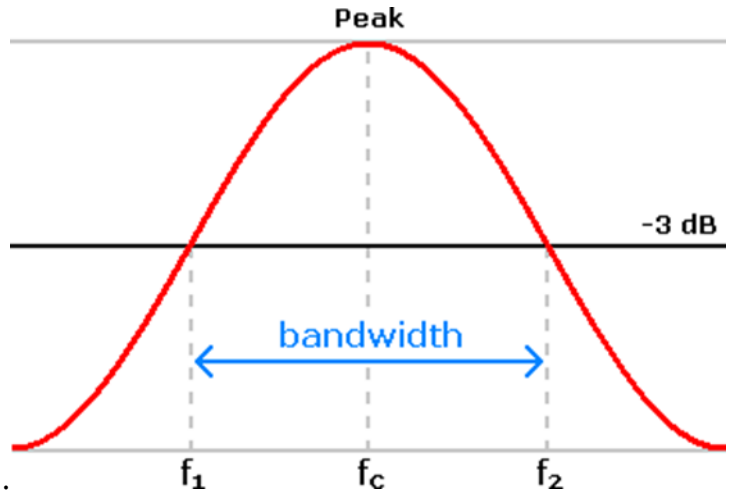

Figure 6- Bandwidth diagram

1.8 Antenna for 4G

Since of the vast range of applications available in such frameworks, portable phone radio wires have picked up a parcel of intrigued with the quick improvement of fourth-generation (4G) versatile communication advances [1–4]. In truth, the whole execution of these communication frameworks is affected by these antennas, which are a vital perspective of portable phone terminals. The conventional portable phone antennas have been appeared to be insufficient for 4G remote communication needs in multiband and broadband applications [5–7]. An assortment of compact Long Term Advancement (LTE) versatile phone receiving wires has been a prominent center of communication industry inquire about within the later few a long time [8–11]. Many attempts have been attempted to make strides in the execution of receiving wires within the LTE groups to fathom the issues of coordination radio wires in 4G portable phones [12–16]. These plan alternatives, on the other hand, habitually require colossal sizes or volumes, which may be inconsistent with the current era of mobile

1.9 Antenna for 5G-

The 5G time is arrived. Clients are lured by the guarantee of quicker high-data-rate network and lower inactivity for real-time engagement. This combination will empower unused video designs such as 360-degree video (video activity is anticipated to account for 73 percent of all portable information activity by 2023), as well as modern advances such as independent driving, expanded or virtual reality interaction, and a material web with applications extending from industry computerization and transportation frameworks to healthcare, instruction, and more. Engineers have continuously found building receiving wires for versatile phones to be a troublesome assignment, and creating radio wires to back the modern 5G recurrence groups will set the bar much higher. The foremost curiously recurrence ranges are recurrence range 1 for communication within the sub-6 GHz groups and recurrence extend 2 for communication at millimeter (mm) wave frequencies over 24 GHz.

1.10 **Microstrip Patch Antenna**

An individual Microstrip Patch Antenna is made up of a fix of metal thwart in different shapes (a fixed receiving wire) on the surface of a PCB (printed circuit board) and a metal thwart ground plane on the inverse side. The lion's share of microstrip radio wires is made up of various patches organized in a two-dimensional array. The least complex fix receiving wire utilizes a half-wavelength fix, with the metal surface acting as a resonator in the same way as half-wave dipole radio wires do. A few fixed radio wires are built of a metal fix situated on a ground plane utilizing dielectric spacers instead of a dielectric substrate. It is straightforward to manufacture on printed circuit sheets, it is commonly utilized inconvenient remote gadgets. Microstrip receiving wires, which comprise several patches receiving wires on the same substrate (see picture), may be utilized to form tall pickup cluster radio wires and staged clusters in which the bar may be electronically directed.

1.11 MIMO Antenna

Multiple-Input Multiple-Output abbreviated as MIMO, is a remote innovation that increments the information capacity of an RF radio by utilizing numerous transmitting and accepting receiving wires. In a MIMO framework, the same information is transmitted through multiple receiving wires over the same way within the same bandwidth. Each spatial stream in MIMO is sent within the same recurrence channel as the transmitter from a particular radio/antenna chain. Each stream is gotten by the recipient through its indistinguishable radio/antenna chains. The collector can reproduce the first streams since it knows the stage offsets of its claim antennas.

1.12 Application in 5G communication-

MIMO could be a major empowering innovation for 5G remote innovation, permitting for expanded throughput and flag to noise ratio. MIMO (Different Input Numerous Yield) may be a well-known innovation utilized in portable communications and an assortment of other areas. Advanced remote advances, such as IEEE 802.11n, 3GPP LTE, and versatile WiMAX, utilize multiple-input, multiple-output (MIMO) receiving wire frameworks. Indeed, within the nearness of obstructions, flag blurring, and multipath, the approach permits for expanded information throughput.

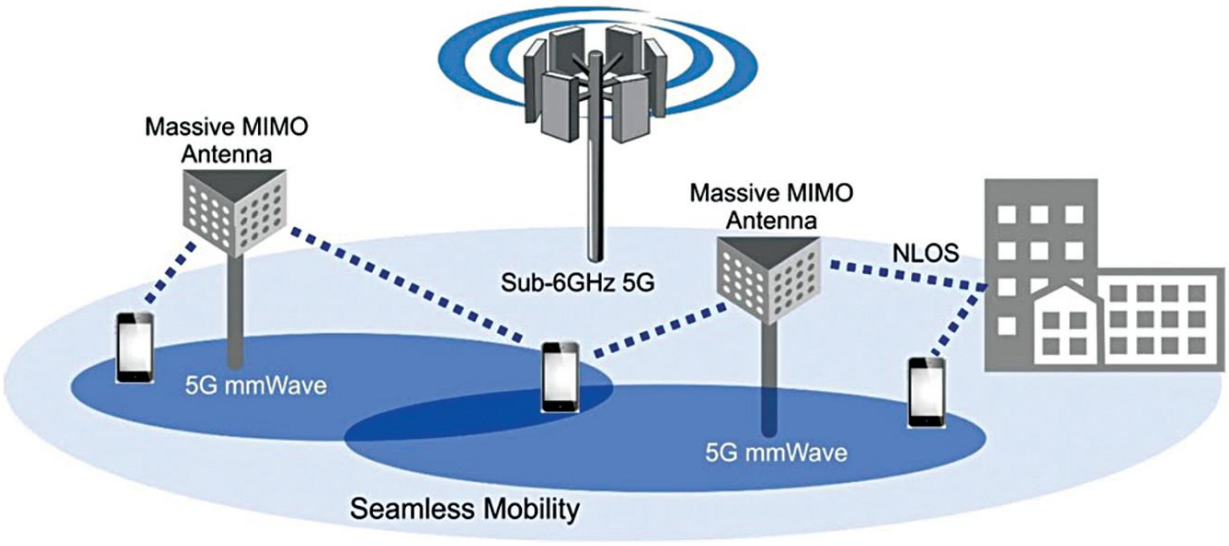

Fig 7. - Role of Massive MIMO antennas in 5G

2nd Chapter. Literature Review

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

The 3rd Generation Partnership Project (3GPP) joins [Seven] media communications standard advancement associations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as Organizational Pattern and gives their individuals a steady climate to deliver the Reports and Specifications that characterize 3GPP advances. The undertaking covers cell media communications advancements, including radio access, center organization and administration abilities, which give a total framework portrayal to versatile mobile telecommunications. The 3GPP determinations likewise give snares to non-radio admittance to the center organization and for interworking with non-3GPP organizations. 3GPP particulars and studies are commitment driven, by part organizations, in Working Groups and at the Technical Specification Group level. 5G New Radio has as of now developed in significant manners since the 3GPP normalized Release 15 in late 2018. The huge upgrades in Releases 16 and 17 are sure to assume a basic part in growing both the accessibility and the pertinence of 5G NR in both industry and public administrations sooner rather than later.

2.1.1 Requirements of 5G:

In arrange to guarantee that the proper 5G remote framework is developed, it is fundamental to gather and concur the necessities of the framework. By collecting the prerequisites, it is conceivable to get the wants and design the 5G remote framework to meet the prerequisites, and in that way satisfy wants. By concurring the prerequisites, all parties can work towards developing the same framework and create work-arounds where them, It possess specific needs may not be sufficiently met. Care should be taken that the 5G prerequisites are carefully collected and examined so that the most excellent framework is accomplished. Something else it seems result in a framework that's not usable

- Potential of 1ms
- 1000x bandwidth in per unit area.
- 10x to 100x number of linked devices.
- Availability is 99.999 percent.
- 100 percent coverage.
- 90 percent saving in system energy usage.

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

TABLE 2.1. TECHNICAL REQUIREMENTS OF 5G

Metric	Requirement
Peak data rate	DL: 20 Gbps UL: 10 Gbps
Peak spectral efficiency	DL: 30 b/s/Hz UL: 15 b/s/Hz
User experienced data rate	DL: 100 Mbps UL: 50 Mbps
Area traffic capacity	Indoor hotspot DL: 10 Mbps/m^2
User plane latency	eMBB: 4 ms URLLC: 1 ms
Control plane latency	20 ms (encouraged to consider 10 ms)
Connection density	1M devices per km^2
Reliability	99.999% success prob.
Bandwidth	>100 MHz, up to 1GHz in > 6GHz

However, there are also differences between LTE and NR as summarized in Table 2.2

TABLE 2.2. DEFFERENCES BETWEEN LTE AND NR

Technology	4G (LTE)	5G (NR)
Data Rates	Avg 25 Mbps Peak 300 Mbps	Avg 100 Mbps Peak 20 Gbps
Latency	~10- 50 ms	~ 1 ms
Mobility Support	Upto 350 Km/h	> 500 Km/h
Spectrum Efficiency	DL – 6 bits/Hz UL- 4 Bits/Hz	x3 Better DL- 30 bits/Hz UL- 15bits/Hz
Users Density	~ 2K / square Km	1000K/square Km
Energy Efficiency	Moderate	x100 Better

A huge amount of new hardware must be installed to correctly device the full version of New Radio (NR). A phased approach has been planned to carry on using current hardware. There are two versions: a non-standalone (NSA) version which will use the existing LTE core, and a standalone (SA) version which will use an NR core and it will be totally liberated of the LTE core network.

