THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE IN COMPUTER SCIENCE & ENGINEERING

DESIGN AND DEVELOPMENT OF MINIATURIZED ULTRA-WIDEBAND (UWB) ANTENNA FOR 5G APPLICATIONS

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DECLARATION

WE HEREBY DECLARE THAT THE WORK IN THIS THESIS IS OUR OWN EXCEPT FOR QUOTATION AND SUMMARIES WHICH HAVE BEEN DULY ACKNOWLEDGED.

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ABSTRACT

Ultra-wideband (UWB) technology has been consumed as a promising wireless communication technology and wireless terminals for upcoming applications necessary to provide different services like fifth generation (5G) communication. The flourishing demand speeds up the necessity of antennas capable of covering ultra-wide and multiple bandwidths for various applications and connecting everything including devices, objectives and machines. 5G wireless technology is meant to deliver multi-Gbps data at high speeds, ultra-low latency, more reliability, large network capacity, enhanced availability and more similar user experience to all users. The design of the UWB antenna for 5G is quite challenging compared to its narrowband counterpart. A suitable antenna must have broad impedance bandwidth to cover the entire UWB range with erotic gain, stable radiation patterns and good time-domain behavior. The conventional 3D monopole antennas are not suitable for embedding in portable devices due to their large perpendicular ground plane which poses a challenge for designing compact UWB antennas. Here microstrip patch antenna is used for its low cost, low weight and ease fabrication. Two omnidirectional microstrip patch antennas for low and high frequencies are designed for 5G applications. The working range for low frequency is 6- 6.3 GHz. Whereas, the working frequency of high frequency single band antenna is 29.3- 30.3 GHz and dual band is 27.7-27.9 GHz and 37.5- 38.1 GHz. The achieved gain from the first prototype is 3.73 dB and 7.58 dB from the second prototype for single band and 8.11 dB achieved from the dual band antenna. FR-4 is used as substrate for having a low dielectric constant of 4.3 and copper is used for the ground plane. A 50Ω microstrip feed line is used to excite the patch. It has been observed all the antennas have satisfactory gain of more than 5.4 dBi, radiation efficiency of more than 88% and stable omnidirectional radiation patterns with low cross-polarization which makes them suitable for different UWB applications. The performance parameters like operating bandwidth, antenna size and area of application, dielectric constant, fractional bandwidth and omnidirectional radiation pattern proposed as a suitable candidate for 5G application. This proposed design is compact in size and can be integrated into limited space around microwave circuitry with low manufacturing cost. Therefore, the proposed prototype can offer good compact characteristics for 5G applications.

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LIST OF ABBREVIATIONS

1G	First Generation
2G	Second Generation
3G	Third Generation
3GPP	3rd Generation Partnership Project
4G	Fourth Generation
5G	Fifth Generation
AR	Augmented Reality
CST	Computer Simulation Technology
ETSI	European Telecommunications Standards Institute
et al.	(et alia): and others
FCC	Federal Communication Commission
FR1	Frequency Range 1
FR2	Frequency Range 2
Gbps	Giga Bit Per Second
GHz	Giga Hertz
GPS	Global Position System
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunication

IoT	Internet of Things
IP	Internet Protocol
ITU	International Telecommunication Union
LTE	Long-Term Evolution
MSA	Microstrip Antenna
NR	New Radio
PC	Personal Computer
PCB	Printed Circuit Board
RF	Radio Frequency
UV	Ultra-violet
UWB	Ultra-Wide Band
VR	Virtual Reality
VSWR	Voltage Standard Wave Ratio
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

With the beginning of the new age of information and communication technology, various advanced technologies for communication have expanded during the past few decades, which have significantly influenced and benefited human life. In particular, the wireless communication revolution that began with the invention of the telephone continued with the invention of the radio. It has been squatted to a whole new level by the introduction of new technologies such as cellular and satellite networks. The proliferation of communication systems such as the second generation (2G) and third-generation (3G) mobile communications, global position system (GPS), Wi-Fi, WiMAX, wireless Bluetooth and ultra-Wideband (UWB) systems have driven the wireless technology to the verge of revolutionary wireless communications. At present, wireless communication technology is extending quickly because of the expansion in the number of clients in terms of internet usage. Keep pace with the users connected devices with internet also increasing exponentially. It is another worldwide remote norm after its previous generation of 1G, 2G, 3G and 4GLTE communication technology. Lacking of feasible frequency resources consider the most affected factor in today’s wireless communication. The newly introduced fourth generation (4G) technology provides a comprehensive internet protocol (IP) arrangement where voice, information and streamed mixed media are offered to the clients whenever and anyplace, and at a higher information rate than previous ages. But it’s not enough to handle millions of connected devices at a time. For solving this problem, researcher concentrated on 5G wireless communication. 5G is referring the 5th generation mobile network. It is the latest global wireless communication system after 1G, 2G, 3G, and 4G networks. Lots of fields have implemented 5G technology with the IoT (Internet of things). One of the main goals of 5G is connecting millions of devices together. This future 5G technology can be used in smart cities, smart transportation, Augmented/virtual reality(AR/VR), remote health care, robotics and more. As the dependencies and the necessity are increased with the increasing number of internet users so higher multi-Gbps peak data speed, low latency, more reliable network, massive network capacity is needed which will be provided by the 5G network.

Comprehensively, 5G is utilized across three fundamental sorts of associated administrations, including enhanced mobile broadband, mission-critical communication, and massive IoT. A characterizing capacity of 5G is that it is intended for sending similarity—the ability to flexibly support future services that are dark now.

Enhanced mobile broadband

Despite making our phones better, 5G convenient development can present new distinctive experiences, for instance, VR (Virtual Reality) and AR (Augment Reality) with snappier, more uniform data rates, lower inaction, and lower cost-per-bit.

Mission-critical communications

5G can engage new organizations that can change adventures with super dependable, accessible, low-inaction joins like remote control of critical infrastructure, vehicles, and clinical techniques.

Massive IoT

5G is planned to reliably associate a monstrous number of installed sensors in essentially everything through the ability to cut back in information rates, force, and portability—giving amazingly lean and ease availability arrangements.

At first, the term was related with the International Telecommunication Union's (ITU) IMT-2020 (International Mobile Telecommunication) standard, which required a theoretical peak download speed of 20 Gbps and upload speed 10 Gbps, alongside different necessities. The principal period of 3GPP 5G particulars in Release-15 is planned to finish in 2019. The second stage in Release-16 is expected to be finished in 2020. 5G NR (New Radio) can include lower frequencies (FR1), below 6 GHz, and higher frequencies (FR2), above 24 GHz. Notwithstanding, the speed and latency in early FR1 arrangements, utilizing 5G NR programming on 4G equipment (non-independent), are just somewhat superior to new 4G frameworks, assessed at 15% to 50% better.

Antennas are fundamental components of any wireless communication system. For UWB communication systems, the antennas must be of low profile, compact size, light weight, low cost and suitable to the architecture of the mounting devices. Amongst different types of antennas such as log periodic, wire, traveling wave, apertures, reflectors, microstrip, the antenna with microstrip patch seems to be the most preferred choice. It has the benefit of a low profile in size, compactness, and easily embeddable into wireless devices or conjugated with other RF circuitry. In this thesis, two types of antennas have been designed in order to meet the requirements of both low and high band of 5G antennas. All of these antennas are measured, simulated and discussed in details with a comprehensive parametric study.

1.2 MOTIVATION

The UWB innovation has encountered numerous noteworthy improvements in recent years especially in 5G wireless communication as the demands of 5G is increasing continuously. In any case, there are quiet difficulties in making this innovation satisfy its maximum capacity. One explicit challenge is the UWB antennas.

The principle challenge in the UWB antenna design is accomplishing the wide impedance bandwidth while as yet keeping up stable radiation characteristics. Traversing 7.5 GHz, just about a time of recurrence, this data transfer capacity goes past the regular meaning of a wideband reception apparatus. UWB radio wires are ordinarily needed to accomplish a data transmission, which arrives at more than 100% of the inside recurrence to guarantee an adequate impedance coordinate. This coordination is accomplished all through the band with the end goal that a force loss of under 10% because of reflections happened at the radio wire terminals.

Among the classical broadband antenna configurations used in UWB systems, a straight wire monopole features contains a simple structure, but low bandwidth around 10%. A Vivaldi radio wire is a directional reception apparatus and consequently unacceptable for indoor frameworks and portable devices. A big size of biconical antenna which limits its application[36]. Log periodic and spiral antennas tend to be dispersive and suffer severe ringing effects, apart from big size. Stacked patch antennas though achieved a wider bandwidth; it is not suitable to be used in portable devices due to its perpendicular ground plane. There is a developing interest for small and ease UWB antenna for 5G that can give satisfactory performances.

Therefore, microstrip or patch antennas are turning out to be progressively useful in light of the fact that they can be printed directly onto a circuit board. Microstrip antennas are getting far reaching inside the cell-phone market. Patch antennas are low cost, low profile and can ease fabrication. In this thesis, the rectangular shape microstrip patch antenna is comprehensively studied in order to examine the ground plane effect on antenna performances, understand its operation and to know the mechanism that leads to the UWB characterization. Based on the understanding of the ground plane modified rectangular shape patch is proposed. A S-shape double slot antenna, which has a relatively large magnetic field is also proposed and studied for UWB applications.

On the other hand, an RF system of antennas with other function blocks could encourage advancing the entire communication system performance. If an optimized antenna impedance is acquired for co-designing at certain frequencies, it is as yet hard to assess the system performance in a wide bandwidth. The antenna scattering parameter can be used in the frequency co-simulation for the circuit design, but it would not be valid in the time-domain co-simulation with mixed analog/digital integrated circuits. Therefore, the need to have wideband modeling of UWB antennas is increased as the design complication of the RF system increases.

1.3 SCOPE OF RESEARCH

Antenna design for UWB applications is facing tremendous difficulties because of its wide working bandwidth and size is one of them for handheld devices because the size of the antenna essentially influences the impedance bandwidth and gain[37]. As the demand of 5G is increasing significantly for its high-speed data rate. Hence the high-speed data rate achieved by wide bandwidth but the reliability of the network may interrupt for wide bandwidth. Also, the range will be limited for higher frequency which is used in 5G antennas. Therefore, minimize antennas that are fit for accomplishing ultra-wide impedance bandwidth with stable radiation patterns, satisfactory gain and good efficiency is as yet a challenging task for antenna designers.

Several types of antennas have been proposed for UWB applications and among them, microstrip patch antennas printed on a piece of PCBs become very popular as they can be easily fabricated into wireless devices or integrated with other RF circuitry. The microstrip antennas had been considered apparently for the term of the last decade. These antennas specially consist of a metallic patch exposed on a dielectric substrate over a ground plane, giving many advances which include simplicity of layout and fabrication, low profile. Currently, with the various changes of new guidelines and complex Wi-Fi devices, there is essential to lessen the presence of these kinds of microstrip fix receiving antennas. These smallness strategies involve varying the shape of the antenna, material inserting, folding, inserting slots and defects inside the ground plane. There are lacking of varying sizes and shapes in the ground plane of a patch antenna improves the methodical parameters like VSWR, return loss, performance and so on. This has been completed by utilizing investigating and testing by methods for slicing different shapes of defects inside the ground of the antenna. For all the above, microstrip patch antennas are recommended. The performance and features of microstrip antennas include cost, cheapness, compactness, less weight made them the most wanted for communication systems engineers. A unique layout of mm-wave microstrip patch antenna in broadband for devices like mobile has acquired different changes the 5G communication system. Thus in order to reduce the ground plane effect on the antenna characteristics and high cross-polarization levels as well as to achieve wide impedance bandwidth, it is necessary to introduce new techniques to achieve the best performances in the UWB operating bandwidth.

Though 5G technology is authorized to operate in the range of frequency lower than 10 GHz for low frequency and 28 GHz to 38 GHz for high frequency, some strong signals from other existing wireless communication systems may interrupt the performances of the system. The slot will be used for improving the performances such that VSWR, low return loss, high gain, high efficiency and so on of the patch antenna.

1.4 OBJECTIVES

The main objective of this research is to design and analysis planar antennas in microstrip technology using commercially available electromagnetic field solvers. The proposed antennas have the ability to tune over low frequency band (3.1 – 10.6 GHz) and high frequency (28 - 38 GHz) as well as can capable of avoiding interference with current WiMAX and WLAN band with indent qualities. The specific objectives of this research can be listed as follows:

1. To design and analyze small, planar, high gain & omnidirectional UWB microstrip patch antenna for 5G applications.
2. To fabricate and measure the proposed antenna.
3. To analyze the performance of the proposed antenna prototype for 5G applications.

1.5 OUTLINE OF THE THESIS

This thesis is coordinating into Six chapters as follows:

Chapter 1 presents the commencement of the thesis. The problem and research motivation are described in this chapter. The research objectives of the thesis are also outlined.

Chapter 2 gives a brief introduction to UWB technology for 5G antenna design. The history of UWB and the idea of innovation is reviewed. The regulations and standards of UWB and 5G as well as its points of interest and applications are likewise talked about. A comprehensive review of the fundamental antenna theory is also described afterward. The key necessities for a suitable 5G antenna and some general techniques to achieve wider impedance bandwidth are also discussed. The research on UWB antennas for 5G is also reviewed historically in this chapter.

Chapter 3 explains the sequential phases of designing a UWB antenna. The flow chart of the research methodology is defined in detail with suitable equations and photos. The precise representation of the simulation and measurement process is an effort to give a complete idea of designing and prototyping of UWB antennas.

Chapter 4 presents the design and simulation of Low frequency microstrip patch antenna. Simulated result for different time domain parameters analyzed with proper photograph and included in the table.

Chapter 5 presents the design and simulation of high frequency microstrip patch antenna for single as well as dual band. The frequency and domain performances of electrical (rectangular shape with slot and without slot) and magnetic (rectangular shape with S slot) antenna are discussed details in this chapter. Photograph of simulated result for various parameter were attached. Also, the simulated result for antenna showed in the table and compared as well.

