PHASED ARRAY ANTENNA DESIGN FOR 5G NETWORK TECHNOLOGY

SUBMITTED BY

Yahya Abdullahi Moalim Osman

181-31-256

This Report Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science in Electronics and Telecommunication Engineering

SUPERVISED BY

Md. Taslim Arefin

Associate Professor and Head

Department of ETE

Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY DHAKA, BANGLADESH

APPROVAL

This thesis titled "**PHASED ARRAY ANTENNA DESIGN FOR 5G NETWORK TECHNOLOGY**", submitted by Yahya Abdullahi Moalim Osman to the Department of Electronics and Telecommunication Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of M.Sc. in Electronics and Telecommunication Engineering. The presentation was held on August 2019.

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(Md. Taslim Arefin)
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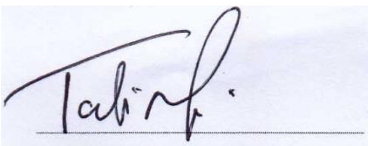

(Md. Taslim Arefin)
Associate Professor & Head
Department of ETE
Faculty of Engineering
Daffodil International University

Submitted by:

Yahya Abdullahi Moalim Osman

ID: 181-31-256

Department of ETE

Daffodil International University

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ABSTRACT

In this thesis, a phased array antenna design for 5G mobile communication is presented. In smart antenna for 5G, it has an ability to radiate signal towards users at far distance with high directivity. Our project we used a notched circular patch antenna array operating at 28 GHz using CST software. Extensive optimization process for optimum antenna performance is generated besides analyzing the beam forming pattern of the antenna for 5G antenna using CST software. Several methods are used throughout the design procedure, such as The antenna design tool Antenna Magus. Antenna Magus is a new software tool to help engineers accelerate the antenna design and modelling process. It has a huge database of designed antennas which can be exported to CST MICROWAVE STUDIO for further analysis and optimization. This simplifies the day-to-day work of antenna designers and modelers ensuring that more projects are completed within specification and on time. Specifically, 2x2 array and 2x4 array antennas which have an antenna spacing of lambda (λ) are designed consecutively. Rogers of εr 2.2 (Rogers RT5880) is used as the dielectric substrate because a low dielectric substrate close to air or close to 1 will allow a higher radiation pattern as compared to much higher permittivity value and also a substrate thickness of 0.5357mm is used. The simulation is successfully completed for getting the results that fulfil the design specification which has return loss of -10. The gain and directivity at the operating frequency is greater than 10dB and 10dBi.The bandwidth is greater than 4 GHz.

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CHAPTER ONE

1.1 Introduction

What will the future be? How long will the current broadband mobile communication, 4G lasts? Internet of Things (IOT) is becoming popular and it is shaping the future. Soon enough, things connected to the internet will no longer limited to mobile phones and computers. In the very near future, the living things such as the pets, wild animals or even human ourselves are connecting to the internet. The possibilities are endless and limitless. With the help of fast internet, augmented reality with low latency can be made possible. However, when it comes to critical applications such as far-distance surgery controlled by robotic arms, 41.5 ms is far too long to ensure a smooth surgical procedure without risking the life of patients. Hence, to guarantee a betterment of the future, 5G is needed. [13]The 5 generations will be a model shift that will contains a very huge carrier with enormous bandwidths, device densities and extreme base station and new numbers of antennas. Mobile communications are becoming progressively demanding as far as bandwidth is concerned due to the increased content requirements. In order to face this challenge, the telecommunication community will channel towards higher frequencies where more spectrum could be accessible. Furthermore, the local multipoint distribution service (LMDS) band around 28 is a potential entrant for short range outdoor wireless communications. However, at higher frequencies, since the wavelength becomes increasingly, the antenna design challenges change from declining size and shrinking to increasing gain and enabling beam navigation. The new spectrum is mostly expected to be allocated in the super high-frequency bands (3-30GHz) as well as the extremely high frequency bands (30-300 GHz), also referred to as mm Wave bands, where the channel transmission characteristics are different from those of frequency bands below 3 GHz. This difference will require a new strategy of the air-interface and network architecture. [17]To make our imagination become reality, we are trying to design an antenna for 5G communication at 28 GHz. This project using Computer SimulationTechnology (CST), it will analysis the important part of the antenna such as return loss, radiation pattern and so on. [18]