Table 2.3 presents the operating frequency bands proposed in the RAN4 meeting held in May 2018. It is an important note that band n261 has been added and, more remarkably, band n259, which was defined in the old versions as 31.8 GHz–33.4 GHz Time Division Duplex (TDD), has been removed. This band was originally called out as a band for study, but CEPT removed it for consideration for 5G in November 2017. Such as 24.25 GHz–29.5 GHz, are being definitely examined for utilizing in 5G NR. In Specialized Report 38.815 this recurrence overhaul is being

followed and effectively detailed. A higher visual layout of the frequencies of intrigued in several areas, taken from that specialized report is given within the taking after recurrence chart.

TABLE 2.3. FREQUENCIES OF INTEREST IN SEVERAL LOCATION

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

2.2 Paper Review

In this section, the works by other analysts that are related to this proposal "Design and Reenactment of a double band MIMO Antenna for 4G & 5G Remote Communication" will be looked into, which is a crucial component to effectively inquire about to the fifth generation (5G) versatile application with the existing antenna. Hence, for the plan and reenactment of a receiving wire with way better execution and simple fabrication.

1. **Research and Design of a High Isolation 5G Antenna for Smart Phone**

   This article describes and examines a multi-band 8-element MIMO antenna cluster that operates in the LTE42 and LTE46 bands. The multi-band 8x8 MIMO application is made possible by creating open gaps of varying lengths at each ends of 8 T-shaped opening radio wire components.

2. **Design of a Dual-band MIMO Antenna for 5G Smartphone Application**

For 5G smartphone applications, a dual-band four-antenna MIMO cluster is proposed. The suggested receiving wire is hidden within the side shape of a full-screen smartphone radio wire layout, in accordance with the slant.

3. **Hybrid Antenna Using Open-Ended Slot for Integrated 4G/5G Mobile Application**

In this paper, a 2-element MIMO antenna framework for the 4G/5G portable application has been displayed. A ground opening antenna with two feeders is sent to cover both 27-40 GHz the 5G band and 1.9-2.7 GHz the 4G band.

4. **Design of a Twelve-Port MIMO Antenna System for Multi-Mode 4G/5G Smartphone Applications Based on Characteristic Mode Analysis**

A twelve-port MIMO antenna framework for multi-mode 4G/5G smartphone applications has been displayed and examined in this paper. The characteristic mode examination (CMA) has been utilized to discover potential reverberation and clarify the working guideline of the antenna

5. **A Dual-Band PIFA for MIMO Half-duplex 4G and Future Full-Duplex 5G communication for Mobile Handsets**

In this paper design a dual-band antenna system for future Tx/Rx FD 5G as well as 2×2 HD MIMO 4G communications dedicated for MT of a standard size suitable for nowadays smartphones. The objective was first, providing the 4G band and the 5G band

6. **Dual Functional MIMO Antenna System for mm Wave 5G and 2 GHz 4G Communications**

In this paper, a 2-element MIMO antenna framework for 4G/5G portable application has been displayed. A ground opening antenna with two feeders is conveyed to cover both 27-40 GHz the 5G band and 1.9-2.7 GHz the 4G band.

7. Design of a Dual-band MIMO Antenna for 5G Smartphone Application

A dual-band MIMO antenna for 5G communication is presented in this study. There are four antennas in the planned antenna. It's running at (3300 - 3600 MHz and 4800 - 5000 MHz). Its modulus reflection coefficient is less than -6 dB. Isolation is greater than 12 decibels. The Antenna Efficiency is all more than 50%. The ECC achieved is significantly lower than 0.1. The side frames are orthogonal to the system ground plane and have an area of (3.9 mm * 17 mm) for each antenna. The size of the system circuit board is chosen to be (130mm * 74mm). A 0.8-mm-thick FR4 substrate is used for both the side-edge frame and the system circuit board. The loss tangent is 0.02 and the permittivity is 4.4. The height of the mobile phone's edge frame is just 5 mm, in order to suit the trend of current ultra-thin smartphones. ANSYS HFSS 15 was used to create the proposed antenna.

8. Design of 6 × 6 Dual-Band MIMO Antenna Array for 4.5G/5G Smartphone Applications.

In this paper, a dual-band 6-antenna cluster within the smartphone has been proposed for the application in a 6 × 6 MIMO framework. In this paper, A dual-band 6 × 6 antenna cluster working within the LTE band7 downlink (2620–2690 MHz) and LTE band46 (5150– 5925 MHz) for 4.5G/5G communication multi-input multi-output (MIMO) operation within the smartphone is displayed. Its Separation (way better than around 10 dB). Its Proficiency is more than 60%. Its Encompass Relationship Coefficient (ECC) is less than 0.05. The complete geometry of proposed radio wire cluster, a 0.8-mm thick FR4 substrate. It contains a relative permittivity of 4.4 and a misfortune digression of 0.02 is utilized as the framework circuit board. IT incorporates a measurement of (140 mm × 70 mm).

9. Design Side-edge Frame Dual-band 8×8 MIMO Antenna Array For 5G Mobile phone.

In this paper, a side-edge outline eight-element MIMO antenna cluster for future versatile phone communications has been displayed. The proposed radio wire cluster is able to completely cover the 3.5 GHz band (3400-3600 MHz) and 5.5 GHz band (5150-5925 MHz). Its return misfortune (< -10 dB). Its Segregation (< -10 dB) within the moo band and (< -15 dB) within the tall band. Its Envelope Relationship Coefficients (ECC) between antenna components are less than 0.1. Its productivity is way better than 60% within the moo band and

80% within the tall band. FR4 substrate (Relative permittivity is 4.4) and (misfortune digression is 0.02) is considered as the printed circuit board (PCB) of framework and side-edge outline. The estimate of PCB is (150 ×75×0.8 mm3). The outline contains a 6.2 mm stature. The rectangular clearance districts are (8×26 mm2). It is saved for (2G/3G/4G) antenna. The monopoles are bolstered by the 50 Ω microstrip line. Besides, the proposed MIMO cluster has differences design that's alluring for MIMO antenna cluster.

10. Sub-6 GHz Dual-Band 8×8 MIMO Antenna for 5G Smartphones.

In this paper, a dual-band 8×8 MIMO antenna that works within the sub-6 GHz range for future 5G multiple-input multiple-output (MIMO) smartphone applications is displayed. It works between (3100- 3850 MHz) and (4800-6000 MHz) groups. Its return misfortune (< -10 dB). Its MEG varieties are (<-3 dB). Add up to radio wire proficiency is (65%-75%) for the moo band and (60%-71%) for the tall band. ECC is less than 0.06. The calculated channel capacities of the MIMO radio wire are (39-40 b/s/Hz) for the moo band and (38-39 b/s/Hz) for the tall band. The measure of the framework ground plane is (70 mm×150 mm). The substrate utilized for the antenna is FR-4 with (dielectric consistent of 4.3 and misfortune digression of 0.025). An FR-4 circle outline with a thickness of 0.8 mm. Stature the edges of the ground plane 6 mm. The orthogonal sets are associated by a 7.8 mm brief unbiased line for common coupling diminishment. Each antenna component comprises a collapsed monopole with measurements (17.85×5)

11. A Compact Dual-Band and High-Isolation MIMO Antenna System for 5G Smartphone Applications

In this paper, a compact dual-band multiple-input multiple-output (MIMO) antenna framework with tall component isolations is planned for a 5G smartphone application. It is working at the 3.5GHz band (3400 –3600 MHz) and 5-GHz band (4800–5000 MHz). The return misfortune -6 dB. The planned MIMO radio wire framework shows tall Isolations is over 14.5 dB. Add up to Efficiencies is over 42%. ECC is lower than 0.2. The component circle antenna contains a compact format in measure of (6.9 × 6.6 mm2) (approximately 0.08λ × 0.08λ) counting two collapsed stubs. The radio wires were modeled on a (0.8-mm) thick FR-4 substrate with a relative permittivity of 4.4 and a misfortune digression of 0.02. EM

reenactment of the planned MIMO antenna system was performed in Computer Reenactment Innovation (CST) Studio Suite.

12. Compact Planar 3.5/5.5 GHz Dual Band MIMO USB Dongle Antenna for WiMAX Applications.

- This paper presents a compact planar 3.5 GHz /5.5 GHz dual-band numerous input different yield (MIMO) USB dongle radio wire for WiMAX applications. The proposed MIMO antenna has two comparable components and for making strides coupling a decreased modified T-molded space is cut in between the radio wire components at the ground plane side. The MIMO radio wire has accomplished coupling less than -20.2 dB in the lower band (3.45-3.59 GHz) and less than -21.5 dB in the upper band (5.46-5.58 GHz). The proposed MIMO radio wire plan features a rectangular fix radiator which is bolstered at 3.35 mm balanced from the center by a 50 Ω microstrip line twist. The estimate of monopole radio wire component is (12.9×22 mm2). Add up to measure of the proposed MIMO antenna is (30×52 mm2). The decoupling circuit gives ≤ -20 dB little sum of current is coupled through the ground plane. The lessening in coupling current is corresponding to the diminishment in size of S21. At 3.5 GHz the |S21| changes from - 10.36 dB to -20 dB and at 5.5 GHz the |S21| changes from 10.36 dB to -20 dB and at 5.5 GHz the |S21| changes from - 19.5 dB to -22.4 dB.