Chapter 6 presents the concluding remarks of the research that has been done in this thesis. The key contributions in this research are featured. Proposals for future work are likewise given in this section.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

The elementary target of this research work to design a microstrip patch antennas for ultra-wideband (UWB) in 5G applications. Prior to beginning the design procedure, it’s better to give an overview of UWB technology and its fundamentals, including definition, standards, regulations, advantages and applications. In design procedure some fundamental parameters need to be considered such as bandwidth, VSWR, return loss, gain, efficiency and radiation patterns are also described in this chapter. At the same time, the essential requisition for a suitable 5G antenna and general methods to accomplished ultra wide bandwidth are addressed. Some exemplary 5G antenna designs are also critically overviewed to determine the potential solutions of the microstrip patch antenna.

2.2 ULTRA-WIDEBAND (UWB) TECHNOLOGY

After the Federal Communication Commission (FCC's) approval of frequency band of 3.1 to 10.6 GHz with power spectral density restrict of -41.3 dBm/MHz for unlicensed radio applications, UWB innovation become the most encouraging contender for a wide scope of new applications that will give noteworthy advantages to public wellbeing, business and purchasers and pulled in a ton of consideration both in industry and educational sector (FCC 2002).These application includes WLAN(wireless local area network), WPAN(wireless personal area network), WBAN(wireless body area network), wireless sensor network, high precision radars and imaging systems.

Many industry observers guarantee that UWB demonstrate more effective than Bluetooth for its prevalent speed, less expensive, consume low power, more secure and gives unrivaled area revelation and device ranging. Organization such as Intel, Google, Microsoft, Tesla, Time Domain, Apple, Huawei, Samsung, Xiaomi, Sony and Xtreme Spectrum are investigating and putting resources into UWB innovation. Actually, Apple already provides UWB chips in its iPhone 11 for enabling high accurate positioning and ranging through "Time of Flight" measurement and the new series of iPhone 12 support 5G.

2.2.1 BACKGROUND

Within the mid evening of Apr 14, 1912, the R.M.S. Titanic sent a distress message. It had just hit an iceberg and was sinking. Even though broadcasting an emergency wireless signal is common today, this was cutting edge technology at the turn of the 20^{th} century. This was not possible without the invention of a broadband radio developed over the previous 20 years: the spark-gap transmitter. Developed by Heinrich Hertz in the 1880s, the spark-gap radio was improved by Guglielmo Marconi who succeeded in sending the first radio wave throughout the Atlantic Ocean in 1901. However, by 1924, Spark Gap radios were prohibited in maximum programs because of their strong and interference to narrowband (continuous wave) radio systems.

The introduction of wideband radio at the turn of the twentieth century however super heterodyne radio slaughtered wideband radios for informing after 1920. Yet, RADAR kept wideband examination alive through World War 2 and the Cold War. Undoubtedly, the narrative of wideband radios was not finished. The advantages of super wideband (UWB) turned out to be more evident as interest for remote correspondences developed in the 1990s. Be that as it may, business sending of UWB frameworks required overall concurrence on recurrence distributions, consonant and force limitations, and so forth. As enthusiasm for the commercialization of UWB expanded, designers of UWB frameworks started constraining the FCC to affirm it for business use. In 2002 the Federal Communication Commission (FCC) at long last permitted the unlicensed utilization of UWB frameworks. The European Telecommunications Standards Institute (ETSI) followed a couple of years after the fact with their own guidelines, shockingly somewhat not quite the same as the FCC guideline. Different areas followed, frequently lining up with FCC or ETSI.

UWB frameworks utilize brief length (for example picoseconds to nanosecond) electromagnetic heartbeats for transmission and gathering of data. They additionally have a low obligation cycle, which is characterized as the proportion of the time that motivation is available to all-out transmission time. In light of emanation guidelines set during the 2000s, a UWB signal is characterized as a sign having a range bigger than 500 MHz Most nations have now concurred on the greatest yield power for UWB, characterized as - 41.3 dBm/MHz

With guidelines currently set up, a coalition of organizations began to frame so as to normalize the physical layers and media access control (MAC) layers. In 2002 the WiMedia Alliance was framed which was a non-benefit industry exchange bunch that advanced the appropriation, guideline, normalization and multi-merchant interoperability of UWB innovations. It was followed, in 2004, by the Wireless USB Promoter Group and the UWB gathering.

So as to comprehend the decisions made by these collisions, we ought to contextualize them. In 2002, WiFi was a generally new innovation. A 802.11b switch, accessible since 1999, had a hypothetical greatest speed of 11 Mbit/s utilizing the 2.4 GHz recurrence band. The 802.11a norm, additionally characterized in 1999 and promising a hypothetical most extreme speed of 54 Mbit/s in the 5 GHz band, was not getting a foothold in the purchaser space fundamentally because of its higher chipset cost. In 2003, the 802.11g standard was presented, giving a hypothetical greatest speed of 54 Mbit/s in the 2.4 GHz band. Despite the fact that the 802.11g standard end up being an incredible achievement, the information rate was as yet restricted by the packed 2.4 GHz band, which was the foundation of remote LANs at that point, and furthermore microwaves and very much showcased (a.k.a. more difficulty than they were worth) cordless telephones!

In the history of UWB, a significant change took place in February 2002, when the US FCC issued the decisions that provided the first radiation limitations for UWB transmission and allowed the operation of UWB devices on an unlicensed basis (FCC 2002). According to the part 15 of FCC rules, UWB is defined as any wireless system that occupies either an absolute bandwidth of more than 500 MHz or a fractional bandwidth greater than 20%. FCC has also permitted 3.1 to 10.6 GHz unlicensed frequency band with restricted transmission power of -41.3 dBm/MHz for the UWB radio transmission as shown in Figure 2.1.

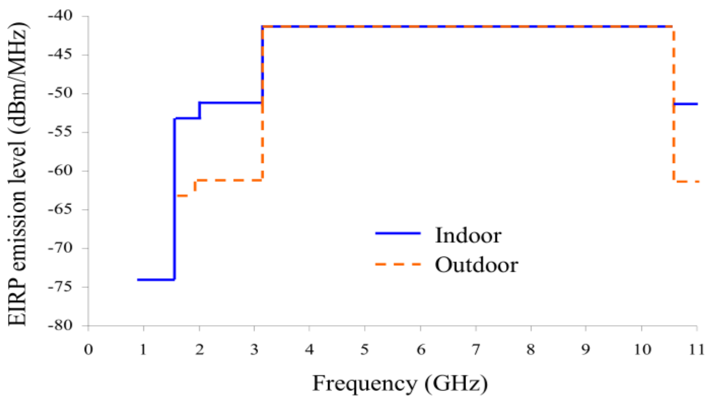


Figure 2.1 UWB spectral mask and FCC part 15 limits

Source: FCC 2002

Unlike the conventional narrow band systems, UWB systems uses short pulse which reduce the cost and power for transmission in ultra-wideband spectrum. A UWB signal covers an area of large bandwidth where the Radio Frequency (RF) energy is spread over a vast spectrum. It is wider than any other occupant narrowband remote system by significant degrees and its discharged force seen by other narrowband frameworks is very small amount of power. If the entire 7.5 GHz band is used ideally, the maximum possible power for UWB transmitters is approximately around 0.556 mW. This is hardly a small amount of available transmit power in the mechanical, scientific and medical (ISM) bands. This adequately limits the UWB plan to indoor and short-range interchanges at high information rate or mid-range correspondences at low information rate. Applications such as wireless USB and WPANs have been proposed with hundreds of Mb/s to more than a few Gb/s with distances ranging from 1-4 meters and around 100-500Mb/s in the range of 10 meters. For ranges beyond 20 meters, the attainable data exchange rate by UWB is mediocre to existing WLAN framework [38].

2.2.2 REGULATIONS AND STANDARDS OF UWB

A. UWB REGULATIONS

Any technology has its own properties and limitation set on it by science just as by guidelines. Government controllers characterize the way that technologies operate in order to make concurrence more amicable and furthermore to guarantee public safety [38]. Since the UWB frameworks work over a ultra wide recurrence range which will cover with the current remote frameworks, for example, WiMAX and the IEEE 802.11 WLAN, it is important to build up guidelines where UWB frameworks can calmly exist together with inevitable systems. All around the world government and non-government organization set the rules and guidelines for UWB usage. The structure of global radio-communication administrative bodies can be assembled into worldwide, provincial, and public levels.

Radio regulation for UWB devices represents when compared with the one for conventional wireless technologies a special case. This is because UWB technology shares frequency bands that are actually intended for other (narrow band) radio services. Considering that many operators have paid huge sums for exclusive licenses it becomes clear that the UWB regulatory process entails a lot of discussion.

Main goal of UWB regulation across the world is to set the definition of UWB, to define emission limits on UWB devices in order to minimize potential interference to licensed services, as well as point out appropriate measurement and certification procedures needed to enable the deployment of UWB technology.

The US FCC published in 2002 the world's first radio regulatory requirements for UWB devices amending part 15 of its rule to permit promoting and the unlicensed operations of products including UWB technology.

In addition to general provisions, The First Report & Order ("First O&R") [26] specially distinguished between the following different categories of UWB devices and adopted for each category special rules:

- Indoor UWB system
- Handheld UWB system
- Ground penetrating radar and wall imaging system
- Through wall imaging system
- Surveillance system
- Medical imaging system
- Vehicular radar system

B. UWB STANDARDS

Standard are defined as to give uniform specialized techniques, process, and comprehension. Various standards exist for various types of technologies and processes. Particularly in remote communication systems, standard give interoperability and interfaces to segments.

Concerning UWB, the IEEE is making standard for these systems. Inside the IEEE 802 standard, the UWB normalization exercises start in the IEEE 802.15 undertaking bunches for WPAN. The IEEE 802.15.3a and IEEE 802.15.4a are two works bunches inside the 802.15 undertaking bunch that build up their guidelines dependent on UWB innovation. The IEEE 802.15.4a undertaking bunch is mainly focused on low rate substitute physical layers for WPANs. The specialized necessity for the IEEE 802.15.4a including cost ease, low data transfer rate, less complex and low power consumption (IEEE 2005). The IEEE 802.15.3a undertaking bunch is focused at developing high rate substitute physical layers for WPANs. The bunch focused on developing Physical Layer standards to support data rates between 110 – 450 Mbps over short ranges (i.e.<10 m) [39]. There are two recommendations for the IEEE 802.15.3a i.e. the Direct Sequence UWB (DS-UWB) and the Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM).

2.2.3 ADVANTAGES OF UWB

UWB has a various advantage over other technology that is why it is an expressive solution for wireless communication. The advantages of UWB are summarized as follows:

I. According to Shannon-Hartley hypothesis, channel limit is corresponding to transmission capacity. Since UWB has an ultra wide recurrence transfer speed, it can accomplish colossal limit as high as many Mb/s to a few Gb/s with range of 1 to 10 meters.

II. UWB waveforms have vast data transmissions because of their brief timeframe beat term. For instance, in wireless communication technology, like in multi-client network applications, exceptionally high bit rate execution can be given by UWB pulses.

III. In mobile and building conditions short term waveforms have relatively great invulnerability to multipath wiping out impacts are observed. High speed, mobile wireless applications are especially appropriate for UWB framework execution.

IV. It provides high security and high reliability in communication technologies. For the low energy density, it makes troublesome in detecting noise like UWB signal.

V. Low system complexity and cost are the main advantages of UWB technology. Those preferences emerge from the basically baseband nature of the signal transmission.

2.3 ANTENNA THEORY

As a basic segment, radio wire assumes a vital part in UWB frameworks and that is the reason the fundamental target of the proposition is to plan reception apparatuses for UWB applications. Previously planning, it is basic to comprehend the essential parts of UWB reception apparatus configuration just as various transmission capacity upgrade strategies. Some essential boundaries that consistently must be considered in receiving wire configuration are depicted in this area.

I. Impedance Bandwidth

Impedance bandwidth is considered one of the main antenna parameters. Antenna impedance associated with the voltage to the current at the input point of the antenna. Impedance bandwidth extents the characterization of the Voltage Standing Wave Ratio (VSWR) and return loss all through the band.

II. Radiation Patterns

The radiation pattern represents the radiation properties of the antenna as an element of space coordinates. The radiation patterns can be the indication of an application for which an antenna will be used. Such that, in mobile communication, a nearly Omni-directional antenna is required, since the location of the user’s is unknown. So, radiated power should be spread out consistently around the user for optimal reception. Notwithstanding, for microwave imaging applications, a directive antenna would be wanted with the end goal that most pf the radiated power is directed to a particular known area.

There are three regular radiation patterns that are describing the radiation property of an antenna:

a. Isotropic: Hypothetically, a lossless antenna providing equal radiation in all the directions. It is just relevant for an ideal antenna and is regularly taken as a perspective for articulating the directive properties of realized antennas.

b. Omni-directional: An antenna having a basically non-directional pattern in a given plane and a directional pattern in any symmetrical plane.

c. Directional: An antenna devising the property of transmitting or receiving electromagnetic waves more viably in certain directions than in others. This is generally relevant to an antenna where its extreme directivity is significantly greater than that of a half- wave dipole.

III. Efficiency

The ratio of the power radiated of the antenna, P_{rad} and the input power of the antenna P_{in} is known as radiation efficiency.

$$\eta_{rad} = P_{rad}/P_{in}$$

Total efficiency is just the result of the reflection proficiency and the radiation productivity. Within the range of 60-90% are considered values for the antenna efficiency, although a few business antennas accomplish around 50 - 60% because of cheap and lossy dielectric materials.

IV. Directivity and Gain

Directivity of an antenna, D is characterized as the proportion of the radiation intensity U in a provided direction from the antenna over that of an isotropic source. It is acquainted with depict the directional properties of antenna radiation design. For an isotropic source, the radiation intensity U_0 is equivalent to the absolute radiated power P_{rad} divided by 4π. So the directivity can be determined by the equation:

$$D = U/U_o = 4\pi U/P_{rad}$$

Antenna gain G is firmly identified with the directivity, however it considers the radiation efficiency η_{rad} of the antenna just as its directional properties, as given by:

$$G = \eta_{rad} D$$

The direction of the gain measurement is not specified the direction of maximum gain is presumed. Gain measurement is ordinarily misconstrued regarding deciding the quality of an antenna. A typical misinterpretation is that the higher the increase, the better the antenna. This is just obvious if the application requires an exceptionally directive antenna. As gain is straightly relative to directivity, gain estimation is an immediate sign of how directive an antenna is.