The 28 GHz band has not been studied for mobile application and there are very few researchers actively pursuing this topic. Therefore, the need to develop antenna solutions for mobile components at these frequencies is a key enabler. Printed solutions for Ka-band are rare. [17].

1.2 Objective of the research

There are three main objectives of this project work enlisted as follows:

I. To explain on the concept of 5G and phased array antenna.
II. To analysis and comparison for exist model and proposal model.
III. To design and simulate phased array patch antenna at 28 GHz band by using CST software.

1.3 Scope of study

The main idea of work is to read and understand the suitable formula and theory in order to get the parameters which are used in designing the antenna array for 28 GHz by using CST software.

1.4 Outline of the thesis:

Chapter 1 we will present the introduction to the project, objective, scope of work, and review of all chapters in this project.

Chapter 2 provides a Literature overview with a brief history of phased array antenna design and 5Gmobile communication and its components stating the contributions of previous researchers, and the classification and discussion based on the materials, the applications, the antenna shapes, or design, the antenna efficiency and characteristics.

Chapter 3 presents problem statement.

Chapter 4 presents the methodology used in the design process in this project and involves the procedure, calculation, Gantt chart and parametric study of antenna using CST.

Chapter 5 presents the results achieved from this project.

Chapter 6 Analysis for exist and proposal models

Chapter 7 finalizes the thesis with conclusions and recommendations for future works.

CHAPTER TWO

Literature Review

2.1 General Introduction

This chapter demonstrates about the journals and research papers related to the design workflow of phased array antenna for 5G applications. There are variety of study and research done on 5G communication system but until today, the clear-cut rule or an international standard for 5G does not exists. Each of the journal has their own distinct research value. Different methods and workflows are used to design the antenna for 5G applications. An idea is nothing more or less than a different mixture of old fundamentals. The journals assist the student to view the project in a whole, new perspective which generally beyond the university academic syllabus. Through literature review, latest news and development of technology related to 5G telecommunication sector will be reviewed while the new design rules and solutions are learned and applied to solve specific problem for this investigation. Sources to obtain the journals are extensively available from the internet and online platform such as IEEE, IET Digital Library, and Science Direct [1].As there is tremendous growth being observed in the use of mobile technology since last few years, there are more and more devices getting connected. This ever growing need for mobile data approaches the limits of 4G technologies. This requirement led to the efforts to work towards next future mobile communication generation i.e. fifth Generation (5G) and define, develop and standardize systems and services for this next generation [1].

2.2. Background

The generations of mobile communication systems are presented in Table [1]. Mobile phone network has been historically divided into five generations, each generation has specific characteristics that distinguish it from other, each generation is different from the other in terms of frequency, data rate, maximum number of users and the geographical area covered by the network.

Table 2. 1**:** summary of mobile communications generations

Cellular phone generation	1G	2G	3G	4G	5G
1st year deployment	1981	1992	2001	2010	2020
Peak supported data rate	2kbps	64 kbps	2 Mbps	100 Mbps	10 Gbps
Frequency	900MHz	900MHz and 1.8GHz	1.7 to 1.9 GHz 2.1 GHZ	2100MHZ 2600MHZ	28GHZ
General functional description	Analogue cellular phones	Digital cellular phones (GSM/CDMA)	Fist mobile broadband utilizing IP protocols (WCDMA2000)	The mobile broadband on a unified standard LTE	Tactile internet enhance M2M communications network