13. Dual-Band Eight-Antenna Array Design for MIMO Applications in 5G Mobile Terminals.

This paper proposes a dual-band eight-antenna cluster for different input and different yield (MIMO) applications in 5G versatile terminals. It works between (LTE) band 42 (3400–3600 MHz) and LTE band 46 (5150–5925 MHz). The return misfortune is higher than 10 dB. The Confinement is more noteworthy than 11.2 dB. Add up to effectiveness is bigger than 51%. The envelope Relationship Coefficient (ECC) is lower than 0.1. The total framework is mounted on an FR4 ($\varepsilon r = 4.4$, $\tan \delta = 0.025$) substrate with a measure of (140 mm × 70 mm × 1 mm). Each space antenna component based on the SIR is energized by a 50 Ω microstrip line carved on the best side of the substrate. The proposed MIMO antenna cluster realizes a recreated channel capacity of higher than 36.9 bps/Hz inside both operation groups. The proposed MIMO getting wire the cluster has been reenacted and affirmed by the estimations

of a made demonstrate. Incredible understanding between the estimation and reenactment comes around has been observed, showing up that the MIMO radio wire cluster finishes extraordinary return l. The proposed MIMO antenna cluster has been mimicked and approved by the estimations of a manufactured model. Great understanding between the estimation and reenactment comes about has been watched, appearing that the MIMO antenna cluster accomplishes great return misfortune, separation, ECC, add up to proficiency, and channel capacity.

14. A Tunable MIMO Antenna with a Dual-Port Structure for Mobile Phones.

They provide a contemporary recurrent reconfigurable dual-port antenna with two free flag bolster ports in a single radio wire component for multi-input multi-output capable flexible phones in this article. Band 7 (2.5–2.69 GHz), Band 22 (3.41–3.59 GHz), Band 38 (2.57–2,62 GHz), Band 41 (2.496–2.69 GHz), and Band 42 (3.4–3.6 GHz) are among the working recurrence ranges. Recurrence tuning ranges of up to 800 MHz are possible with the proposed dual-port radio cable. The separation between ports is more than 10 decibels. The PCB board's dimensions are (60 100 1 mm3). It's printed on a FR4 substrate with a beat. In typically, the antenna PCB circuit stature is 1.3mm, taking into account the size of the antenna.

15: Research and Design of a High Isolation 5G Antenna for Smart Phone.

In this paper a multi-band 8×8 MIMO antenna cluster working in LTE42 band (3400-3600 MHz) and LTE46 band (5150-5925MHz) is outlined and examined. The working transfer speed of the radio wire covers LTE42 and LTE46. Return misfortune is more prominent than 6dB. Segregation is more prominent than 10dB. It can be utilized in large-scale MIMO applications of 5G savvy phones. The 8 units of the antenna are set along the side of the FR4 substrate (relative dielectric consistent 4.4 and digression of misfortune Point 0.02). The FR4 substrate is (150mm×80mm×0.8mm). The rectangular estimate is (16mm×2.5mm). The edge of the PCB is (0.5 mm×0.5 mm). T slots add up to width is as it were 3mm, and the proposed radio wire component can fit the estimate of a contract outline smartphone. The F formed feeder comprises of three parts: the vertical portion (50ohm microstrip feeder) with a estimate of (11.5mm×1.5mm) the brief on a level plane tuned portion amplifying from the edge of the T-shaped space score.

16: Compact, Two-Port, Slot, Antenna for Dual-Band Wi-Fi 2x2 MIMO Applications.

This paper presents a novel planar compact two harbor opening radio wire for 2.45GHz/ 5.5GHz dual-band Wi-Fi 2x2 MIMO applications. The two Wi-Fi groups are (2.402-2.48) GHz and (5.15- 5.835) GHz with central frequencies of (2.442GHz and 5.4925GHz). The antenna's two ports are exceptionally well-coordinated within the two groups of intrigued with a great separation (respectively -11.7dB and -31dB) within the two groups. Radiation productivity (over 96%). ECC is less than 0.2. This antenna adds up to measurements are (50x50x1.2mm3). It is printed on an FR4 substrate (permittivity = 4.2, tan = 0.02). It is composed of circular space with a breadth of 38mm within the radio wire beat energized by means of a circular monopole with a distance across of 18mm on the radio wire foot. The radio wire distinctive parameters are displayed and completely analyzed uncovering a palatable execution.

17: Compact, Integrated, Four-Sector, Antenna for Sub 6GHz 5G Indoor Access and Content Distribution over Wi-Fi.

This paper presents a novel planar compact coordinates four-sector receiving wire for sub-6GHz 5G indoor get to and substance conveyance over 2.45GHz/ 5.5GHz dual-band WI-FI in 2x2 MIMO arrangement. The four divisions, for 5G applications, are gotten by means of Vivaldi receiving wires with ground reuse for accomplishing exceptionally compact measurements. It covers the recurrence (2.45GHz - 5.5GHz). The radio wire is printed on a FR4 substrate (Permittivity = 4.2, tan = 0.2). Thickness 1.2mm. The antenna's reenacted within the program (ANSYS HFSS). The antenna's distinctive parameters are displayed and completely analyzed uncovering a palatable execution.

18: Element-level Phase Measurement of Array Antenna using Stabilized Planar Imaging System for Emerging Sub-6 GHz 5G Communications.

In this paper, an exact stage estimation strategy at the antenna component level in cluster antenna is proposed. A profoundly stabilized planar field imaging framework with double electro-optic sensors is created to the degree stage within the responsive near-field locale of the cluster radio wire. The proposed MIMO dual-polarized radio wire cluster is comprised of 8 fix components, 8 receiving wire ports, 16 nourishing arrange circuits, and a PCB with the ground plane. This radio wire cluster comprises 8 square patches and each fix is backed with

a dielectric jig over the ground plane with a moo profile. The ground plane is printed on one side of the FR4 substrate. The entire measurement of the cluster antenna is 233 × 247 × 10 mm3. The FR4 substrate has a dielectric consistent of 4.3 and a thickness of 2 mm. They accepted that the proposed strategy could be an exceptionally promising arrangement for beam calibration of 5G cluster antennas.

19: Dual-Band Ten-Element MIMO Array Based on Dual-Mode IFAs for 5G Terminal Applications.

In this paper, A dual-band ten-element MIMO cluster based on dual-mode inverted-F radio wires (IFAs) for 5G terminal applications is advertised. The proposed dual-mode IFA is composed of two radiators, which are carved on the external and inward surfaces of the side-edge outline. The external portion of the radio wire creates the low-order mode at 3.5 GHz, whereas the internal portion emanates another one-quarter wavelength mode at 4.9 GHz. The proposed antenna can cover 3.3-3.6 GHz and 4.8-5.0 GHz. The reflection coefficients are still way better than −6 dB over the operation transmission capacity for all components. The isolations are way better than 12 dB. The measured radio wire efficiencies are almost 45%–78% within the 3.5-GHz band and 45%–65% within the 4.9-GHz band. The gotten ECCs of all the antenna components are lower than 0.15. The measurement of the framework circuit board is (150 × 70 × 0.8mm3). Two clearance regions (70 × 5mm2). Two side-edge outlines with a width of 6 mm. Each side-edge outline is printed with five antenna components.

20: A Compact Dual-Broadband Multiple-Input Multiple-Output (MIMO) Indoor Base Station Antenna for 2G/3G/LTE Systems.

In this paper, they propose a dual-broadband multiple-input multiple-output (MIMO) indoor base station radio wire for 2G/3G/LTE frameworks. The antenna works at 800–960 within the lower band and 1700–2700 MHz within the higher band. The return misfortune of higher than 14 dB. The isolations of the radio wire are 18 and 25 dB. The antenna picks up of 3.6 and 7.2 dBi for the lower and upper recurrence groups. The tallness of the antenna is large (> 10 cm) and the radio wire gain isn't exceptionally tall. The proposed MIMO antenna incorporates a moo profile with its by and large measurements of 220×220×42 mm3 and utilizes both spatial and polarization diversities. The proposed MIMO receiving wire is outlined and manufactured

with its commonsense sending in intellect, such as the solidness and generally moo fetched. Comparing with existing commercial 2G/3G/LTE radio wires, their proposed plan offers a more compact estimate and a less complex nourishing structure.

21: Wideband 5G MIMO Antenna with Integrated Orthogonal-Mode Dual-Antenna Pairs for Metal-Rimmed Smartphones.

For fifth-generation (5G) multiple-input multiple-output (MIMO) metal-rimmed smartphones, this article offers a wideband orthogonal-mode dual-antenna match with shared radiator. It is capable of transferring data at a rate of (3.3-5.0 GHz). ECC is less than 0.02 and separation is much greater than 12.0 dB. Productivity of radio wires, The measured radio wire productivity for Ant1 ranges from 58.9% to 88.6%, with a typical esteem of 74.7 percent. The assessed radio wire effectiveness for Ant2 ranges from 31.6 to 76.7 percent, with a normal esteem of 57.8%. (150757.5 mm3) is the total volume of the suggested geometry. 0.8 mm thickness FR-4 (permittivity = 4.4, tan = 0.02) substrate The cut ground clearing's measurement ground clearance for the dual-antenna match is (40×3 mm2). They predict that the proposed plan conspire, with merits of shared radiator, wide transmission capacity, and metal edge compatibility, has the potential for the application of future 5G smartphones.

22: Dual Band Monopole Antenna For WLAN MIMO Applications at 2.4 and 5 GHz.

. A double band monopole resonator antenna is suggested in this work. The receiving wire is split into two separate groups, each with a center frequency of (2.4 GHz and 5 GHz). -10 dB is the return misfortune. ECC is less than 0.5. The suggested receiving wire is built on a FR4 substrate with dimensions of 18 mm x 14 mm. A 50 CPW transmission line with a 2 mm flag strip width, 0.45 mm crevice remove, and 0.4 mm crevice remove (right and cleared out individually). For 2.4GHz and 5.0GHz, the microstrip bolster line width is 0.75 mm and 1 mm, respectively. The coplanar ground plane has dimensions of (7.9 mm 4.55 mm) and (7.9 mm 6 mm). Furthermore, the planned radio wire cluster seems predominant execution strength and MIMO capabilities beneath distinctive hand-grip conditions. The proposed MIMO antenna plan and cluster is promising for WLAN applications

23: Super wideband Dual Notched Band MIMO Hexagonal Slot Antenna for Wireless Applications.