For UWB applications focused in this research, the requirements of antenna can be summarized in the following Table:

TABLE 2.1 Requirements of antenna

Parameters	**Requirements**
Band Width(Low Frequency)	3-10 GHz
Band Width(High Frequency)	24-38 GHz
Efficiency	High(>70%)
Return Loss	<-10dB
Gain	>3dBi
VSWR	<2.0
Physical Profile	Small, Compact, Planar

2.4 UWB ANTENNAS FOR 5G APPLICATIONS

A U-slot microstrip patch antenna dimension of 7.55mm×9.55mm and fabricated on RT5880, lower permittivity($\in_r$=2.2) and thickness h=0.508mm that resonate at 60 GHz**[1]**. Impedance bandwidth of 11.6% (S11 <= -15 dB) and gain of 8.2 dBi is obtained from this antenna. For a high frequency of 60 GHz there has been a high path loss. So, reduce the path loss array antenna, loop antenna and dipole antenna can be used which is very complex. Therefore, using U-slot in a single patch provides high performance as U-slot provides double resonance on the patch to have a wideband feature.

A Dual-band microstrip patch antenna for 5G smartphones using an array for making its low-profile antenna**[2]** which resonance frequency is 28GHz, 24.9GHz and bandwidth of 0.9GHz, 0.3GHz respectively where the gain is about 8.42 dBi. The size of the antenna is 9mm×8mm×0.64mm with a high permittivity substrate of RO3210 ($\in_r$=10.2). Instead of using a series of feed line in a patch with a substrate of low dielectric substrate ($\in_r$), high value of ($\in_r$) also gives the proper parameter results.

A printed monopole patch antenna fed by a 50ohm coplanar waveguide (CPW) and operating in a lossy coupling medium**[3]**with a dimension of 26×30×0.6 $mm^3$and achieved the return loss is below 9.6 dB in arrange of 3.4 - 9.9 GHz. An UWB antenna 3.1 to 10.6 GHz, which will ensure a balance between the two conflicting needs of better spatial goal, higher frequencies and better permeation.

Because of troubles in gathering the operator's real network data, there is a major hole between the information we really got and what we really need **[4]**. To reduce this problem, the fifth era of remote (5G) is accompanying better performances, higher information transmission rate, lower latency and considerably more. In IoT devices the delay of data transmission may occur a big problem. An adequate frequency spectrum should be accessible so as to accomplish 5G necessities or over 6 GHz. In China, they found the 6GHz to 100GHz frequency range is suitable.

The design of Microstrip Patch Antenna with Rectangular slot is proposed for UWB where partial ground plane technique**[5]** is used in place of ground plane structure to convert narrow band antenna into wide band antenna which dimension of 17mm×20mm. Using FR-4 Epoxy Dielectric Substrate of ($\in_r$= 4.4) and having standard thickness of 1.58mm. The result for this antenna is return loss -11.25 dB, bandwidth of 7.3 GHz, VSWR 1.75, gain 3.71 and directivity 4.58 dB.

The performance of the normal dipole antenna and the rectangular patch antenna is compared in terms of data rate and radiation pattern**[6]**. The design of an inset-fed rectangular patch antenna resonate at 2.45 GHz with 50 Ω line edge feed using FR4($\in_r$= 4.3) and the substrate height h=1.6mm with dimension of 29mm×38mm. Rectangular patches generally have the largest impedance bandwidth for their larger shapes than others. S11 = -38dB and gain 8.31 is measured for this antenna.

Dual band **U- Shaped** Slotted Microstrip Patch antenna**[7]** that works on 28 GHz and 30 GHz with a total dimension of 8mm×8.5mm×0.254mm, substrate material is FR-4 ($\in_r$= 2.2) and copper grounded. Slot is used for creating multiband and this multiband is essential for uninterrupted services. Using line feeding technique achieved gain is 6.7dB at 28GHz, 7.92dB at 38GHz with return loss of -32dB and -40dB respectively.

Single wide band microstrip patch antenna works on 6.1 GHz with a total dimension of 30.7×22.4 mm^2, substrate material is FR-4 ($\in_r$= 4.3) fully copper grounded**[8]**. Using Proximity feed technique achieved gain is 3.7dB with a directivity of 6.62dB and a bandwidth of more than

500MHz. Frequency above 10GHz affected by rain thus they choose around 6GHz frequency to avoid the rain issue.

Modified **bi- convex** shaped circular patch and metallic rings used for gain enhancement**[9].** working frequency 27.6 GHz with a total dimension of 40mm×40mm×1.6mm and substrate material is FR-4 epoxy ($\in_r$= 4.4). Achieved gain is 4.69dB at directivity of 5.69dB with VSWR 1.05, return loss is -30.6dB with radiation efficiency of 79%.

Focused on the 3.5GHz propagation channel where FR4 epoxy material with dielectric constant of 4.3 has been selected for the substrate material**[10]** total size of 25.2×48×1.6mm^3 which is small enough to fit in any communication device. An ellipse shaped and line fed technique is used for radiating the patch. Elliptical elements offer better matching circular elements because of their broader structure factor and more steady shape. Gain of this antenna is 5db; return loss -30dB, efficiency 96.6%.

A high gain microstrip patch antenna is designed, using air substrate (∈r= 1) which operates at 28GHz with a dimension of 4.975×5.125mm^2**[11]**. The bandwidth, gain, returns loss and efficiency of the proposed antenna are 1.29GHz, 9.82 dBi, 42 dB and almost 100% respectively. Air substrate is used for its very low dielectric constant as well known to all that the substrate of low dielectric constant material patch is one of the method to increase the gain of the antenna but in real life it's not very easy to use air as a substrate, it's very complex.

An antenna with metamaterial structure is composed of 8×8mm^2 on Rogers RT/duroid 5880 ($\in_r$= 2.2), by using metamaterial gain is increased significantly**[12]**nearly 2dBi but its design complexity is more than general design. An array of four patches in antenna has been proposed with a thickness of 0.0175 mm printed on the same Rogers RT/duroid 5880 substrate. The achieved gain on 28 GHz is 16.6 dBi.

The proposed antenna examined with various types of substrate material like Foam, FR-4, Roger RT-5880, Taconic TLC-3.2and quarter wave transformer feeding technique **[13]** is used for optimized the value of designed parameter at 28 GHz and 38 GHz. The antenna produced best result by using quarter wave transformer feeding technique and foam substrate with a height o.5mm. Achieved results on 28 GHz is (Size: 3.39×2.31, VSWR: 1.001, Gain: 4.98, Directivity: 7.18, Efficiency: 60.21%, Bandwidth: 1.88) and on 38 GHz is (Size: 2.39×1.63, VSWR: 1.003, Gain: 4.65, Directivity: 6.97, Efficiency: 59.2%, Bandwidth: 3.6). Here, efficiency of 99% is achieved by using foam material and its well known to all high efficient antennas consume less battery power.

Using inset feeding technique, the antenna resonates at 38.256 GHz**[14]**. The antenna is fabricated using a single FR4 substrate of dimension 2.69×4.55×1.6 mm^3. The return loss and VSWR of this antenna is -21.16 and 1.19 dB respectively with 5.48 dB gain and 7.716 dB directivity. Although its return loss below -10 and gain above 5, it can be improved.

A single band microstrip patch antenna for 5G application consist of two slot with new H and E shape**[15]** loaded on the patch using line feeding technique and simulated on a substrate Rogers RT5880 ($\in_r$= 2.2), loss tangent 0.0009, and thickness of 1.6mm and dimension of 8×8mm^2. The proposed antenna produced return loss -40.99dB, gain 5.48dB at 60 GHz. For of increasing the data rate of frequency on higher bands, need smaller data transmission range and widening the bandwidth that's why H-slot and E-slot are used in the patch.

A modified rectangular ring with fork shaped strip is used with dimension of 30×40×1.6 mm^3**[16]**and the substrate is RT/Duroid 5880

($\in_r$= 2.2).The optimized size of the ground plane 30×40 $mm^2$is connected with 50 Ω feeding. This antenna resonated at triple frequencies 28 GHz, 31.45 GHz and 34.6 GHz. The total gain is achieved 3.7308 dB, and the directivity is 3.8336 dB at 28 GHz. This antenna generated triple band but time domain values such as return loss, gain, VSWR are not so good it just passed the minimum requirements.

With rhombus-shaped slots on patch and using inset fed technique this antenna operates at 32.216 GHz**[17]**. FR4 ($\in_r$ = 4.3) is used as a substrate fully copper grounded, total dimension is 4.6×5.2×0.3 mm^3. Achieved gain is 6.6 dBi, return loss -44.059 dB and bandwidth 1.008 GHz. By changing the geometrical dimensions from microwave to THz region, the antenna can be tuned.

Teaching-Learning-Optimization (TLBO) algorithm is applied for designing a dual band E-shaped microstrip patch antenna**[18]**. The geometrical parameters of the aperture coupled antenna are the inputs of the optimization algorithm. The technique provides acceptable design solutions accomplishing simultaneously minimize S11 and low VSWR at the resonated frequency of 25GHz and 37GHz. Both antenna and feed line using same substrates consist of Arlon ($\in_r$= 3.38), Achieved results are at 25 GHz is (Gain 6.71, VSWR 1.09, S11 -25.73) and at 37 GHz (Gain 1.72, VSWR 1.09, S11 -25.77). In the second band (37GHz) gain does not fulfill the requirements which is below 3.

A 2×2 microstrip patch array antenna for 5G C-band (3.4 – 3.6GHz) application has been designed, the total dimension of the antenna array is 88.5×88.5×1.6mm^3**[19].**Flame Retardant-4 (FR-4), with a dielectric constant of 4.4 is used as substrate, using microstrip feed network technique this antenna resonated at 3.45GHz and 3.57GHz. Achieving gain for the proposed antenna is 5.37dBi and radiation efficiency is about 30%. Its overall size is very large.

This dual band mm wave microstrip patch antenna has the total dimension of $7.2\times5.0\times0.787$ mm^3 and resonates at 37 GHz and 54 GHz band **[20]** where Rogers RT5880 is used as substrate. For radiating patch and ground plane copper material is used and an inset feed technique is utilized for resonating the patch. Achieved result at 37 GHz (Gain 5.5 with minimum return loss of -25.8 dB and efficiency of 65%), at 54 GHz (Gain 8.67 with minimum return loss of -25.7dB and efficiency of 75%). As this antenna efficiency is below 80%, it doesn't consider an efficient antenna.

This wideband antenna works at the band from 2.8 to 5.2 GHz**[21]**. Total dimension is 0.84×0.68×0.06 mm3, FR4 is used as substrate. Three elliptical slots are carved to reveal the feeding line for impedance matching on the two folded walls are also printed on both ends of the vertical dielectric portion. This antenna operates on four different operating modes are 3.05, 3.75,4.55 and 4.9 GHz with peak gain of 6.2dB at bandwidth of 58.3% with average of 64% radiation efficiency.

With the dimension of18.4×13.0×0.787 mm^3, this array antenna be made up of 4 elements which are set over Rogers RT5880 substrate material with dielectric constant ($\in_r$= 2.2) and fully copper grounded**[22]**. Wilkinson power divider is used for equivalent power division at every component of the array. The designed array antenna produces return loss of -28 dB, maximum gain of 11 dBi, bandwidth of 500 MHz and exceptionally well efficiency of 94% at resonating frequency of 9.9 GHz.

Reconfigurable Y slotted mm-wave patch antenna has been designed that are suitable for radar and satellite communications**[23].** The frequency re-configurability is attained by using 2 PIN diodes (MA4AGFCP910) combined with the radiating component of the antenna. This antenna works at 4 frequencies of 31.4GHz, 31.65GHz, 45.45GHz and 49.84GHz. Dimension of this antenna is 1.95×4.2mm^2 and constructed with lossy copper material on Rogers RO3003 substrate ($\in_r$=3).Microstrip feed line technique is used for feeding. Achieved Gain 7.45 dB and efficiency 91% at 49.84GHz, gain 4.15 dB and efficiency 50% at 31.65 GHz, gain 4 dB and efficiency 60% at 31.4 GHz, Gain 5.3 dB and efficiency 83% at 45.45 GHz.

A 4×2 dual band microstrip array antenna has been designed on this paper with dimension of 8×8 mm²**[24].** This 8-element MPA (microstrip patch antenna) array is designed from this single element and corporate fed and series fed technique are used for exciting the patch. Total dimension of this proposed array antenna is 38×15mm^2 and FR-4($\in_r$= 2.2) material is used as substrate. This antenna operates at 29.5 GHz and 38 GHz, and attained gain is 8.4 dBi and 9.3 dBi with radiation efficiency of 98.3% and 98% at the center resonance frequencies respectively.

A high-gain and high-orientation rectangular patch antenna is designed which resonates at 3.5GHz**[25]** with a relative bandwidth of 2.28% and a gain of 7.43dB. Designing a new sort of scale down antenna with 10 split ring resonators (SRR) metamaterial structures that are equally carved on the radiation patch. Metamaterials are developed so that the size of every unit is smaller than the frequency of the dielectric. By designing the structure and arrangement of the unit, it is easier for obtaining the desired dielectric characteristics. So far, metamaterials have made progress in 3G and 4G, for example antenna size reduction, wide frequency band, high gain and low profile.

A low-profile small antenna is designed with a dimension of 8.52×7.14mm^2 and material substrate Taconic TLY-5 type**[27]** with thickness of 0.12mm is used which dielectric constant ($\in_r$=2.2) is similar to RT5880 but Taconic TLY-5 is being used for the thickness, as the thickness of material will affect the dimension of the antenna. Here different width gaps on the patch and length of the feeding line were tested and observed that the width gap and length of the feeding line significantly influenced the target resonant frequency. The simulation result at 28 GHz was obtained for the bandwidth of 454 MHz with return loss ≤ -10 dB, VSWR and gain are respectively, 1.003 and 6.72dB.