2.3. 5G Mobile Networks

Today's mobile users want faster data speeds and more reliable service. The next generation of wireless networks—5G—promises to deliver that, and much more. With 5G, users should be able to download a high-definition film in under a second (a task that could take 10 minutes on 4G LTE). And wireless engineers say these networks will boost the development of other new technologies, too, such as autonomous vehicles, virtual reality, and the Internet of Things [2]. If all goes well, telecommunications companies hope to debut the first commercial 5G networks in the early 2020s. Right now, though, 5G is still in the planning stages, and companies and industry groups are working together to figure out exactly what it will be. But they all agree on one matter: As the number of mobile users and their demand for data rises, 5G must handle far more traffic at much higher speeds than the base stations that make up today's cellular networks. To achieve this, wireless engineers are designing a suite of brand-new technologies. Together, these technologies will deliver data with less than a millisecond of delay (compared to about 70 ms on today's 4G networks) and bring peak download speeds of 20 gigabits per second (compared to 1 Gb/s on 4G) to users [2].At the moment, it's not yet clear which technologies will do the most for 5G in the long run, but a few early favorites have emerged. The front-runners include millimeter waves, small cells, massive MIMO, full duplex, and beamforming [see Figure (2.1)].To understand how 5G will differ from today's 4G networks, it's helpful to walk through these five technologies and consider what each will mean for wireless users.