In this inquire about the article, a super-wideband monopole MIMO radio wire with double scored band characteristics is displayed. Antenna is additionally able of dismissing two interferometer groups, WLAN (5.150GHz-5.825GHz) and DSS (7.25GHz-7.75GHz). Antenna offers expansive working transfer speed of (2.70GHz-18.40GHz). In terms of differences execution of MIMO radio wire , ECC<0.1 , DG>9.95dB and TARC-<40dB are well inside passable values. Greatest pick up of radio wire is 5.95dBi. Radiation productivity of 91%. All the over said highlights of MIMO antenna makes it reasonable for distinctive remote applications.

24: User Influence on Mobile Terminal Antennas: A Review of Challenges and Potential Solutions for 5G Antennas.

In this work, we examine single and MIMO terminal antennas for present and future 5G distant communication groups that take into account user engagement. It appears that the evolution of mobile spectrums towards 5G has largely influenced antenna operational requirements, and therefore their evolution patterns, from single-band to multiband, then MIMO to massive MIMO. The following are the paper's extreme points:

1. to draw attention to the many frequencies of a flexible terminal antenna for a variety of applications

2. to showcase the versatility of terminal antennas designed for 5G applications

3. to think about and discuss the effects of users' actions

3rd Chapter-Methodology

3.1 Methodology

Methodology is the organized, hypothetical examination of the methodologies associated to a field of think about. It consolidates the speculative examination of the body of methodologies and lessons related to a division of data. Customarily, it incorporates concepts such as standard, hypothetical demonstrates, stages, and quantitative or subjective strategies for exploration [51]. Strategy can be said a set of sharpens or techniques. This term may be utilized to imply to sharpens which are broadly utilized over an industry or consistent instruct, the procedures utilized in a specific ask around think almost. Be that because it may, a procedure does not set out to bear solutions— it is subsequently, not the same as a technique. Instep, a methodology deals with the hypothetical support for understanding which methodology or set of procedures can be commonsense to a particular case.

3.2 Research Design

: The investigation plan is a strategy that has been designed to find solutions to the inquiry about questions. A work plan tracks the assets of a research project, such as the research address, subordinate and autonomous elements, exploratory strategy, and, if applicable, data gathering techniques and a factual examination plan. For this inquiry, enquire about design.

- Study on evolution towards 5G.
- Study on antenna requirements for 5G.
- Select 5G millimeter wave band.
- Study literature on Dual Band MIMO Antenna and existing 5G antennas.
- Study procedure of Dual Band MIMO Antenna design.
- Study antenna design process in CST Microwave Studio.
- Calculate essential parameters to design antenna.
- Discover best substrate material
- Discover best substrate height
- Discover best feeding technique
- Implement the process.

3.3 Plot Study

A pilot study may be a investigate think about appeared some time recently the expecting consider. Pilot thinks about are ordinarily executed as arranged for the aiming consider, but on a smaller scale. In spite of the fact that a pilot consider cannot expel all precise mistakes or startling issues, it diminishes the probability of making a Sort I or Sort II error. Both sorts of mistakes make the most consider a squander of exertion, time, and cash.

3.3.1 Importance of Pilot Study:

There are many important of a pilot study before implementing the main study. Here are a few good reasons:

- To test the inquire about prepare and/or convention. These are regularly alluded to as possibility thinks about since the pilot think about tests how conceivable the plan is in reality.
- To recognize factors of intrigued and choose how to operationalize each one.
- To test a mediation methodology and recognize the components that are most imperative to the assistance of the mediation.
- To test methodological changes to usage or organization of an instrument and/or prepare work force on the organization of disobedient.
- To create or test the adequacy of investigate disobedient and conventions.
- To assess measurable parameters for afterward examinations. Certain factual investigations require the test measure is adequately expansive and contains sufficient inconstancy to distinguish contrasts between bunches, given there any genuine contrasts to be recognized.

3.4 Software

Software is a collection of instructions and data that tells a computer how to operate. In contrast to physical equipment, which is used to construct the framework and actually does the work. A computer program is all data generated by computer frameworks, counting programs, and information in computer science and computer program design. Computer programs, libraries, and associated non-executable material, such as online documentation or digital media, are all included in a computer program. Computer hardware and software are inextricably linked, and neither can be used effectively without the other.

3.4.1 CST Software:

CST Studio Suite is a high-performance 3D electromagnetic (EM) investigative software package for designing, evaluating, and improving EM components and frameworks. CST Studio Suite contains electromagnetic field solutions for applications in the EM range in a single client interface. Engineers may use the solvers to do half breed recreations, allowing them to examine whole frameworks made up of several components in a productive and transparent manner. Co-designing with others allows EM recreation to be integrated into the plan stream and drives development management from the earliest stages. The execution and prod are two common subjects of EM research.

3.5 Objective of Research

o To design a dual-band MIMO antenna for 4G & 5G Applications.

o To simulate the designed antenna in CST.

o To validate the simulated antenna by comparing with existing antennas in various literature

3.6 Design Procedure

The system circuit board was chosen to be 130mm * 74mm in size, which is suitable for a 5-inch smartphone. The side-edge outline and the framework circuit board are both made from a 0.8-mm-thick FR4 substrate with a relative permittivity of 4.4 and a loss digression of 0.02. The antenna's radiation portion may be divided into two sections: the front radiation portion is a bending line monopole, and the rear radiation portion is an L-shaped short-circuit stub. The bent line structure is obtained by the monopole, and the coupling capacitance created by the L-shaped department behind it makes a difference in matching the impedance of the moo repetition band so that the low frequency can cove. The front feeder belt and monopole lengths echo about 4.9 GHz, and the coupling capacitors formed by the back L-shaped branches and the front twist line contribute to high frequency impedance coordination. The position of the port has been altered. As a result, we have strong reflection and transmission co-efficients.

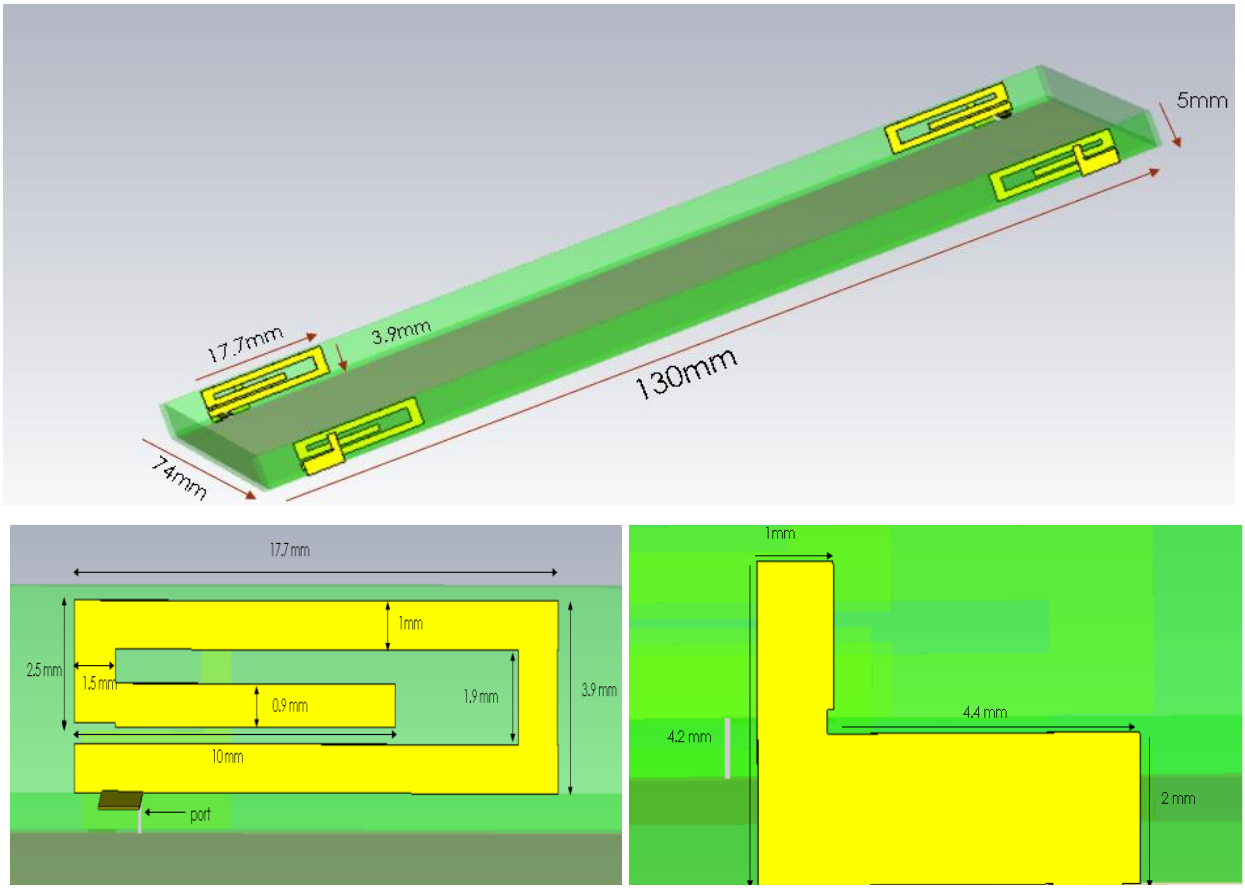

Fig – Design Procedure of Antenna

3.7 Antenna Substrates

. The first stage in antenna design is to select a suitable dielectric substrate with the right thickness (h). To advance electrical and mechanical soundness, dielectrics are used. They are used to reduce the antenna's size and aid in the creation of uprooting current, which generates a time shifting Attractive Field (according to Ampere's Law). By Faraday's law, this time shifting Attractive Field may provide a time shifting Electric Field, resulting in a proliferating electromagnetic field. A substrate can increase the radio wire's radiation capacity in this way. They're used to make the antenna's size smaller (greater permittivity, smaller size). They are utilized to diminish the measure of the antenna (higher permittivity, lower measure) and can offer assistance to create relocation current which produces time shifting Attractive Field (by Ampere's Law). This may in turn deliver time changing Electric Field (by Faraday's law) and a proliferating EM field is made.