In this paper, the 3.5 GHz antenna is designed with various types of substrate and thickness**[28].** Among three proposed designs, design-1 used FR-4 with a dimension of 36×29.8×1.6 mm^3, RT-5880 with a dimension of 47×31.7×1.575 mm^3 and TLC-30 with a dimension of 42×33.7×1.58 mm^3. The simulated result at 3.5GHz for design-1 S11 -28.48dB, VSWR 1.078, Gain 3.338dB, Bandwidth 247 MHz for design-2 S11 -14.13dB, VSWR 1.48, Gain 4.66dB, Bandwidth 129MHz and for design-3 S11 -18.81dB, VSWR 1.26, Gain 5.08dB, Bandwidth 177 MHz Above result shows that relative permittivity and height of the substrate affect the gain and bandwidth significantly.

Three circular shapes with ring antennas**[29]** are being designed with a dimension of 30×30×1.57 mm^3 where RT5880 is used as a substrate. Design-1 is circular shaped, Design-2 is ring shaped and design-3 is ring rounded outside the circle patch. Circular ring loaded on a patch that works as a parasitic element which improves the overall performance of the antenna in terms of gain, bandwidth, and efficiency. The simulation result at 18 GHz for design-1 S11, Gain, Bandwidth, Efficiency are -33.59dB, 7.87dBi, 1197MHz, 82.8% respectively for design-2 S11, Gain, Bandwidth, Efficiency are -18.3dB, 6.33dBi, 1170MHz, 85.5% respectively for design-3 S11, Gain, Bandwidth, Efficiency are -66.48dB, 9.18dBi, 1307MHz, 91.9% respectively. It's clear that among these three, design-3 rings around the circle perform better than others.

A compact antenna is designed for mobile phones**[30]** with a dimension of 8.6×7.39 mm^2 and using FR-4($\in_r$=4.4) substrate with 0.8 mm thickness. For reducing the impedance problem, coaxial feed technique is used. The antenna is operated at 43.7 GHz with return loss -23.356 dB, VSWR 1.18 and gain 4.35 dB is obtained. As the proposed antenna working in Extremely High Frequency range, it also seems to be suitable for satellites along with mobile phones.

A monopole pentagon shaped microstrip antenna design for IoT application**[31]** with a dimension of 40×40×1.6mm^3 and used FR-4 ($\in_r$=4.4) as a substrate. For enhancing the bandwidth defected ground structure is used. This antenna has produced triple resonance bands which cover from 4.10- 5.13 GHz, 5.21- 5.81 GHz (IoT band) and 6.24- 7.87 GHz respectively. The simulated result for band covers at 4.10- 5.13 GHz produces resonant frequency, return loss, impedance bandwidth is 4.9 GHz, -22.01 dB, 21.02% respectively. For band covers at 5.21- 5.81 GHz produces resonant frequency, return loss, impedance bandwidth is 5.4 GHz, -33.71 dB, 11.11% respectively. For band covers at 6.24- 7.87 GHz produces resonant frequency, return loss, impedance bandwidth is 7.3 GHz, -16.95 dB, 22.32% respectively. As good performance in 5.21-5.81GHz (IoT band) is observed it can be used in IoT applications.

An ultra-wideband microstrip patch antenna array is designed using a combination of U-slot and stepped cut line **[32]**. Here Array is used for improving the gain and directivity and slot and stepped line technique used for increasing the bandwidth. The dimension of this antenna is 23.41×19.86 mm^2 where RT5880 as substrate height is 0.787 mm. Proximity coupling method is used for exciting the patch. Proximity coupling increases the bandwidth 13% as it increases the thickness of the patch. The antenna resonates at 28 GHz and bandwidth 4.47 GHz, return loss -20.52dB and gain 8.71 dB is observed.

Optically transparent high gain patch antenna is designed for satellite communication**[33]**. Transparent patch is helpful to reduce the shadow effect of solar antennas as well as ensure the maximum surface usage. The dimension of this antenna is 45×35×3 mm^3 where Pyrex glass is used as a substrate with relative permittivity of 4.82 and for radiating patch Indium Tin Oxide (ITO) film is used. The proposed antenna resonates at 24.8 GHz that covers the range of K band (18 - 30 GHz). This antenna produces 12 GHz of bandwidth, return loss -31.2 dB, VSWR 1.05, gain 11.5dB, efficiency 92%. High bandwidth makes the antenna suitable for satellite communication.

A sub 6 GHz dual polarized microstrip filtering antenna using differentially fed technique is designed for high gain and efficiency performance, low cross polarization and Common Mode Rejection **[34],** to achieve filtering characteristic four half wavelength open ring slots are loaded on the patch. Rogers TMM3 is used as a substrate with dielectric constant of 3.45, loss tangent of 0.002 and height 3.2 mm. The resonating frequency is 3.54 GHz with return loss of -25dB and gain of 7.5 dB.

On a single design multiband characteristic are achieved using a crossed-slot on the patch **[35]**. Total dimension of this antenna is 100 mm^2 with height of 0.254, FR4 (Ɛ= 4.4) is used as substrate. This design is partially grounded with a small slot on the substrate for impedance matching, this antenna resonates at three major frequencies 28, 32.5 and 38 GHz with the return loss of -27 dB, -14 dB and -14.5 dB respectively, at 38 GHz the bandwidth is nearly 3 GHz. Achieved gain on is 4.73 dBi and 5.13 dBi at 28 and 38 GHz respectively.

TABLE 2.2 Summarized Literature Review Table

Title of work	Author Name&Year	Working Frequency	Gain	Application
Multiband Microstrip Patch Antenna For 5g Wireless Application[7]	W. Hussain et al. (2020)	28 GHz, 38 GHz	6.7dB, 7.92dB	5Gwireless application.
Single Wideband Microstrip Patch Antenna for 5G Wireless Communication Application[8]	M. A. Summakieh et al. (2016)	6.1 GHz	3.7 dB	5G wireless communication
GainEnhancementof a Biconvex Patch Antenna using Metallic Rings for 5G Application[9]	R. A Panda et al. (2019)	27.6 GHz	4.69 dB	Satellite and 5G communication
Design of A Small Patch Antenna At 3.5 Ghzfor 5g Application[10]	N. Ferdous et al. (2019)	3.5 GHz	5 dB	5Gcommunication applications.
Design and Simulation of a Single Element High Gain Microstrip Patch Antenna for 5G Wireless Communication [11]	M. M. A. Faisal et al. (2018)	28 GHz	9.82 dBi	5G wireless communication.
Beam Steering in Metamaterials Enhancing Gain of Patch Array Antenna Using Phase Shifters for 5G Application [12]	S. Mingle et al. (2019)	28 GHz	16.6dBi	5G wireless application.
Optimization Of DesignParametersOf Microstrip Patch Antenna At 28 GHz And 38 GHz For 5g applications[13]	M. M. Soliman et al. (2019)	28 GHz, 38 GHz	10.1 dB 10.3 dB	5G wireless applications.
High Directive Wideband Microstrip Patch Antenna for 5G Mobile Phone Application [14]	M. M. Islam et al. (2019)	38.26 GHz	5.48 dB	5G mobile phone.
Design a Single Band Microstrip Patch Antenna at60 GHz Millimeter Wave for 5G Application.[15]	S. K. Agarwal et al. (2017)	59.9 GHz	5.42 dB	5G wireless applications.
Modified Triple Band Microstrip Patch antenna for Higher 5G bands.[16]	S.Subramanian et al. (2018)	28 GHz, 31.45 GHz, 34.6 GHz	3.73 dB	Higher band applications.

A Modified Square Patch Antenna with Rhombus slot for High bandwidth [17]	M. R. Prabhu et al. (2019)	32.2 GHz	6.6 dB	Higher Band.
Evolutionary Design of a dual band E shaped patch antenna for 5G mobile application[18]	S. K. Goudos et al. (2017)	25 GHz, 37 GHz	6.71 dB, 1.72 dB	5G Mobile Communication.
Design of 2×2 microstrip patch array antenna for 5G C-band access point applications[19]	W.S. Chen et al. (2018)	3.4 GHz, 3.6 GHz	5.37 dB	5G C - band access point applications.
mmWave Novel multiband patch antenna design for 5G communication [20]	Z. Lodro et al. (2019)	37 GHz, 54 GHz	5 dB, 6 dB	5G wireless communications .
Low-Profile and Wideband Microstrip Antenna with Stable Gain for 5G Wireless Applications [21]	Wenxing An et al. (2018)	2.8 - 5.2 GHz	3 dB	5G wireless communication
Compact Microstrip Patch Antenna Array Design for 5G Wireless Communication. [22]	ZeeshanLodro et al. (2019)	9.9 GHz	5 dB	5G wireless communication
Frequency Reconfigurable patch antennafor millimeter wave applications [23]	W. A. Awan et al. (2019)	49.56 GHz 31.34 GHz 31.2GHz 45.52GHz	7.45 dB 4.15 dB 4 dB 5.3 dB	Radar, 5Gwirelessnetwork, satellite cross-linkingand millimeter wave energy harvesting
A Low-Cost Dual-Band Patch Antenna Array for Future5GCommunication Applications[24]	M. E. Hossain et al. (2019)	29 GHz, 40.5 GHz	5.69 dB 4.54 dB	5G communication wireless Communication applications.
Design of a Miniaturized Antenna Based on Split Ring Resonators for 5G [25]	R. Li et al. (2019)	3.5 GHz	7.43 dB	5G Wireless Communications
Design and simulation of a rectangular patch microstrip antenna for 5G application [27]	M darsono et al. 2020	28 GHz	6.72 dB	5G devices

Design and Performance Analysis of Different Dielectric Substrate based Microstrip Patch Antenna [28]	N. Ramli et al. 2020	3.5 GHz	3.34 dB, 4.66dB, 5.08 dB	5G wireless application.
Developed high gain microstrip antenna like microphone structure for 5G application[29]	H. Yon et al. 2020	18 GHz	7.87dBi 6.33dBi 9.18dBi	Wireless communication systems.
Microstrip Patch Antenna Design for Fixed Mobile and Satellite 5G Communications[30]	Rashmitha R. et al. 2020	43.7 GHz	4.35 dB	Mobile device and satellite 5G communication
Penatgon Shaped Microstrip Antenna for Wireless IoT Application[31]	P. SyamSundar et al. 2020	4.9 GHz, 5.4 GHz, 7.3 GHz	Not reported	Wireless IoT Application
Ultra-wideband Microstrip Array Antenna for 5G Millimeter-wave Applications[32]	E. Sandi et al. 2020	28 GHz	8.71dB	Millimeter Wave Applications.
An ITO Based High Gain Optically Transparent Wide Band Microstrip Antenna for K Band Satellite Communication [33]	L C Paul et al. 2019	24.8 GHz	11.5 dB	Satellite Communication
New High-Gain Differential-Fed Dual-Polarized Filtering Microstrip Antenna for 5G Applications [34]	Y. I. A. Al-Yasir*et al* 2020	3.54 GHz	7.5 dB	5G Application
Design of Multi-band Slotted mmWave Antenna for 5G Mobile Applications[35]	M.B. Almashhdany et al 2020	28GHz, 38 GHz	4.73dBi , 5.13dBi	5G Mobile Applications.

2.5 SUMMARY

In this section, an overall review of UWB technology is introduced and its points of interest, applications and guidelines and principles are additionally examined. The future of UWB is promising and inspiring. Nonetheless, most of the discussion on UWB is around whether or not it will acquire adverse impedance to other existing systems and services.

Despite the fact that UWB devices are needed to work with a power level consistent with the emission mask, the worry about the potential impedance will continue and numerous approaches to deflect the potential induction have just been proposed. Inferable from its unmistakable focal points, UWB technology can be applied in a wide scope of zones including communications technology, satellite, radar, sensors, positioning, imaging and so on.

CHAPTER III

ANTENNA DESIGN METHODOLOGY

3.1 INTRODUCTION

This part portrays the methodology of designing UWB antennas in detail. The cycle begins by a legitimate comprehension of the last focused on UWB antenna. Afterwards a lot of simulations, optimizations and ultimately estimations have been done. The antenna literature review has been described in chapter II. This chapter emphasizes on design and simulation consideration as well the measurement mechanism. The measurement equipment is described with suitable visualization. Infact, this part is a work to give a reasonable and valuable thought of viable UWB antenna designing, prototyping and measurement processes.

3.2 METHODOLOGY

Figure 3.1 describes the design and fabrication process of an UWB antenna. With an extensive literature review on the Low and High frequency UWB antenna, and Various Shaped slotted Dual Band UWB antenna from where the requirements of the antenna are collected according to the specifications. Once the antenna's geometrical parameters and dielectric substrate are specified, the antenna models are ready for simulation. Meanwhile the familiarization with the simulation software CST Microwave Studio 2018 simulator has been performed. Next, the design is simulated and its performance has been examined until a satisfactory result is obtained.