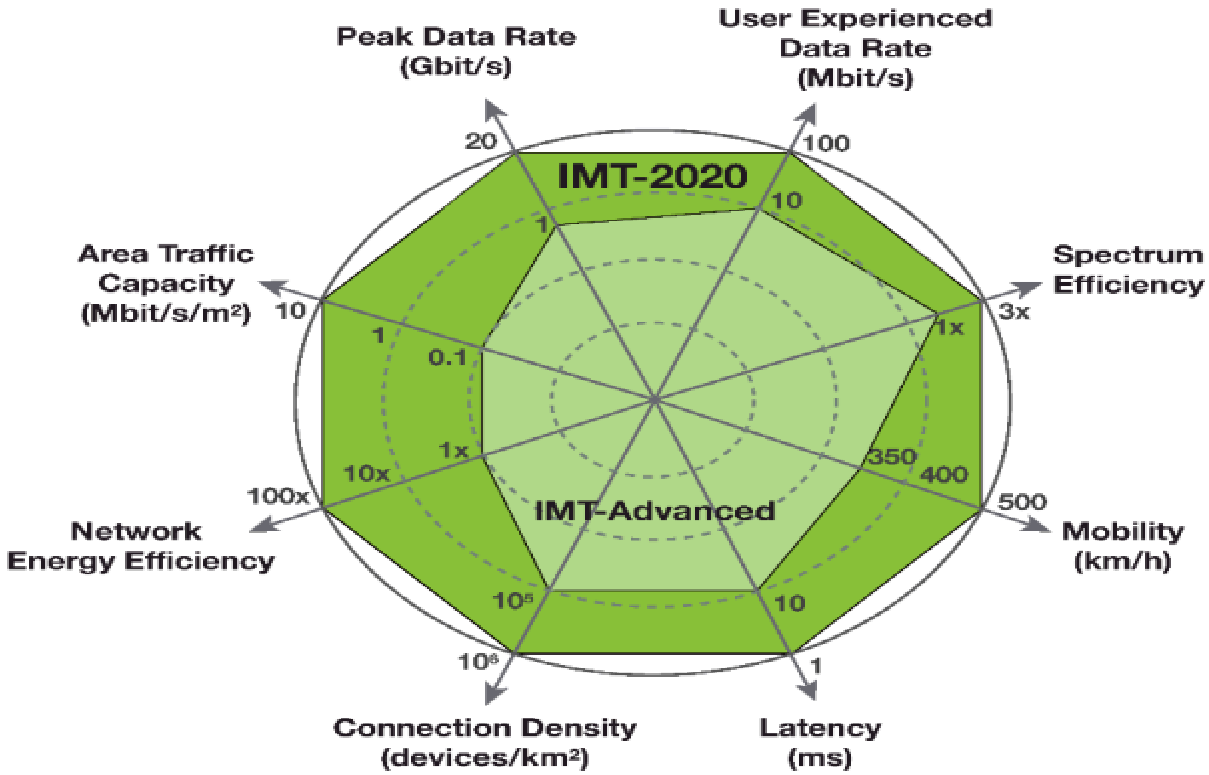


Figure 2. 1: Key capabilities of 5G compared to 4G

2.4. Technologies that could enable ultrafast 5G networks

Millimeter waves, massive MIMO, full duplex, beamforming, and small cells are just a few of the technologies that could enable ultrafast 5G networks

2.4.1. Millimeter Waves

Today's wireless networks have run into a problem: More people and devices are consuming more data than ever before, but it remains crammed on the same bands of the radio-frequency spectrum that mobile providers have always used. That means less bandwidth for everyone, causing slowerservice and more dropped connections. One way to get around that problem is to simply transmit signals on a whole new swath of the spectrum, one that's never been used for mobile service before. That's why providers are experimenting with broadcasting on millimeter waves, which use higher frequencies than the radio waves that have long been used for mobile phones [see Figure (2.2)].Millimeter waves are broadcast at frequencies between 30 and 300 gigahertz, compared to the bands below 6 GHz that were used for mobile devices in the past. They are called millimeter waves because they vary in length from 1 to 10 mm, compared to the radio waves that serve today's smartphones, which measure tens of centimeters in length.

Until now, only operators of satellites and radar systems used millimeter waves for real-world applications. Now, some cellular providers have begun to use them to send data between stationary points, such as two base stations. But using millimeter waves to connect mobile users with a nearby base station is an entirely new approach.

There is one major drawback to millimeter waves, though—they can't easily travel through buildings or obstacles and they can be absorbed by foliage and rain. That's why 5G networks will likely augment traditional cellular towers with another new technology, called small cells [2].