4th Chapter- Simulations and Results' Analysis

The findings obtained after performing simulation of the proposed antenna are given and discussed in this chapter.

4.1 Simulation Results of MIMO Antenna

In this section, the performance metrics of the proposed MIMO antenna are analyzed. The antenna design is evaluated based on the basic parameters of the MIMO antenna. The distribution of return loss, radiation pattern, VSWR and 3D–gain. Antenna parameters are analysis at different resonating frequencies (3.3-3.6GHz, & 4.8-5 GHz). The resonating frequency 3.3-3.6GHz and 4.8-5 GHz are chosen for low band & high band respectively and those frequencies used for 4G & future 5G applications.

4.2 Result analysis on different substrate elements

This antenna is mainly designed one substrate elements that is FR-4_epoxy_1. By observing the results of antenna designed with the substrate elements described above, the bandwidth measuring 233MHz at 3.3-3.6GHz and 109MHz at 4.8-5GHz. Here the extracted reflection coefficient with a variable distance. The reflection coefficient at the center frequency is still lower than -10dB. The larger dB of reflection coefficient is measuring -12.3dB at 3.3-3.6GHz which is low band and -36.4dB at 4.8-5GHz which is high band frequency.

4.3 Simulation Results

The antenna design is evaluated based on the basic parameters of the MIMO antenna, distribution of return loss, VSWR, 2D radiation pattern, 3D radiation pattern and antenna efficiency. The result parameters of antenna array are discussed at both frequency of operation 3.3-3.6GHz and 4.8-5GHz. Bandwidth is the difference between the upper and lower frequencies in a continuous band of frequencies. We have basically got two bandwidths in the output of this design. Here, A view of the bandwidth and S11 parameter at 3.3GHz - 3.6GHz is shown in Figure 4.1. and S11 parameter views for 4.8GHz - 5GHz is shown Figure 4.2.

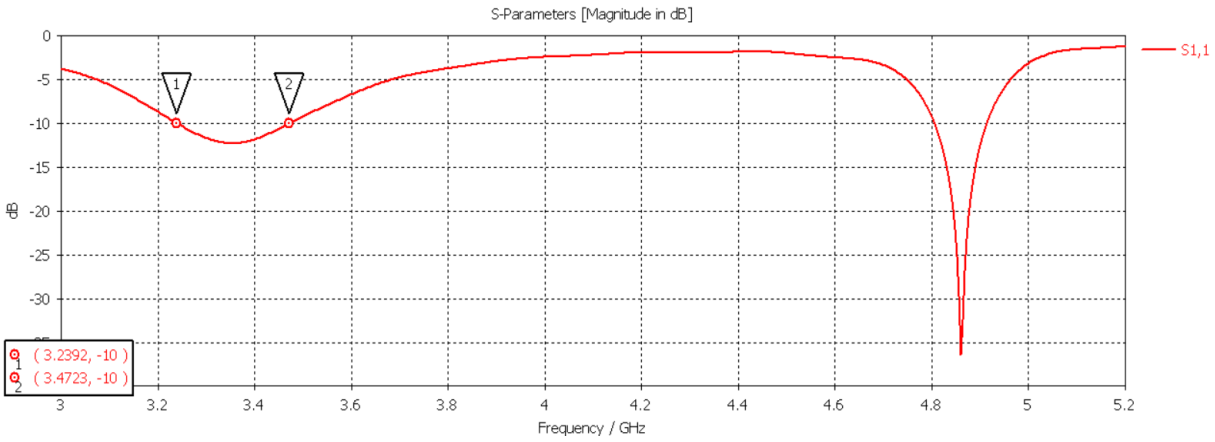

Figure - 4.1- Bandwidth at 3.3-3.6GHz

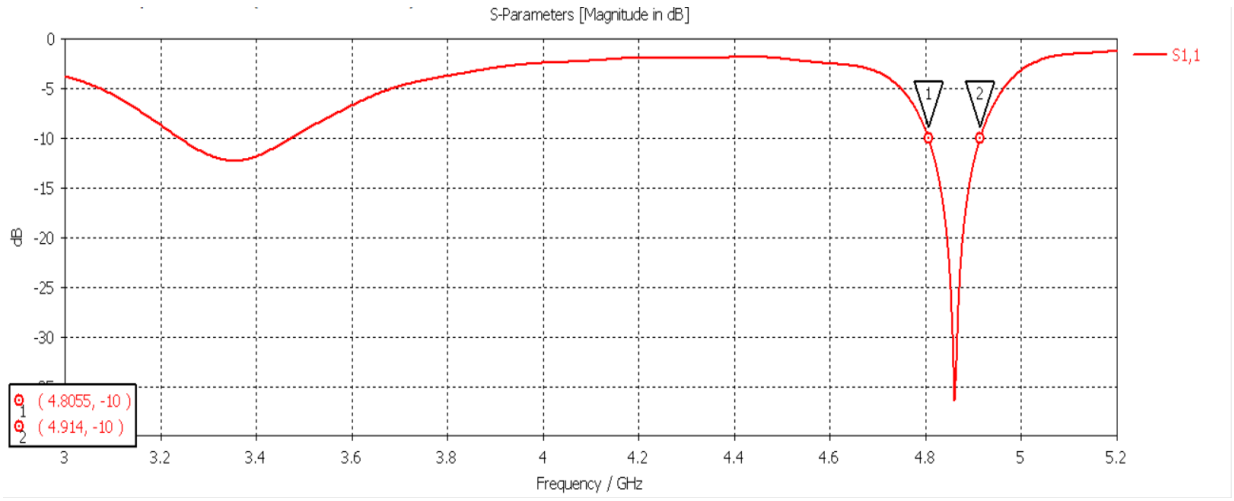

Figure - 4.2- Bandwidth at 4.8-5GHz

VSWR

Tha VSWR (Voltage Standing Wave Ratio) is always a real and positive number for antennas. Th minimum VSWR is 1.0For a standard reliable communication, the VSWR needs to be in between 1& 2 in our case this simulation results shows that the design final result around 3.3-3.6GHz & 4.8-5GHz are respectively around 1.68 & 1.15. The smaller the VSWR is the better the antenna is matched to the transmission line and the more power is delivered to the antenna.

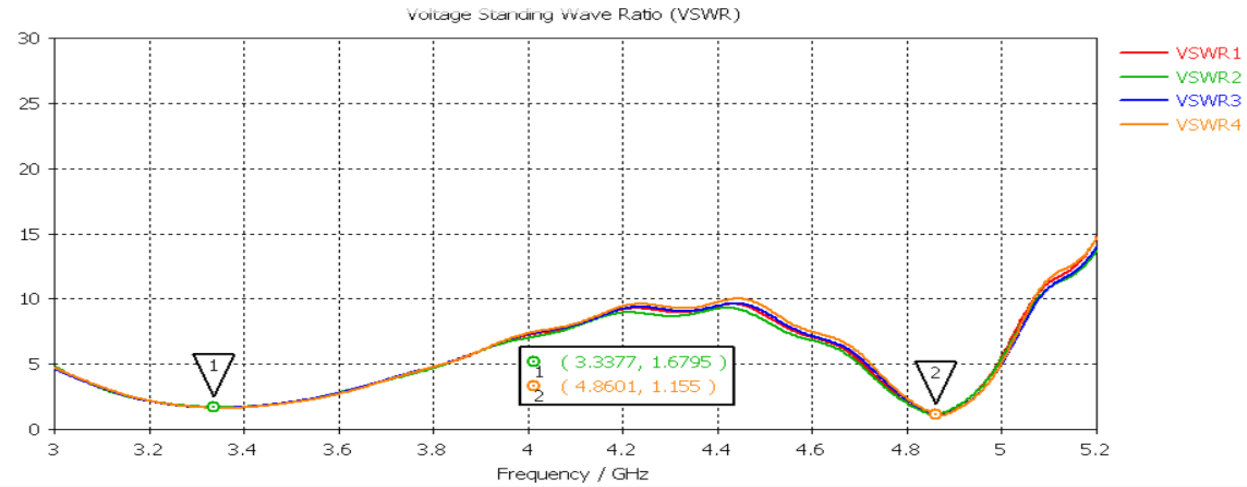

Figure 4.13 - VSWR plot of the final design antennas at 3.3-3.6 GHz and 4.8-5 GHz

Finally, it can be said that the antenna designed by the Fr-4 epoxy_1 material covers the 4G & 5G. Therefore, Fr-4 epoxy_1 is selected as the substrate material for designing the antenna at both frequency of operation.4.4 Result analysis on different technique.

Reflection coefficient and Transmission coefficient

The simulation S parameters (reflection coefficient and transmission coefficient) of the MIMO antenna are shown in Figure 4.9(a) & Figure 4.9(b). Total simulation results after optimization of final design of antennas for 3.3-3.6 GHz and 4.8-5 GHz are presented in the table. Those antennas indicate good return loss through the whole 3.3-3.6 GHz and 4.8-5GHz band. In the following figure.4.9. The return loss graph is shown for both frequency operation 3.3-3.6 GHz and 4.8-5 GHz. Reflection coefficient s S11, S22, S33, S44 of four antennas are less then -10dB in the desired frequency range of 3.3-3.6GHz and 4.8-5GHz. The reflection coefficients of the antenna are around -12.63dB & -38.18dB in figure 4.9 is shown for both 3.3-3.6 GHz and 4.8-5 GHz respectively. The resonating frequency 3.35GHz and 4.86GHz are chosendue to its low return loss behaviour.