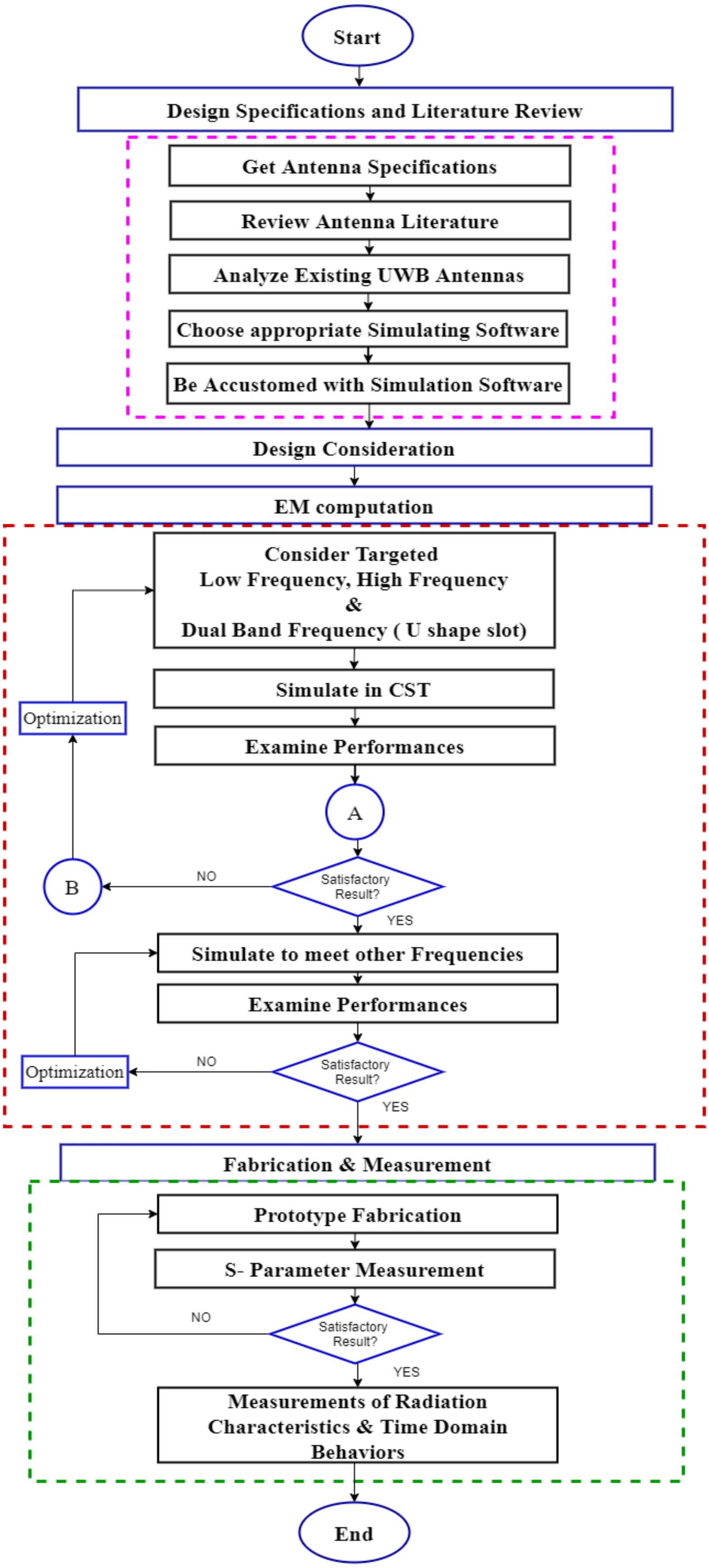


Figure 3.1 Flow chart of design, fabrication and measurement of UWB antenna

3.2.1 DESIGN SPECIFICATIOS

Antenna design process starts with the collection of targeted specifications according to the application of the antenna and review process of the literature. The proposed antennas are designed for UWB applications and designed antennas must have an operating frequency band ranging from 3.1 - 10.6 GHz for low frequency application and 28 - 38 GHz for high frequency application. To fulfill the base necessities of UWB tasks, the proposed antennas should have the option to exhibit a decent impedance coordinating to accomplish wide working data transfer capacity, stable radiation patterns and satisfactory gain to help the UWB applications.

An extensive literature is reviewed for the design process. It can be divided into two parts. Firstly, characteristics of the microstrip antenna have been reviewed, which includes return loss, gain, radiation patterns and so on. However, the objective is to learn the basic concept of the antenna mechanism and familiarization to the design process. Secondly, some existing UWB antennas with and without slots on patches have been reviewed to get a full idea of the antenna designing process. The existing UWB antennas provide a great assistance for the initial design process and realizing the mechanisms to improve impedance matching, antenna profile, gain, radiation patterns and other essential parameters.

After the fruitful finishing of broad literature review, the antenna computation software must be picked and be familiar with the antenna simulation measure utilizing the software. Bunches of antenna simulation software financially accessible on the lookout. They vary from each other by their simulation techniques, for example, HFSS uses 3D finite element method (FEM) to compute the behavior of an antenna design, where CST uses finite difference time domain (FDTD) technique for figuring qualities of antenna parameters. Nonetheless, for the improvement of the current UWB antenna, CST Simulation Software is picked.

TABLE 3.1 Design specification Table of the proposed antennas

ANTENNA CHARACTERISTICS	FREQUENCY CATEGORY		
	LOW FREQUENCY	HIGH FREQUENCY	
OPERATING FREQUENCY	SINGLE BAND	WITHOUT SLOT	S SHAPE SLOT
	3.1 - 10.6 GHz	28 - 38GHz	28 - 38GHz
RETURN LOSS	≤ -10 dB	≤ -10 dB	≤ -10 dB
VSWR	≤ 2.0	≤ 2.0	≤ 2.0
INPUT IMPEDANCE	50 Ω	50 Ω	50 Ω
GAIN	≥ 3 dBi	≥ 3 dBi	≥ 3 dBi
EFFICIENCY	≥ 70%	≥ 70%	≥ 70%
PROFILE	Small, Compact and Planar	Small, Compact and Planar	Small, Compact and Planar
WEIGHT	Light	Light	Light
POLARIZATION	Linear	Linear	Linear
RADIATION PATTERN	Omnidirectional	Omnidirectional	Omnidirectional

3.2.2 DETERMINATION OF DESIGN DIMENSIONS

Designing antenna elements usually starts with fundamental equations for determining the width (W) and length (L) of microstrip patch antennas. To realize the dimensions of the patch is first step to determine width of the patch using the following classical equation [40].

$$W = \frac{C}{2f_r} \frac{1}{\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{3.1}$$

where C is free space velocity, resonant frequency is f_r and dielectric constant ε_r. The effective dielectric constant ε_{re} is obtained [41]

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right) \tag{3.2}$$

where the substrate height is h. Considering the fringing field effect, the length of the patch L can be determined by the following [40],

$$L = \frac{C}{2f_r\sqrt{\varepsilon_{re}}} - 2\Delta L \tag{3.3}$$

Where additional ΔL of the patch caused by the fringing field at both radiating edge are given as [42],

$$\frac{\Delta L}{h} = \frac{\epsilon_1\epsilon_3\epsilon_5}{\epsilon_4} \tag{3.4}$$

$$\epsilon_1 = 0.434907 \frac{\varepsilon_{re}^{0.81}+0.26}{\varepsilon_{re}^{0.81}-0.189} * \frac{\left(\frac{w}{h}\right)^{0.8544}+0.236}{\left(\frac{w}{h}\right)^{0.8544}+0.87} \tag{3.5}$$

$$\epsilon_2 = 1 + \frac{\left(\frac{w}{h}\right)^{0.371}}{2.358_{\varepsilon_r+1}} \tag{3.6}$$

$$\epsilon_3 = 1 + \frac{0.527tan^{-1}\left[0.84\left(\frac{w}{h}\right)^{\frac{1.9413}{\epsilon_2}}\right]}{\varepsilon_{re}{}^{0.9236}} \tag{3.7}$$

$$\epsilon_4 = 1 + 0.0377tan^{-1}\left[0.067\left(\frac{w}{h}\right)^{1.456}\right] * \left[6 - 5e^{[0.036(1-\varepsilon_r)]}\right] \tag{3.8}$$

$$\epsilon_5 = 1 - 0.218e^{-7.5\left(\frac{w}{h}\right)} \tag{3.9}$$

$$\sqrt{\varepsilon_{re}} = 1 + \frac{h}{H-h}\left(\bar{a} - \bar{b}ln\frac{w}{H-h}\right)\left(\sqrt{\varepsilon_r - 1}\right) \tag{3.10}$$

Where, $\bar{a} = \left(0.5173 - 0.1515ln\frac{h}{H-h}\right)^2$ (3.11)

And, $\bar{b} = \left(0.3092 - 0.1047ln\frac{h}{H-h}\right)^2$ (3.12)

The width W of the patch is chosen (W/L ~ 1.5) to achieve maximum co polarization and cross polarization ratio [43].

3.2.3 CST COMPUTATION

Electromagnetic simulation is an advanced computation technology to yield highly accurate analysis and design of complicated microwave and RF printed circuits, antennas and other electronic components. After the determination of the antenna dimensions with suitable model, the next step of the design process is to simulate the design in the CST 2018 electromagnetic simulator. CST is an integrated full-wave electromagnetic simulation and optimization package for the analysis and design of 3D, planar microwave antennas on high-speed PCB.

3.3 SUMMARY

This part puts forth an attempt to portray the procedure of UWB antenna design. The design methodology is talked about broadly, which prompts the design, simulation, fabrication and experimental validation appropriately. The design area assists with characterizing the elements of the antenna in the underlying level. At that point electromagnetic calculation is done which follows streamlining of the antenna structure. At that point the prototyping of the antenna is finished. The prototyping stream is likewise depicted in the part with appropriate figures. In conclusion, the antenna measurement procedure is depicted with a concise presentation of the estimating equipment and environment.

CHAPTER IV

UWB ANTENNA FOR LOW FREQUENCY

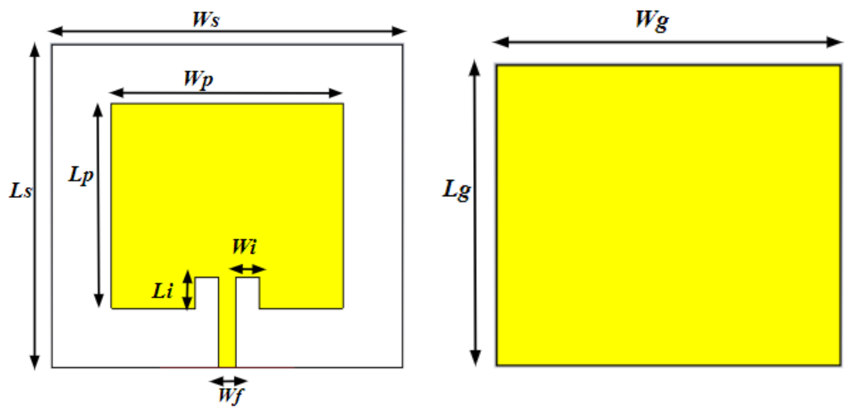
4.1 INTRODUCTION

As mentioned in chapter II, several types of antennas have been proposed for UWB applications. Among all these configurations, planar structure features are simple, easy for fabrication, large bandwidth and easily embeddable to portable devices which make them suitable for numerous applications. In this chapter, the design, simulation and result have been discussed for low frequency single band antennas. Antenna performance is analyzed by using CST simulation software before the actual prototype is fabricated.

4.2 LOW FREQUENCY ANTENNA DESIGN

4.2.1 ANTENNA GEOMETRY

A low-profile low-cost antenna has been designed for 5G application with total dimension of this antenna Ws x Ls. The substrate of this antenna is ROGERS RT5880 with thickness Hs 0.6436 is used for its low dielectric constant. This design is fully copper grounded. Inset and 50Ω microstrip feedline technique is used to excite the patch. This antenna resonates on 6 GHz which is considered as low frequency. On figure 4.1 the front view and back view of this proposed design is illustrated.



(a) (b)

FIGURE 4.1 (a) Front view (b) Back view

TABLE 4.1 Optimized attributes of this low frequency antenna

Parameters	Description	Values (mm)
Ws	Substrate width	**30**
Ls	Substrate Length	**26**
Wg	Ground width	**30**
Lg	Ground Length	**26**
Lp	Patch length	**16.53**
Wp	Patch width	**19.75**
Wf	Feedline width	**1.50**
Hs	Substrate height	**0.6436**
Li	Inset height	**2.50**
Wi	Inset Width	**2.00**

4.2.2 ANTENNA PERFORMANCE

RETURN LOSS

Return loss is the ratio of the reflected power to the incident power, in decibels (dB). A high return loss indicates a large amount of power is being reflected back. So, the standard value of return loss should be lower than -10 dB. The simulated return loss for this low frequency antenna on the peak frequency at 6 GHz is -16.86 dB< -10 dB which is quite good for low frequency microstrip patch 5G antennas. The working frequency is 5.92 GHZ to 6.06 GHZ and the bandwidth is nearly 140 MHz On figure 4.2 the simulated S11 is shown.

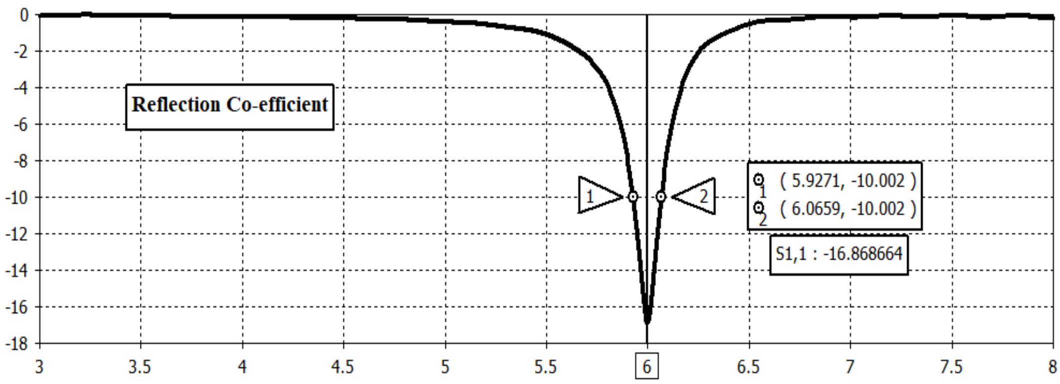


FIGURE 4.2 Reflection coefficient of the proposed antenna.

VOLTAGE STANDING WAVE RATIO

The Voltage Standing Wave Ratio indicates the mismatch between an antenna and the feed line. The value of VSWR ranging from 1 to ∞. Value below 2 is considered suitable for most antenna applications. The proposed antenna resulted in VSWR 1.33 which is between 1 and 2 quiet quite an acceptable result for this proposed design. The VSWR of the proposed design is projected in figure 4.3.

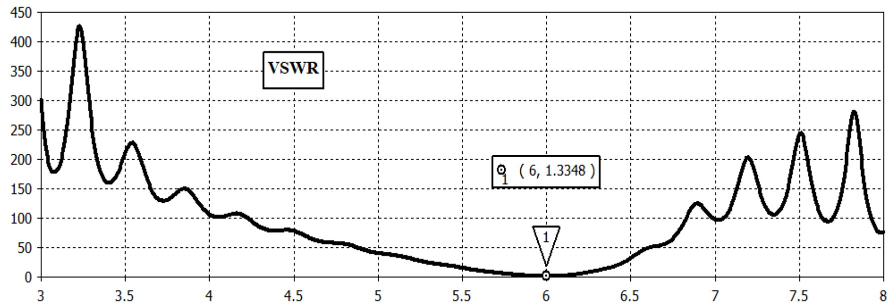


FIGURE 4.3 VSWR

EFFICIENCY

The ratio of total delivered power to the antenna and the power radiated from the antenna indicates the efficiency of the antenna. On a highly efficient antenna most of the power present at the antenna's input that gets radiated away. Low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch. The efficiency for this proposed antenna is depicted in Figure 4.4

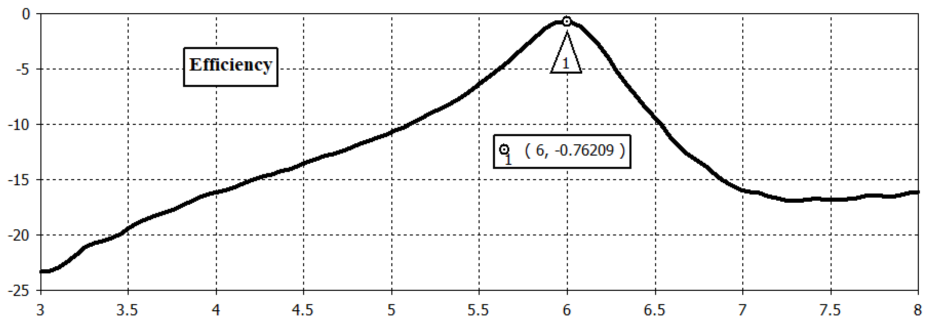


FIGURE 4.4 Efficiency

GAIN

Gain is the combination of antenna's directivity and electrical efficiency. Gain describes how well the antenna converts input power into radio waves headed in a specified direction during transmitting signal. For low frequency microstrip antennas the gain should be ≥ 3.5 dB. Here the simulated gain on peak 6 GHz is 6.45 dB > 3.5 dB that is illustrated on figure 4.5.

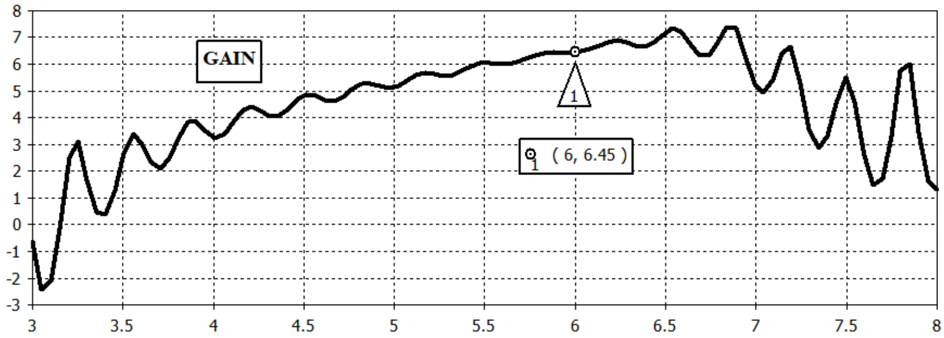


FIGURE 4.5 Gain

CURRENT DISTRIBUTION

To get proper understanding about the electromagnetic behavior of the antenna the surface current distribution should be investigated. The surface current of the proposed design is depicted on figure 4.6. It is clearly observed that the current is concentrated all over the patch and deeply concentrated on the middle part of the patch and near the inset gap. The proper distribution of the current on the patch ensures the proper performance of this antenna, for lower frequencies it depends on the feed line.

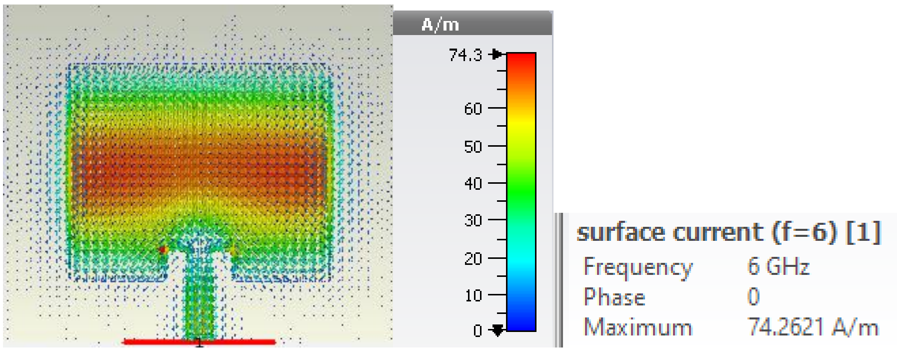
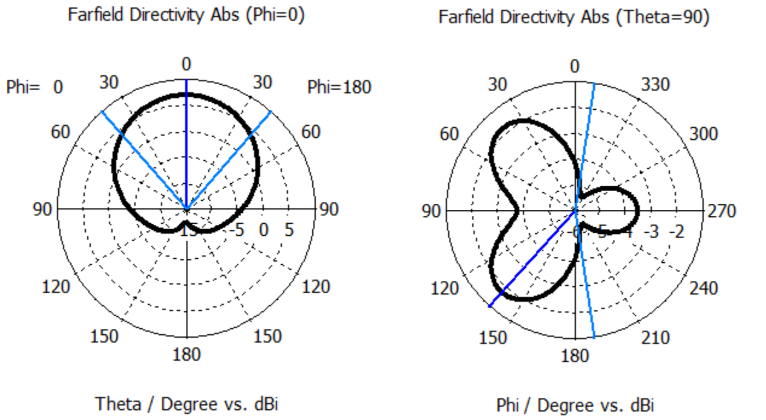


FIGURE 4.6 Surface current distribution

RADIATION PATTERN 2D

The radiation pattern of this proposed single band high frequency antenna in E-plane (phi= 0°) and H-plane (phi= 90°) are calculated and measured for the peak resonance frequency 28 GHz that are widely used for 5g wireless communication and mobile communication. Figure 4.7

illustrates the 2D radiation pattern that has been measured in terms of E_ϕ and E_θ components.



(a) (b)

FIGURE 4.7 (a) E- plane at 6 GHz (b) H- plane at 6 GHz

RADIATION PATTERN 3D

The 3D radiation patterns for electric fields at 6 GHz is shown on figure 4.8. In the radiation pattern the red parts indicate the strongest radiated E- field and the blue indicates the weakest part of the radiation. From this radiation pattern it is observed that the pattern is almost 360 degree scattered and it acts like omnidirectional which is the key need factor in 5g wireless communication and 5g enabled devices.

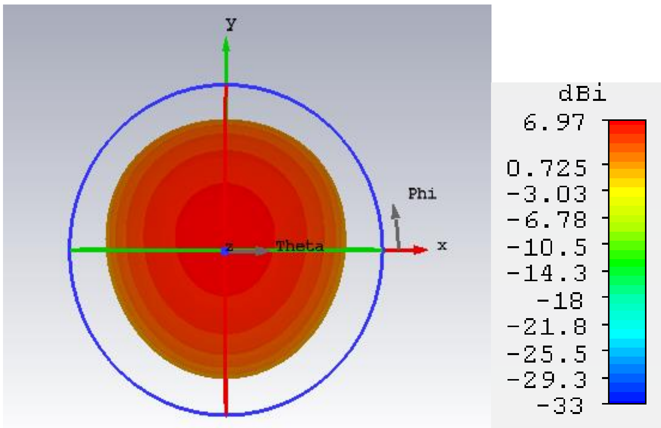


FIGURE 4.8 Simulated 3D radiation pattern at 6 GHz

TABLE 4.2 Summarized result of low frequency antenna

Parameters	**Value**
Size	30 X 26 mm^2
Operating frequencies	5.91 GHz - 6.06 GHz
Peak gain	6.44 dB
Directivity	6.97 dB
Efficiency	92%

4.3 SUMMARY

In this chapter the design simulation and performance of the proposed low frequency antenna results have been discussed. Doing so much parametric study on the position and size of the inset on the patch finally the perfect S11 and bandwidth has been achieved.

CHAPTER V

UWB ANTENNA FOR HIGH FREQUENCY

5.1 INTRODUCTION

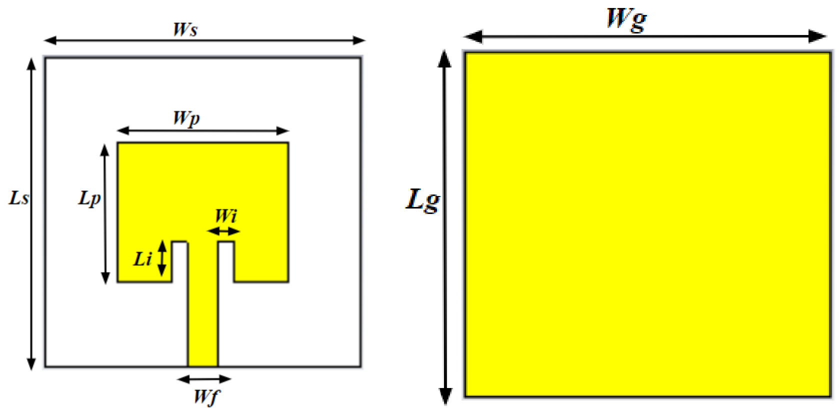
In this chapter, the design, simulation and result have been discussed for high frequency single band and dual band both antennas. Normally the both single and dual band antennas have the same design parameter but a little bit change on dual band, S shaped slot has been added on patch. Owing to addition of S-shaped slot in the patch of prior designed single band MPA, an additional band has attained. Due to the insertion of the slot the proposed antenna got dual band characteristics. The effects of slots on antenna performance are analyzed by using CST simulation software before the actual prototype is fabricated.

5.2 HIGH FREQUENCY ANTENNA DESIGN

(A) SINGLE BAND DESIGN

5.2.1 SINGLE BAND ANTENNA GEOMETRY

A miniaturized antenna has been designed with the dimension of Ws x Ls which is 7.9 X 7.7 mm2 and low-cost substrate material Rogers RT 5880 is used as substrate having a dielectric constant 2.2 with the thickness Hs of 0.254 mm. This fully copper grounded design with the same dimension Wg x Lg as substrate and it is excited with 50Ω microstrip feedline which is Wf. Inset has been added on the patch to get improved results. Length and width are optimized to improve performance of S11 parameter. An inset of 1 mm height and 0.4 mm width has been added to improve the gain and bandwidth. On figure 5.1 the front view and back view of this proposed design is illustrated.



(a) (b)

FIGURE 5.1 (a) Front (b) Back view of the antenna.

TABLE 5.1 Optimized attributes of high frequency single band antenna

Parameters	Description	Values (mm)
Ws	Substrate width	**7.9**
Ls	Substrate Length	**7.7**
Wg	Ground width	**7.9**
Lg	Ground Length	**7.7**
Lp	Patch length	**3.466**
Wp	Patch width	**4.232**
Wf	Feedline width	**0.782**
Hs	Substrate height	**0.254**

Li	Inset height	**1**
Wi	Inset Width	**0.4**

5.2.2 ANTENNA PERFORMANCE

RETURN LOSS

Return loss is the ratio of the reflected power to the incident power, in decibels (dB). A high return loss indicates a large amount of power is being reflected back. So, the standard value of return loss should be lower than -10 dB. The simulated return loss on the peak 28 GHz is -31.61 db < -10 db which is quite good for high frequency 5g antennas. The working frequency is 27.67 GHZ to 28.33 GHZ and the bandwidth is nearly 660 MHz is wide bandwidth. on figure 5.2 the simulated S11 is shown.

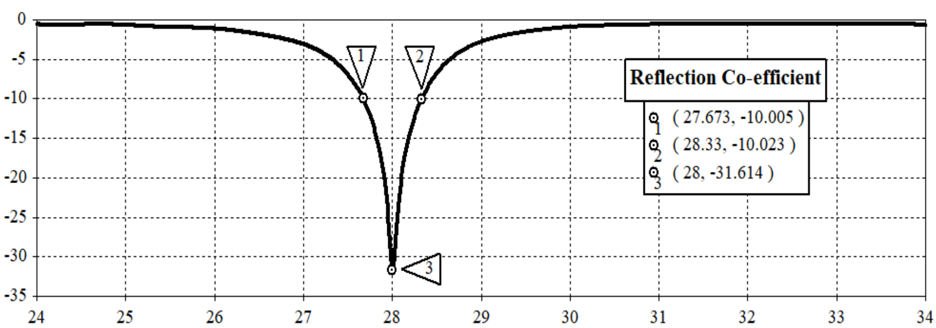


FIGURE 5.2 Simulated S- parameters of the proposed antenna.

VOLTAGE STANDING WAVE RATIO

The Voltage Standing Wave Ratio indicates the mismatch between an antenna and the feed line. The value of VSWR ranging from 1 to ∞. Value below 2 is considered suitable for most antenna applications. The antenna can be described as having a “Good Match”. The proposed antenna resulted in VSWR 1.05 in between 1 and 2 which is quite an acceptable result at higher frequencies. The VSWR of the proposed antenna is projected in figure 7.

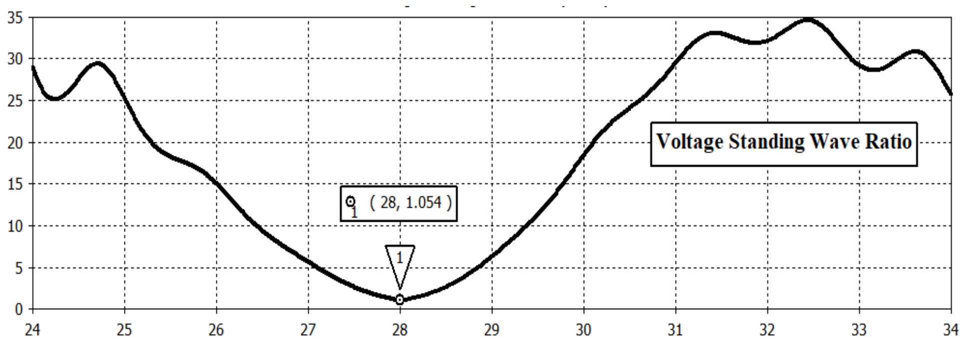


FIGURE 5.3 VSWR

EFFICIENCY

The ratio of total delivered power to the antenna and the power radiated from the antenna indicates the efficiency of the antenna. On a highly efficient antenna most of the power present at the antenna's input that gets radiated away. Low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch. Figure 5.4 shows the efficiency.