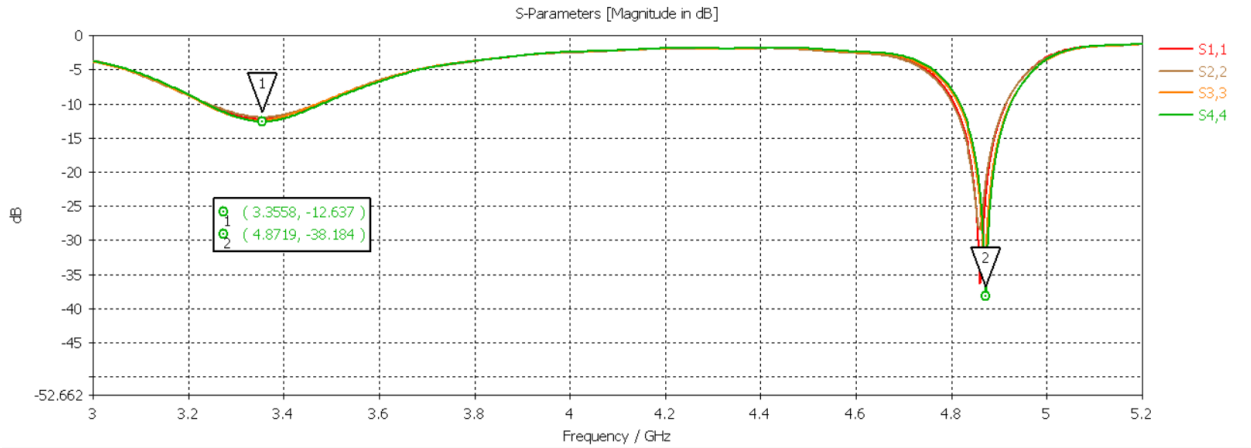

Figure 4.9(a) - Return loss plot of the final design antennas at 3.3-3.6 GHz and 4.8-5 GHz

Fig4.9(b) shows the transmission coefficient of the antenna. The obtained S12 and S34 are better than -15.65dB at frequency level 3.3-3.6GHz and -24.67dB at frequency level 4.8-5GHz. In other words, between these two frequency ranges transmission coefficient is better at 3.3-3.6GHz.

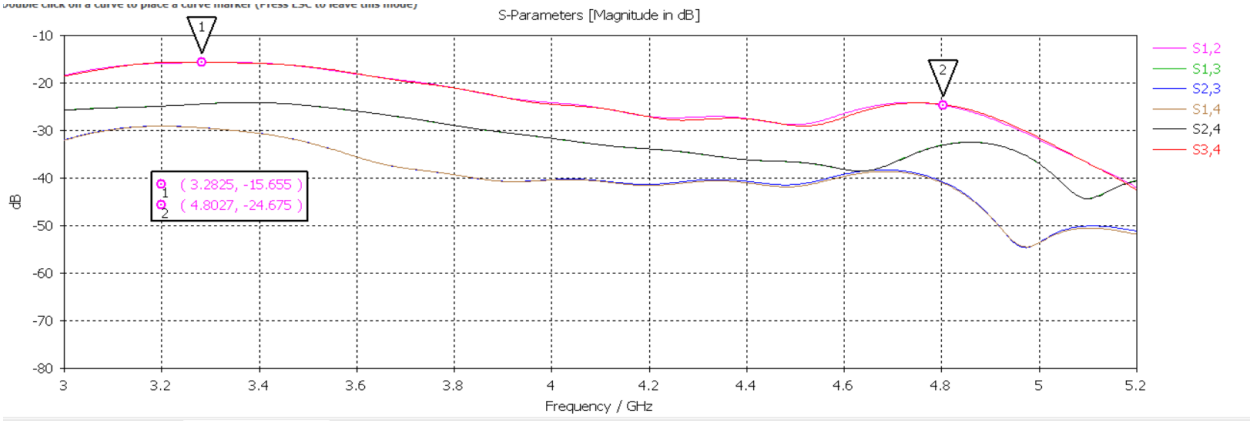

Figure 4.9(b) - Transmission coefficient plot of the final design antennas at 3.3-3.6 GHz and 4.8-5 GHz

Directivity & Gain

The directivity of an antenna is the ratio of the maximum power density P(θ,φ)max to its average value over a sphere as observed in the far field of an antenna. The directivity of this antenna using FR-4 lossy as substrate is 5.43 dBi at 3.3 GHz -3.6 GHz and 6.3 dBi at 4.8 GHz -5 GHz. The values of the directivity of low band and high band frequency are greater than 1. It is normal to refer to the directional patterns and gain in terms of the transmitted signal. Gain of the antenna is quite good compared to the recent designs. Gain around 4.53 dBi at 3.3 GHz -3.6 GHz and 2.64 dBi at 4.8 GHz -5GHz are obtained by the antennas. Those antennas directivity is around 5.43 dBi at 3.3 GHz -3.6 GHz and 6.3 dBi at 4.8 GHz -5 GHz which indicates good directional performance. Also, the 3D and polar plot of radiation pattern at both around 3.3 GHz -3.6 GHz and 4.8 GHz -5 GHz are shown in figure 4.10, 4.11, 4.12, 4.13 4.14 and 4.15 respectively.

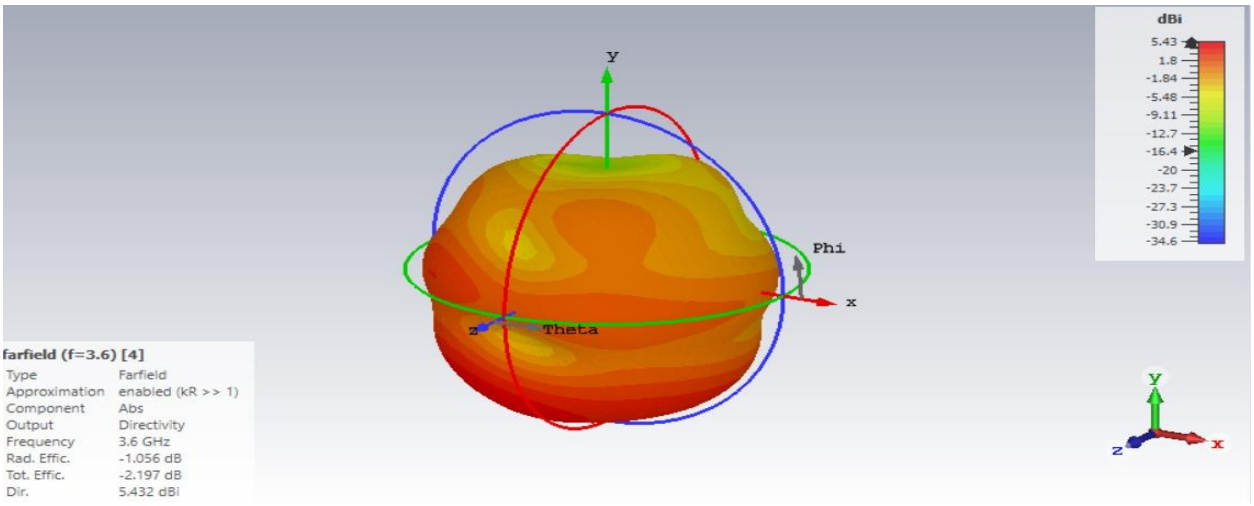

Figure 4.10- 3D radiation pattern plot of the final design antennas at around 3.3-3.6 GHz (Directivity)

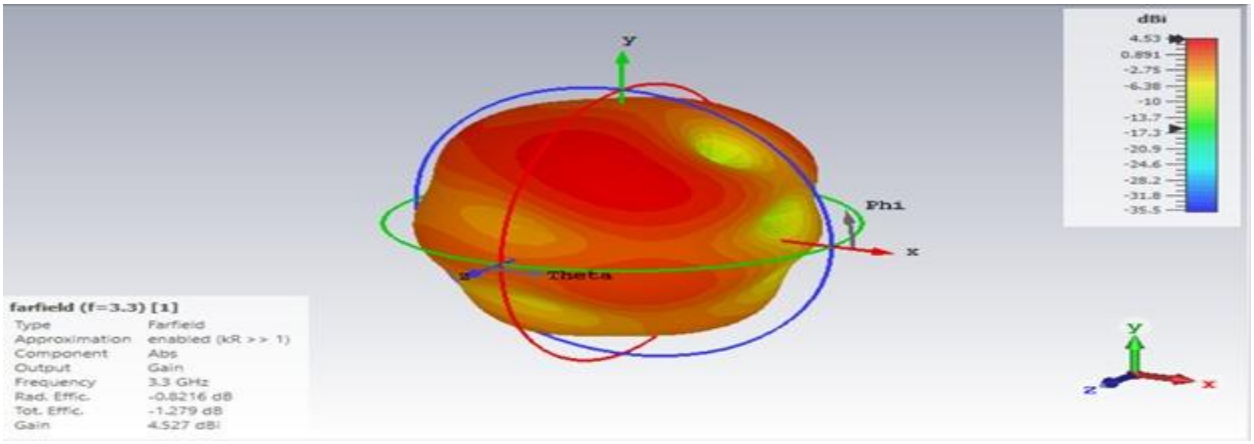

Figure 4.11- 3D radiation pattern plot of the final design antennas at around 3.3-3.6 GHz (Gain)