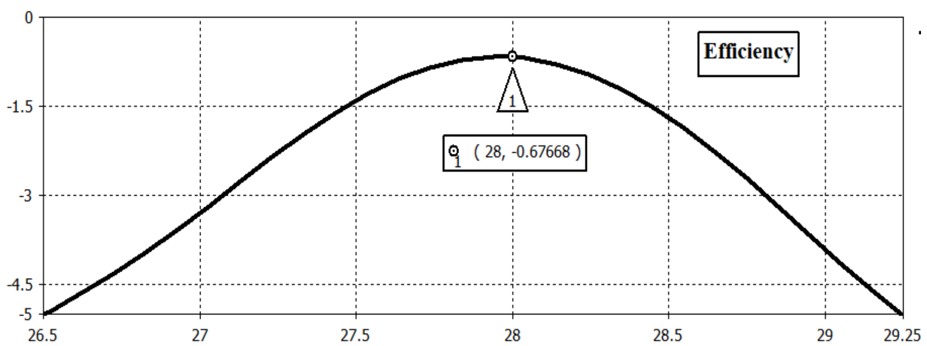


FIGURE 5.4 Efficiency

GAIN

Gain is the combination of antenna's directivity and electrical efficiency. Gain describes how well the antenna converts input power into radio waves headed in a specified direction during transmitting signal. For high frequency microstrip antennas the gain should be ≥ 3.5 dB. Here the simulated gain on peak 28 GHz is 7.39 dB > 3.5 dB that is illustrated on figure 5.5.

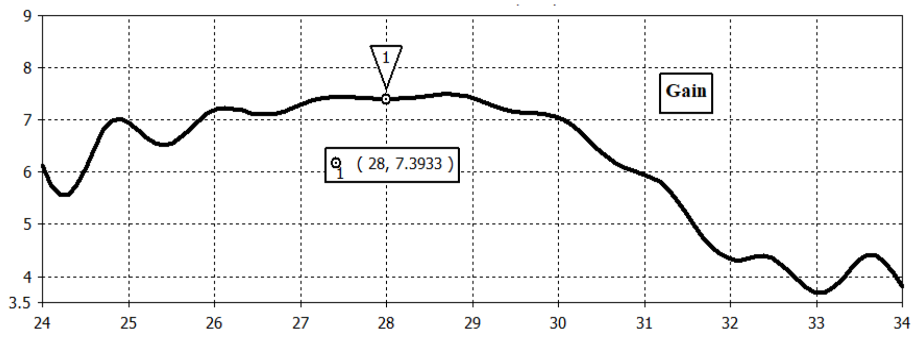


FIGURE 5.5 Gain

CURRENT DISTRIBUTION

To get proper understanding about the electromagnetic behavior of the antenna the surface current distribution should be investigated. The surface current of the proposed design is depicted on figure 5.6. It is clearly observed that the current is concentrated all over the patch and deeply concentrated on the two inset gaps near the feed line and the middle part of the patch. The proper distribution of the current on the patch ensures the proper performance of this antenna, for high frequency antennas it specially depends on radiating patch and for lower frequencies it depends on the feed line.

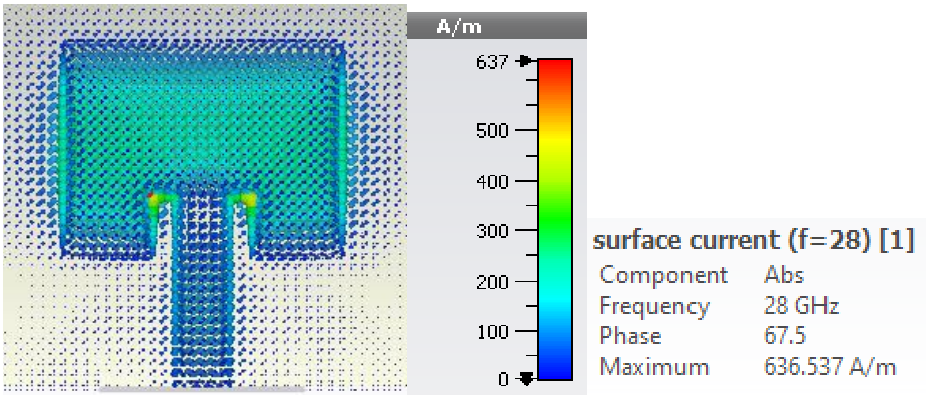
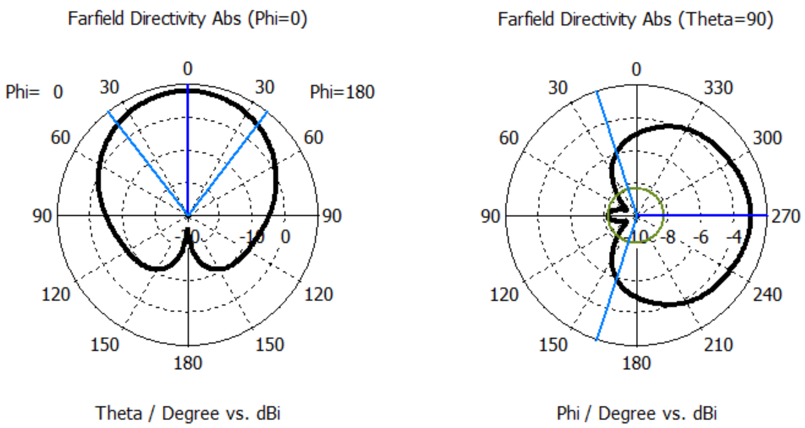


FIGURE 5.6 Surface current distribution

RADIATION PATTERN 2D

The radiation pattern of this proposed single band high frequency antenna in E-plane (phi= 0°) and H-plane (phi= 90°) are calculated and measured for the peak resonance frequency 28 GHz that are widely used for 5g wireless communication and mobile communication. Figure 5.7 illustrates the 2D radiation pattern that has been measured in terms of E_ϕ and E_θ components.



(a) (b)

FIGURE 5.7 (a) E- plane at 28 GHz (b) H- plane at 28 GHz

RADIATION PATTERN 3D

The 3D radiation patterns for electric fields at 28 GHz are shown on figure 5.8. In the radiation pattern the red parts indicate the strongest radiated E- field and the blue indicates the weakest part of the radiation. From this radiation pattern it is observed that the pattern is almost 360 degree scattered and it acts like omnidirectional which is the key need factor in 5g wireless communication and 5g enabled devices.

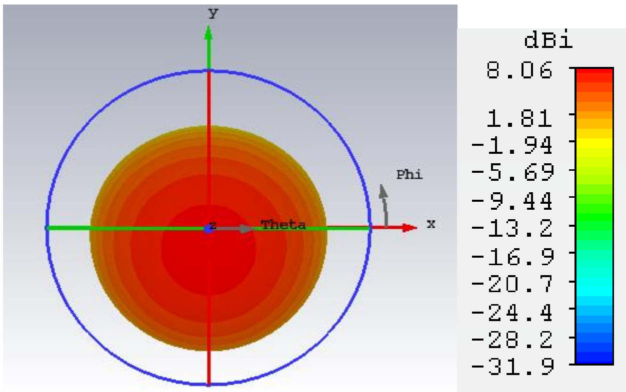


FIGURE 5.8 Simulated 3D radiation pattern at 28 GHz

TABLE 5.2 Summarized result of high frequency single band antenna

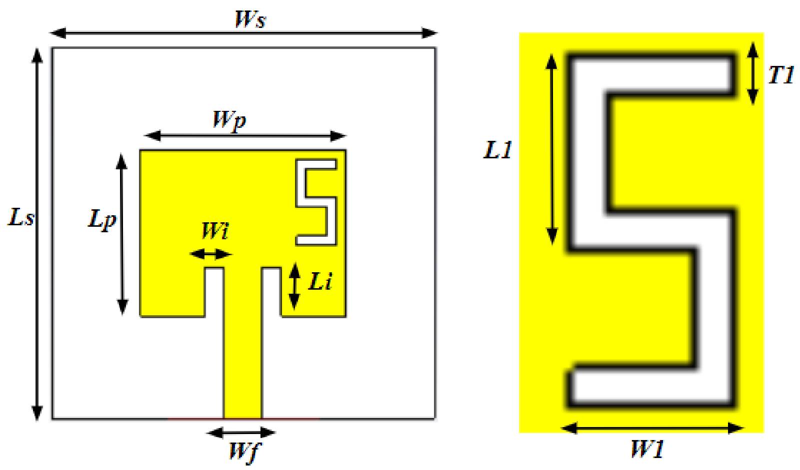
Parameters	**Value**
Size	7.9 X 7.7 mm^2
Operating frequencies	27.67 GHz - 28.33 GHz
Peak gain	7.39 dB
Directivity	8.05 dB
Efficiency	91%

5.3 (B) DUAL BAND DESIGN

5.3.1 DUAL BAND ANTENNA GEOMETRY

A dual band antenna has been designed on the same dimension as a high frequency single band antenna that has already been discussed above on section 5.2.1 doing little bit modification on patch by adding a S shaped slot on right top corner of the patch that has avail the characteristics of dual band. The antenna resonates at 27.27 GHz as well as 36.43 GHz.

After doing many parametric studies on the position of this S shaped slot on the patch finally on the right top corner is chosen due to antennas good performance. Thickness of this slot is T1 which is 0.2mm and the width and length of this slot is W1 and L1. Here the same 50-ohm microstrip feedline technique is used to excite the patch. Inset gaps are added on patches to improve the bandwidth and gain. Figure 5.9 illustrates the front view and the slot dimensions of this dual band antenna.



(a) (b)

FIGURE 5.9 (a) Front view, (b) Slot dimension of the dual band antenna.

TABLE 5.3 Optimized attributes of this dual band antenna

Parameters	Description	Values (mm)
Ws	Substrate width	**7.9**
Ls	Substrate Length	**7.7**
Lp	Patch length	**3.466**
Wp	Patch width	**4.232**
Wf	Feedline width	**0.782**
Hs	Substrate height	**0.254**
Li	Inset height	**1**
Wi	Inset Width	**0.4**
T1	Slot Thickness	**0.2**
L1	Slot Length	**1**
W1	Slot Width	**0.8**

5.3.2 ANTENNA PERFORMANCE

RETURN LOSS

As an S slot has been added on the patch that the antenna gets dual band characteristics. It has two sharp peaks of 27.27 GHz and 36.43 GHz respectively. After doing so many parametric studies finally the top right most corner is selected for the slot placement thus the return loss and bandwidth get improved. The simulated values of the S11 is -14.63 dB and -21.77 dB respectively on 27.27 GHz and 36.43 GHz. As it is a dual band antenna the first working band is 27 GHz to 27.50 GHz which is nearly 500 MHz and the second working frequency band is 36.14 GHz to 36.71 Ghz which is nearly 570 MHz Figure 5.10 depicts the S11 coefficient values on each peak frequency.

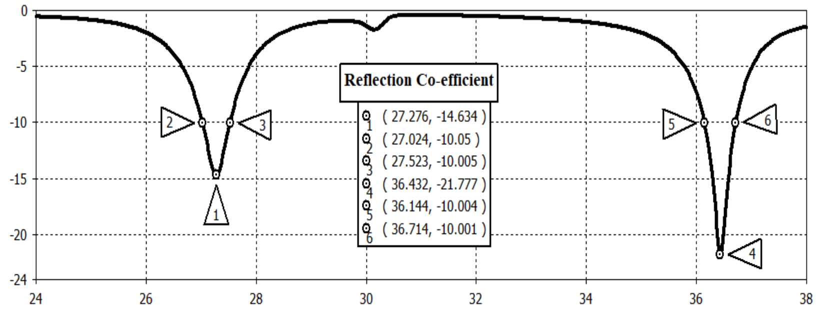


FIGURE 5.10 S11 parameter of dual band antenna

VOLTAGE STANDING WAVE RATIO

The standard value of the VSWR for high frequency microstrip patch antennas should be between 1 and 2. After simulation the resulting vswr for this dual band antenna is 1.45 < 2 at 27.27 GHz and 1.17 < 2 at 36.43 GHz. Figure 5.11 depicts the resulting vswr values for this dual band antenna.

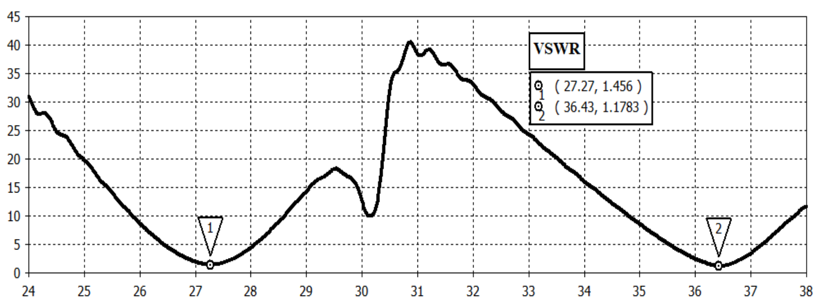


FIGURE 5.11 VSWR

EFFICIENCY

This dual band antenna has nearly good efficiency. Some low performance caused due to impedance mismatch and dielectric loss tangent. Figure 5.12 shows the efficiency of the dual band antenna.

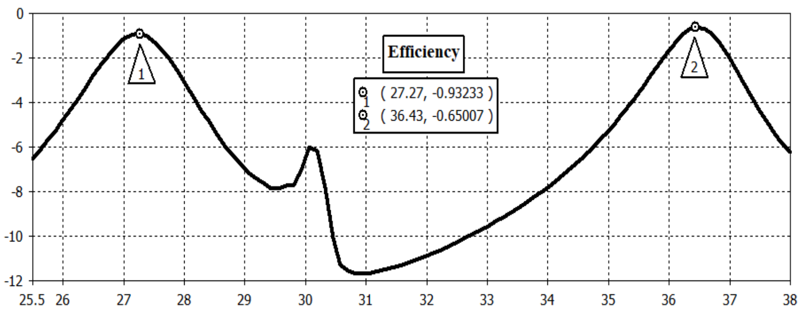


FIGURE 5.12 Efficiency

GAIN

The peak gain of this dual band antenna is measured 7.29 dB at 27.27 GHz and 6.05 at frequency 36.43 GHz both of them are > 3.5 dB Figure 5.13 illustrates the values of simulated gain for this design.

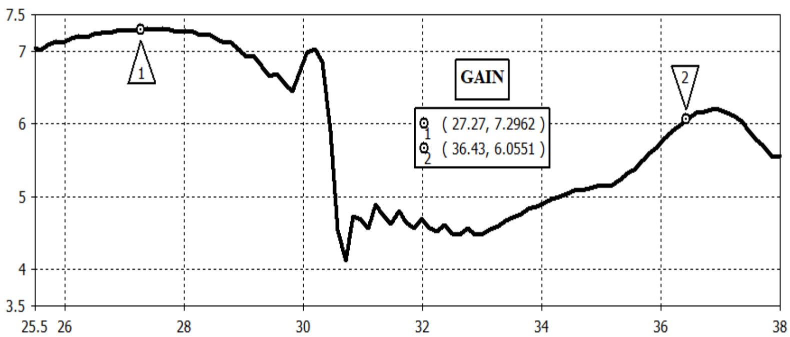
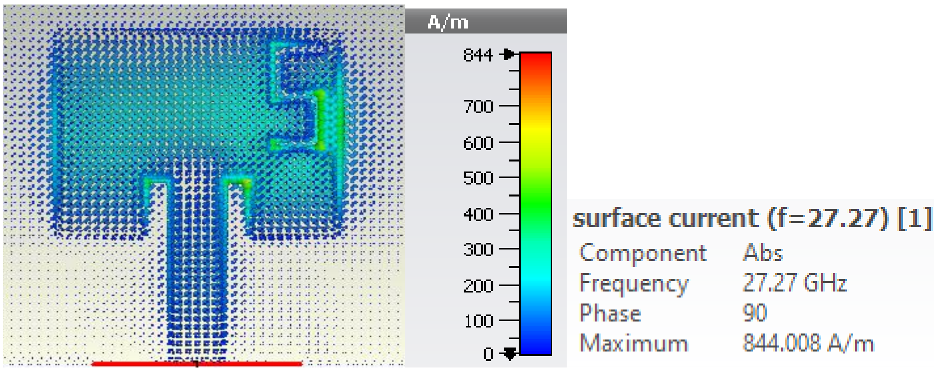


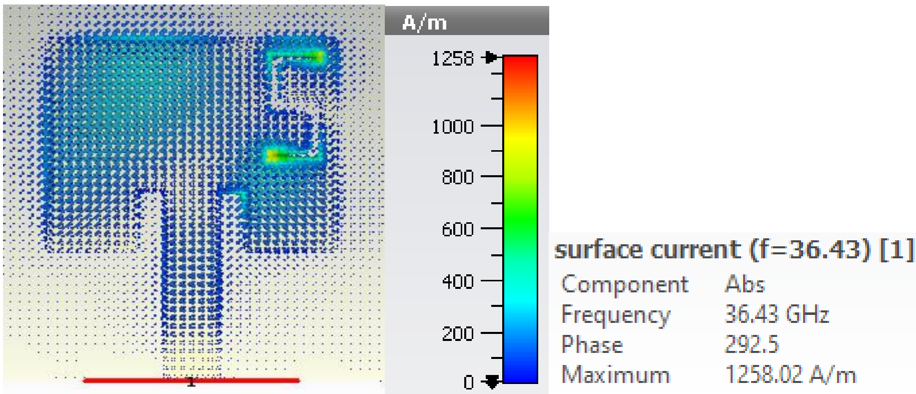
FIGURE 5.13 GAIN

CURRENT DISTRIBUTION

To get proper understanding about the electromagnetic behavior of the antenna the surface current distribution should be investigated. The surface current of the proposed design is depicted on figure 5.14. It is clearly observed that the current is concentrated all over the patch and deeply concentrated on the two inset gaps near the feed line and the middle part of the patch. The proper distribution of the current on the patch ensures the proper performance of this antenna, for high frequency antennas it specially depends on radiating patch and for lower frequencies it depends on the feed line.



(a)

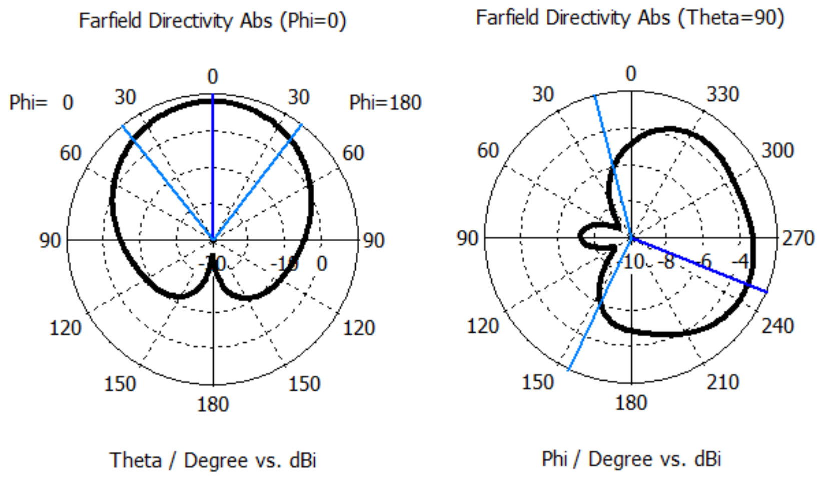


(b)

FIGURE 5.14 (a) surface current at 27.27 GHz (b) surface current at 36.43 GHz

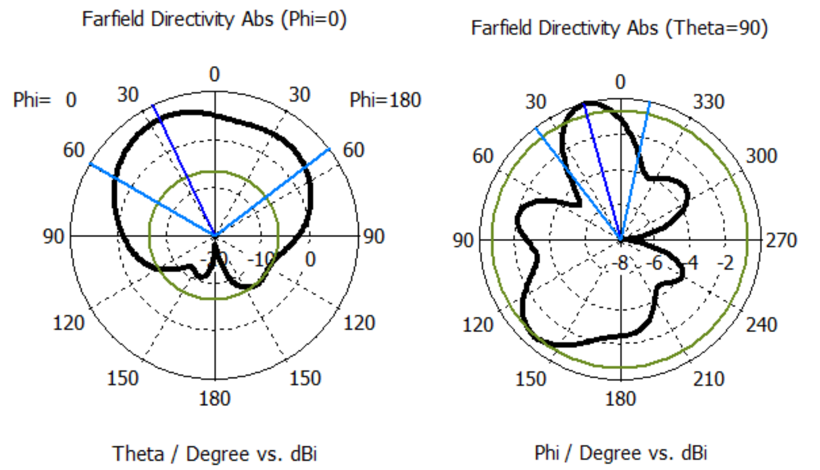
RADIATION PATTERN 2D

The radiation pattern of this proposed single band high frequency antenna in E-plane (phi= 0°) and H-plane (phi= 90°) are calculated and measured for the peak resonance frequency 27.27 GHz and 36.43 GHz that are widely used for 5g wireless communication and mobile communication. Figure 5.15 and 5.16 illustrates the 2D radiation pattern that has been measured in terms of E_ϕ and E_θ components.



(a) (b)

FIGURE 5.15 (a) E- plane at 27.27 GHz (b) H- plane at 27.27 GHz



(a) (b)

FIGURE 5.16 (a) E- plane at 36.43 GHz (b) H- plane at 36.43 GHz

RADIATION PATTERN 3D

The 3D radiation patterns for electric fields at 27.27 GHz and 36.43 GHz are shown on figure 5.17. In the radiation pattern the red parts indicate the strongest radiated E- field and the blue indicates the weakest part of the radiation. From this radiation pattern it is observed that the pattern is almost 360 degree scattered and it acts like omnidirectional which is the key need factor in 5g wireless communication and 5g enabled devices.

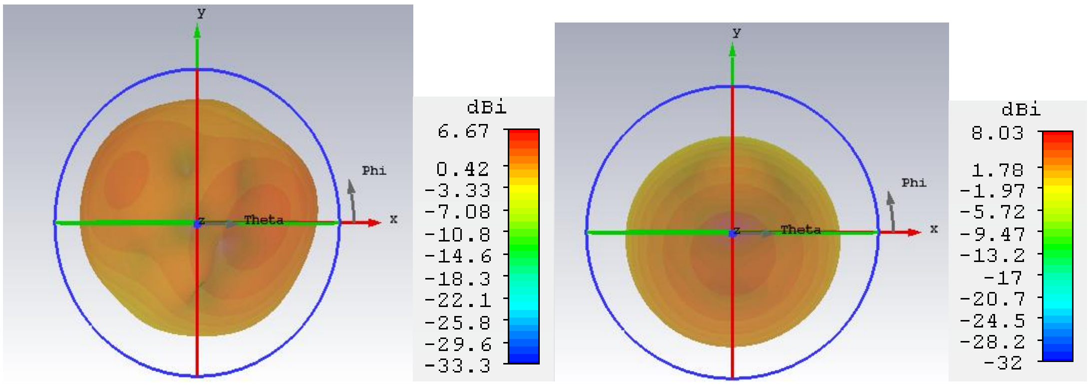


FIGURE 5.17 3D radiation pattern at (a) 36.43 GHz (b) 27.27 GHz

TABLE 5.4 Summarized result of this high frequency dual band antenna

Parameters	**Value**
Size	7.9 X 7.7 mm^2
Operating frequencies	27.02 GHz - 27.52 GHz 36.14 GHz - 36.71 GHz
Peak gain	7.29 dB, 6.05 dB
Directivity	8.03 dB, 6.67 dB
Efficiency	90%, 90%

TABLE 5.5 Comparison between single and dual band

Parameters	**SINGLE BAND**	**DUAL BAND**
Size	7.9 X 7.7 mm^2	7.9 X 7.7 mm^2
Operating frequencies	27.67 GHz - 28.33 GHz	27.02 GHz - 27.52 GHz 36.14 GHz - 36.71 GHz
Peak gain	7.39 dB	7.29 dB, 6.05 dB
Directivity	8.05 dBi	8.03 dBi, 6.67 dBi
Efficiency	91%	90%, 90%

5.4 SUMMARY

This chapter mainly focuses on design, simulation and measurement of the two high frequency antennas, one for single band and another for dual band operation for 5G advanced communication. Both antennas are capable of wideband operation. Several parametric studies are done for getting good results from these two proposed antennas. Last of all the comparison between two types of antennas are also discussed.

CHAPTER VI

CONCLUSION

6.1 CONCLUSION

Ultra-Wide Band is a promising innovation that brings the convenience, versatility and mobility of correspondences to high-speed interconnections in remote gadgets and wireless devices. As a fundamental part of the communication system, designing antenna is challenging since there are more particular requirements for UWB antennas compared to its narrow band counterpart. Likewise, to be effortlessly incorporated into convenient devices, small in size and compact planar profile UWB antennas are exceptionally attractive and essential for a wide assortment of uses. Therefore, the design and analysis of planar antenna for UWB applications are conducted in this thesis.

We are designing three antennas for two 5G bands. One is designed for lower frequency which range 3 GHz to 8 GHz and another antenna was designed for higher frequency range 24 GHz to 38 GHz. In higher frequency there were two antennas designed one for single band and another for dual band.

For lower frequency we observed that this antenna works on 6 GHz, with reflection coefficient of -16.86 dB. The simulated Gain of this proposed antenna is 6.45 dB & the VSWR is 1.33 which is in between 1 and 2.

The high frequency single band antenna works on 28 GHz, with resulted reflection coefficient of -31.61 dB. The simulated Gain of this proposed antenna is 7.39 dB & VSWR is 1.05 which is in between 1 and 2.

A rectangular planar antenna that was initially chosen as conventional structure due to its low profile and ease of fabrication. However, its performance is significantly affected by the large ground plane. It is observed that the cutting S- shaped slots on the ground plane help to increase the bandwidth. This antenna works on 27.27 GHz and 36.43 GHz, with return loss of -14.63 dB and -21.77dB respectively. The simulated Gain of this proposed dual band antenna is 7.29 dB & 6.05 dB.

6.2 CONTRIBUTION OF THE THESIS

Three microstrip line-fed rectangular for lower frequency, rectangular for higher frequency and rectangular with S -slot antennas were proposed. All the design features compact size, simplicity of manufacture, low profile and compatibility with PCB. A novel S-slot antenna was proposed which can be considered as one of the smallest UWB antennas.

All the antennas proposed in the thesis can exhibit UWB characteristic with almost 360-degree (Omni-directional) radiation patterns and efficient Time Domain Behaviors which make them entirely appropriate for being utilized in viable UWB applications.

6.3 FUTURE WORKS

Design of UWB antenna for 5G application is as yet an intriguing issue. Some aspects of the present research work can be further investigated and improved in the following areas.

Firstly, additional study is needed with different kind of feeding techniques, like coplanar waveguide (CPW) for this proposed antenna. This will be useful for the future design, in order to reduce the inaccuracy due to copper metal dielectric losses, mismatch between patch and ground plane on both sides of the substrate during the fabrication process.

Secondly, for some directional systems, a high gain antenna is essential to attain high quality communication hyperlink in addition to high bandwidth can also be required in some communication sectors. Therefore, the research on improvement of bandwidth and directional antenna and antenna array will be carried out in future.

Finally, in this research work we use ROGERS RT 5880 dielectric substrate. For this reason, efficiency and gain can be affected due to dielectric losses. Therefore, in future the antennas can be fabricated on other low loss dielectric substrate material to compare and improve the antenna performance.

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