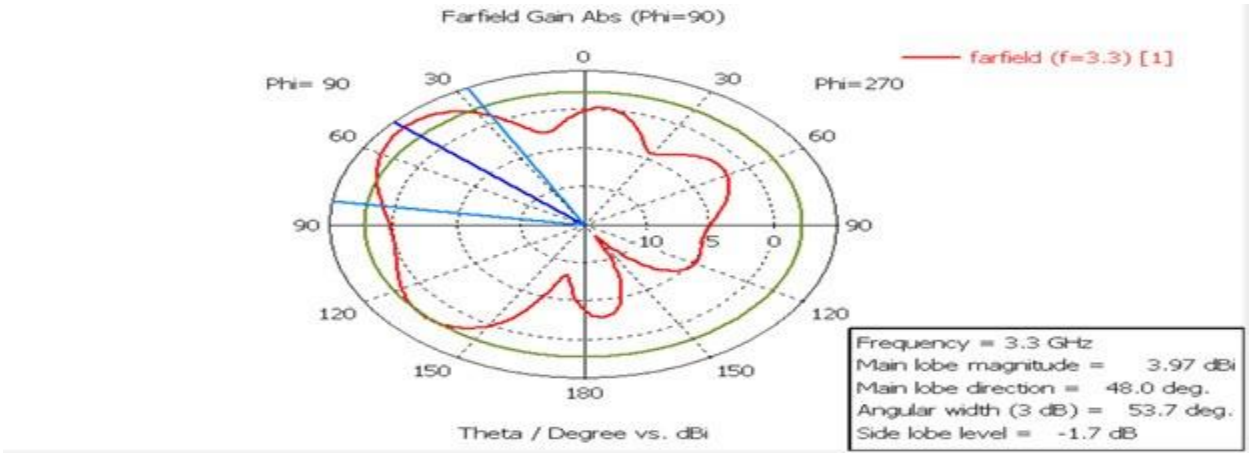

Figure 4.12. Polar radiation pattern plot of the final design antennas at around 3.3-3.6 GHz

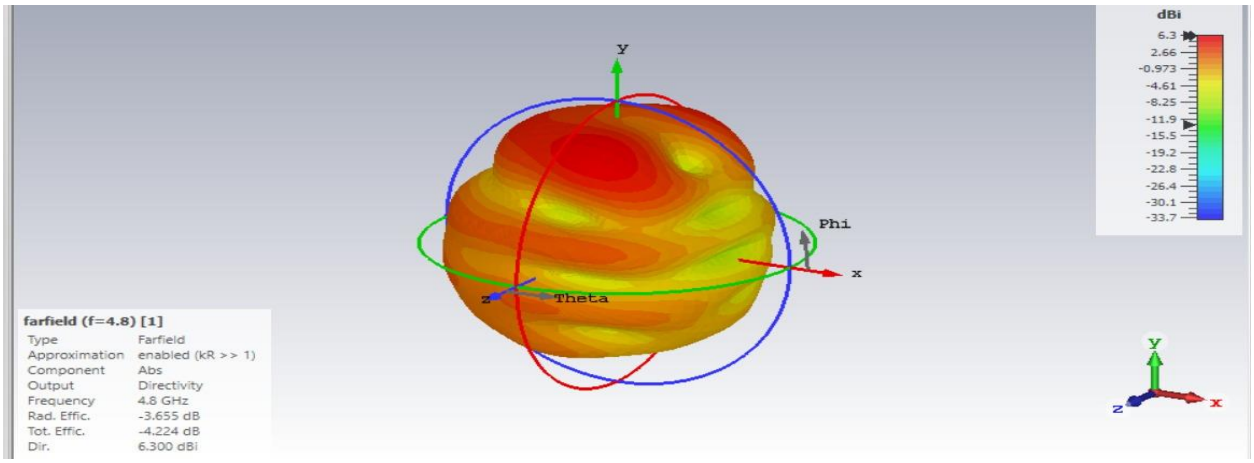

Figure 4.13- 3D radiation pattern plot of the final design antennas 4.8 - 5GHz (Directivity)

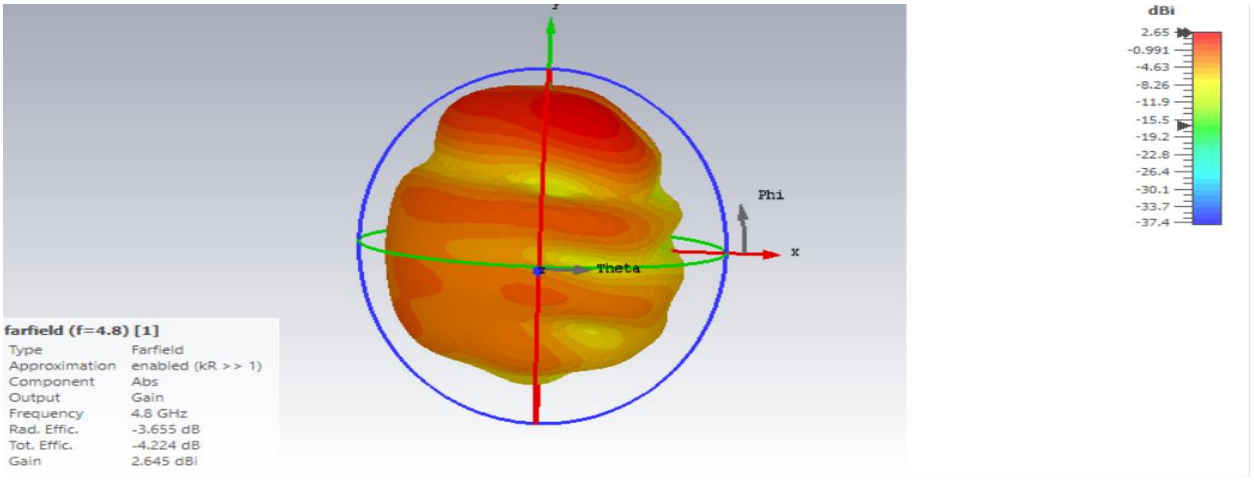

Figure 4.14- 3D radiation pattern plot of the final design antennas 4.8 - 5GHz (Gain)

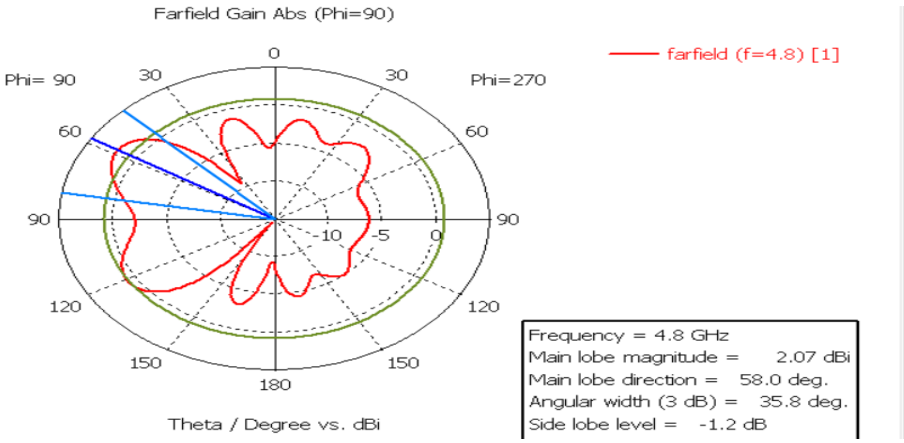

Figure 4.15- Polar radiation pattern plot of the final design antennas 4.8 - 5GHz

4.5 Final Design Result MIMO antenna

This antenna indicates good return loss through the whole 3.3-3.6 GHz band and 4.8 GHz - 5 GHz. Besides, the VSWR of both antennas is below than 1.68. Gain of the MIMO antenna is quite good compared to the designs. Directivity of antenna is 5.43 dBi at 3.3-3.6 GHz and 6.3 dBi at 4.8 GHz - 5 GHz are obtained by MIMO antenna. Those antenna directivities which indicates good directional performance.

4.3 Comparison with the existing single element

S/L	MIMO Antenna	S11 (dB) at 3.3-3.6 GHz, 4.8-5GHz	S22 (dB) at 3.3-3.6 GHz, 4.8-5GHz	S33 (dB) at 3.3-3.6 GHz, 4.8-5GHz	S44 (dB) at 3.3-3.6 GHz, 4.8-5GHz	Size(mm2) at 3.3-3.6 GHz, 4.8-5GHz	Transmission coefficient at 3.3-3.6 GHz, 4.8-5GHz
1	This research work	-12.28 dB & -36.38 dB	-11.98 dB & -28.25 dB	-12.45 dB & -33.15 dB	-12.63 dB & -38.33 dB	130mm * 74mm	-15.6dB & -24.6dB
2	Design of a Dual-band MIMO Antenna for 5G Smartphone Application	-10 dB & -11 dB	-10 dB & -12 dB	-10 dB & -11 dB	-10 dB & -11 dB	130mm * 74mm	-16dB & -24.9dB
3	Design of 6 × 6 Dual-Band MIMO Antenna Array for 4.5G/5G Smartphone Applications	-11dB & -10.9dB	-12dB & -11.2dB	-14.8 dB & -11.2dB	-13dB & -11dB	140 mm * 70 mm	-20dB & -14dB
4	Research and Design of a High Isolation 5G Antenna for Smart Phone	-17dB & -17dB	-15.8dB & -16.8dB	-15.8dB & -15.8 dB	-16.7dB & -14dB	150mm*80mm	-13dB & -12dB
5	Sub-6 GHz Dual-Band 8×8 MIMO Antenna for 5G Smartphones	-18dB & -15dB	-16dB & -15dB	-17dB & -15dB	-16dB & -14dB	70 mm*150 mm	-15dB & -16dB
6	A New Broadband MIMO Antenna System for Sub 6 GHz 5G Cellular Communications	-10dB & -15dB	-10dB & -15dB	-10dB & -15dB	-10dB & -15dB	75mm*150mm	-12dB & -20dB

In the following table 4.3(a) and 4.3(b), total simulation results after optimization of MIMO antenna are presented.

TABLE 4.3(a) - TOTAL SIMULATION RESULTS OF MIMO ANTENNA AT 3.3-3.6 GHZ

Parameters	**Value**	**Standard [10]**
Resonant Frequency	3.3-3.6 GHz	As per essential
Bandwidth	233MHz	As per essential
Return loss (S11)	-12.63 dB	less than -10 dB
VSWR	1.68	2 – 1
Gain	4.53 dBi	4-6dBi
Directivity	5.43 dBi	5-8dBi

TABLE 4.3(b) - TOTAL SIMULATION RESULTS OF MIMO ANTENNA AT 4.8-5 GHZ

Parameters	**Value**	**Standard [10]**
Resonant Frequency	4.8-5 GHz	As per essential
Bandwidth	109MHz	As per essential
Return loss (S11)	-38.18 dB	less than -10 dB
VSWR	1.15	2 – 1
Gain	2.64 dBi	4-6dBi
Directivity	6.3 dBi	5-8dBi

5th Chapter- Conclusion

The major goal of this project was to describe the MIMO antenna design based on 4G and 5G specifications. The rationale for this project was that the current antenna design meets the particular requirements of 4G and 5G. Four antenna design factors are used to make this job successful. For 5G smartphone applications, a dual-band (4 antenna) MIMO array is proposed. To construct a full-screen smartphone antenna, the suggested antenna is placed on the side frame. Following that, using those parameters, antennas constructed at 3.3-3.6GHz and 4.8-5GHz satisfied the 4G and 5G criteria and outperformed the prior work.

Achievements

In this thesis, a relatively high isolation was obtained while the antenna size was kept tiny, making it appropriate for today's ultra-thin smartphone communications. The proposed antenna operates at 3.3 GHz -3.6 GHz and 4.8 GHz -5GHz band with return loss below - 10dB. The VSWR of the simulated antenna is less than 1.68 through the whole frequency band which maintain the standard to exist between 1 and 2. The bandwidth of the antenna is around 233MHz. Gain is 4.53 dBi at 3.3 GHz -3.6GHz and 2.64dBi at 4.8 GHz -5 GHz which shows better result than the existing antenna.

Future Work

As we see that A.E in high band is low so our intention to increase it in higher band. From analysis of the those papers we propose that antenna is design on the top surface of circuit board. In future, need to reduce antenna losses (reducing conduction losses, dielectric losses) by using good substrate material like low temperature Co-fired Ceramic substrate has the advantage of low dielectric and conduction losses to increase efficiency.

Reference

[1] D. Liu, M. Zhang, H. Luo, H. Wen and J. Wang," Dual-Band Platform Free PIFA for 5G MIMO Application

[2] of Mobile Devices", IEEE Transactions on Antennas and Propagation, vol. 66, no. 11, pp. 6328- 6333, 2018.

[3] Available: 10.1109/tap.2018.2863109

[4] D. Liu, M. Zhang, H. Luo, H. Wen and J. Wang," Dual-Band Platform Free PIFA for 5G MIMO Application of Mobile Devices", IEEE Transactions on Antennas and Propagation, vol. 66, no. 11, pp. 6328- 6333, 2018. Available: 10.1109/tap.2018.2863109.

[5] X. Shi, M. Zhang, S. Xu, D. Liu, H. Wen and J. Wang," Dual band 8-element MIMO antenna with short neutral line for 5G mobile handset", 2017 11th European Conference on Antennas and Propagation (EUCAP), 2017. Available: 10.23919/eucap.2017.7928046.

[6] Xueliang Shi, Ming Zhang, Huailin Wen and Jun Wang," Compact Quadruple Band MIMO Antenna for 5G Mobile Applications", 12th European Conference on Antennas and Propagation (Eu CAP 2018), 2018.

[7] Available: 10.1049/cp.2018.0372

[8] L. Malviya, R. Panigrahi and M. Kartikeyan," MIMO antennas with diversity and mutual coupling reduction techniques: a review", International Journal of Microwave and Wireless Technologies, vol. 9, no. 8, pp. 1763-1780, 2017. Available: 10.1017/s1759078717000538.

[9] I. Nadeem and D. Choi," Study on Mutual Coupling Reduction Technique for MIMO Antennas", IEEE Access, vol. 7, pp. 563-586, 2019. Available: 10.1109/access.2018.2885558. [8] Z. Ding, T. Yao, X. Liu, X. Wang and Z. Liu," An Eight-Port Dual-Band Antenna Array for 5G Smartphone Applications", 2018

Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC), 2018. Available: 10.1109/csqrwc.2018.8455745.

[10] J. Guo, L. Cui, C. Li and B. Sun," Side-Edge Frame Printed Eight Port Dual-Band Antenna Array for 5G Smartphone Applications", IEEE Transactions on Antennas and Propagation, vol. 66, no. 12, pp. 7412- 7417, 2018. Available: 10.1109/tap.2018.2872130

[11] Z. Ying, C. Chiu, K. Zhao, S. Zhang and S. He, "Antenna Design for Diversity and MIMO Application. Handbook of Antenna Technologies," 2015.

[12] H. Xu, H. Wang, S. Gao, H. Zhou, Y. Huang, Q. Xu, and Y. Cheng, "A Compact and Low-Profile Loop Antenna With Six Resonant Modes for LTE Smartphone," IEEE Transactions on Antennas and Propagation, vol. 64, pp. 3743-3751, 2016.

[13] K. Wong, J. Lu, "3.6ü GHz 10ü antenna array for mimo operation in the smartphone," Microwave and

[14] Optical Technology Letters, vol. 57, pp. 1699-1704, 2015.

[15] K. Wong, J. Lu, L. Chen, W. Li, and Y. Ban, "8ü antenna and 16üantenna arrays using the quadü antenna linear array as a building block for the 3.5ü GHz LTE MIMO operation in the smartphone," Microwave and Optical Technology Letters, vol.58, pp. 174-181, 2016.

[16] Ban, C. Li, C. Sim, G. Wu, and K. Wong, "4G/5G multiple antennas for future multi-mode

[17] smartphone applications," IEEE Access, vol. 4, pp.2981-2988, 2016.

[18] http://www.3gpp.org/releases

[19] https://www.remcom.com/xfdtd-3d-em-simulation-software

[20] D. Gesbert, M. Shafi, D. S. Shiu, et al, “From theory to practice: an over- view of MIMO space-time coded wireless systems,” IEEE Journal on Selected Areas in Communications, vol. 21, no. 3, pp. 281-302, Apr. 2003.

[21] [2] Z. Li, Z. Du, M. Takahashi, K. Saito, and K. Ito, “Reducing mutual coupling of MIMO antennas with parasitic elements for mobile terminals,” IEEE Trans. Antennas Propag., vol. 60, no. 2, pp. 473-481, Feb. 2012.

[22] [3] M. Ikram, M. S. Sharawi, A. Shamim., and A. Sebak. “A multiband dual-standard MIMO antenna system based on monopoles (4G) and connected slots (5G) for future smart phones.” Microwave And Optical Technology Letters, vol 60, no 6, pp.1468-1476, 2019.

[23] [4] Q. Sun, B. Sun, L. Sun, W. Huang, and Q. Ren, “Broadband Two-Element Array With Hybrid Decoupling Structures for Multimode Mobile Terminals” Antennas and Wireless Propagation Letters, vol.14, pp.1431-1434, 2019.

[24] [5] S. Wang and Z. Du, “A dual-antenna system for LTE/WWAN/WLAN/WiMAX smartphone applications,” IEEE Antennas Wireless Propag. Lett., vol. 14, pp. 1443–1446, 2015.

[25] [6] J. Dong, X Yu, Deng L. “A Decoupled Multiband Dual-Antenna System for WWAN/LTE Smartphone Applications,” IEEE Antennas and Wireless Propagation Letters, vol. 16, pp.1528-1532,2017.

[26] [7] Z. An and M. He. “A Multiband Dual-Antenna System for MIMO Operation in Mobile Terminals,” Applied Computational Electromagnetics Society Journal, vol.34, no.10, pp. 1529-1534, Oct. 2019

[27] [8] K. Yu, Y. Li, X. Liu. “Mutual coupling reduction of a MIMO antenna array using 3-D novel meta-material structures,” Applied Computational Electromagnetics Society Journal. vol 33, no. 7, pp.758-763, 2018.

[28] [9] M.-Y. Li, Y.-L. Ban, Z.-Q. Xu, J. Guo, Z.-F. Yu, “Tri-polarized 12-antenna MIMO array for future 5G smartphone applications,” IEEE Access, vol. 6, pp. 6160-6170, 2018.

[29] [10] Y. L. Ban, C. Li, G. Wu, and K. L. Wong, “4G/5G multiple antennas for future multi-mode smartphone applications,” IEEE Access, vol. 4, pp. 2981–2988, 2016.

[30] [11] Y. Li, C. Y. D. Sim, Y. Luo, and G. Yang, “High-isolation 3.5 GHz eight antenna MIMO array using balanced open-slot antenna element for 5G smartphones,” IEEE Trans Antennas Propag., vol. 67, no. 6, pp. 3820–3830, Jun. 2019.

[31] [12] J. Li et al., “Dual-band eight-antenna array design for MIMO applications in 5G mobile terminals,” IEEE Access, vol. 7, pp. 71636–71644, 2019.

[32] [13] Y. Li, C. Y. D. Sim, Y. Luo, and G. Yang, “Multiband 10-antenna array for sub-6 GHz MIMO applications in 5-G smartphones,” IEEE Access, vol. 6, pp. 28041–28253, 2018.

[33] [14] L. Cui, J. Guo. and Y Liu. “An 8-Element Dual-Band MIMO Antenna with Decoupling Stub for 5G Smartphone Applications,” IEEE Antennas and Wireless Propagation Letters, vol. 18, pp. 2095-2099, 2019.

[34] [15] J. Guo, L. Cui, C. Li, and B. Sun, “Side-edge frame printed eight-port dual-band antenna array for 5G smartphone applications,” IEEE Trans. Antennas Propag., vol. 66, no. 12, pp. 7412–7417, Dec. 2018.

[35] [16] S. Blanch, J. Romeu, and I. Corbella, “Exact representation of antenna system diversity performance from input parameter description,” Electronics Letters, vol. 39, no. 9, pp. 705–707, 2003.

[36] [17] Kumar, N., Khanna, R. “A compact multi-band multi-input multi-output antenna for 4G/5G and IoT devices using theory of characteristic modes.” International Journal of RF and Microwave Computer Aided Engineering, vol.30, no.1, 2019.

[37] [18] Hallbjorner P. “The significance of radiation efficiencies when using S-parameters to calculate the received signal correlation from two antennas,” IEEE Antenna And Wireless Propagation Letters. vol. 4, pp. 97-99, 2005.