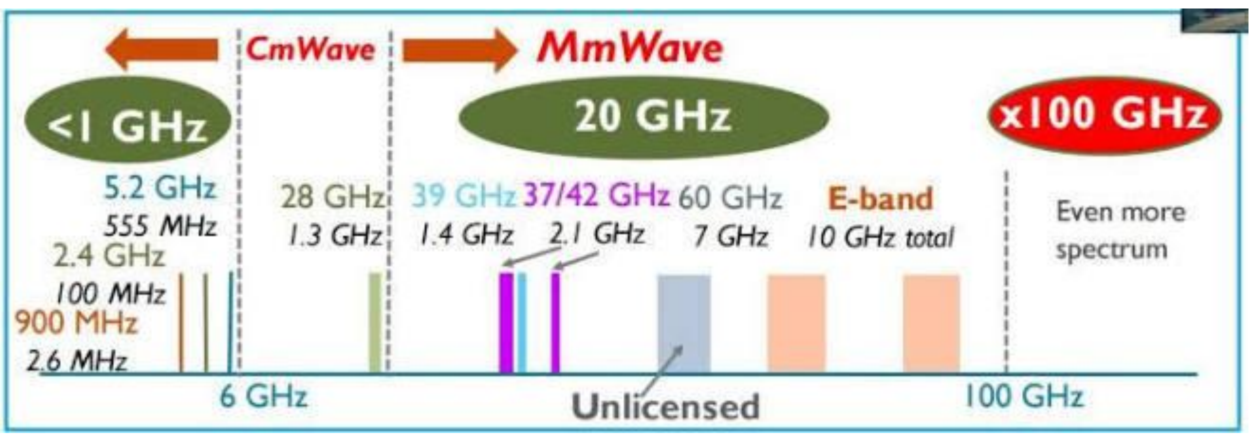


Figure 2. 2: millimeter wave availability

2.4.2. Small Cells

Small cells are portable miniature base stations that require minimal power to operate and can be placed every 250 meters or so throughout cities. To prevent signals from being dropped, carriers could install thousands of these stations in a city to form a dense network that acts like a relay team, receiving signals from other base stations and sending data to users at any location [see Figure (2.3)]. While traditional cell networks have also come to rely on an increasing number of base stations, achieving 5G performance will require an even greater infrastructure. Luckily, antennas on small cells can be much smaller than traditional antennas if they are transmitting tiny millimeter waves. This size difference makes it even easier to stick cells on light poles and atop buildings. This radically different network structure should provide more targeted and efficient use of spectrum. Having more stations means the frequencies that one station uses to connect with devices in one area can be reused by another station in a different area to serve another customer.There is a problem, though—the sheer number of small cells required to build a 5G network may make it hard to set up in rural areas. In addition to broadcasting over millimeter waves, 5G base stations will also have many more antennas than the base stations of today's cellular networks—to take advantage of another new technology: massive MIMO [2].

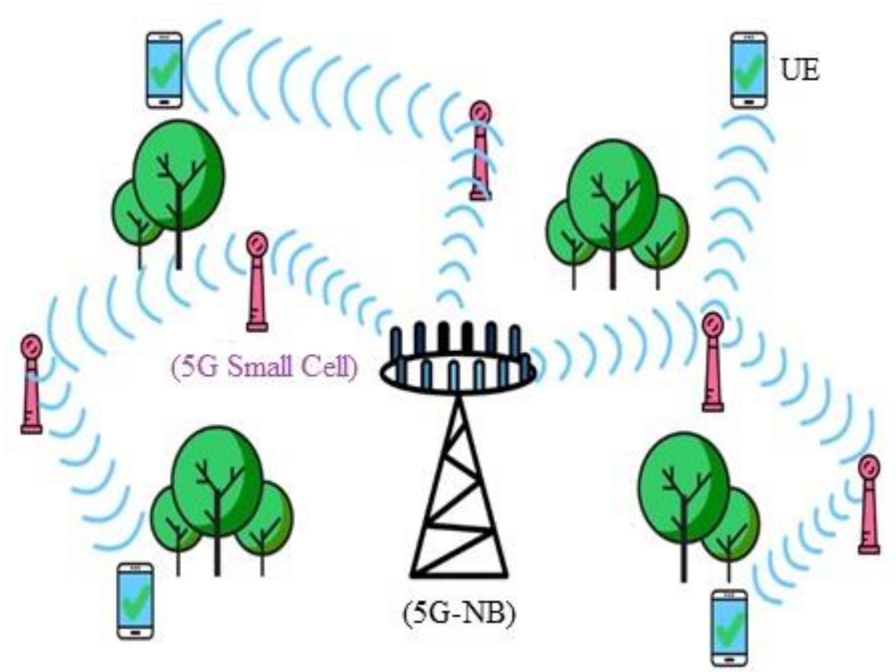


Figure 2. 3: 5G small cells

2.4.3. Massive MIMO:

Today's 4G base stations have a dozen ports for antennas that handle all cellular traffic: eight for transmitters and four for receivers. But 5G base stations can support about a hundred ports, which means many more antennas can fit on a single array. That capability means a base station could send and receive signals from many more users at once, increasing the capacity of mobile networks by a factor of 22 or greater. This technology is called massive MIMO. It all starts with MIMO, which stands for multiple-input multiple-output. MIMO describes wireless systems that use two or more transmitters and receivers to send and receive more data at once. Massive MIMO takes this concept to a new level by featuring dozens of antennas on a single array. MIMO is already found on some 4G base stations. But so far, massive MIMO has only been tested in labs and a few field trials. In early tests, it has set new records for spectrum efficiency, which is a measure of how many bits of data can be transmitted to a certain number of users per second. Massive MIMO looks very promising for the future of 5G [see Figure (2.4)]. However, installing so many more antennas to handle cellular traffic also causes more interference if those signals cross. That's why 5G stations must incorporate beamforming [2].

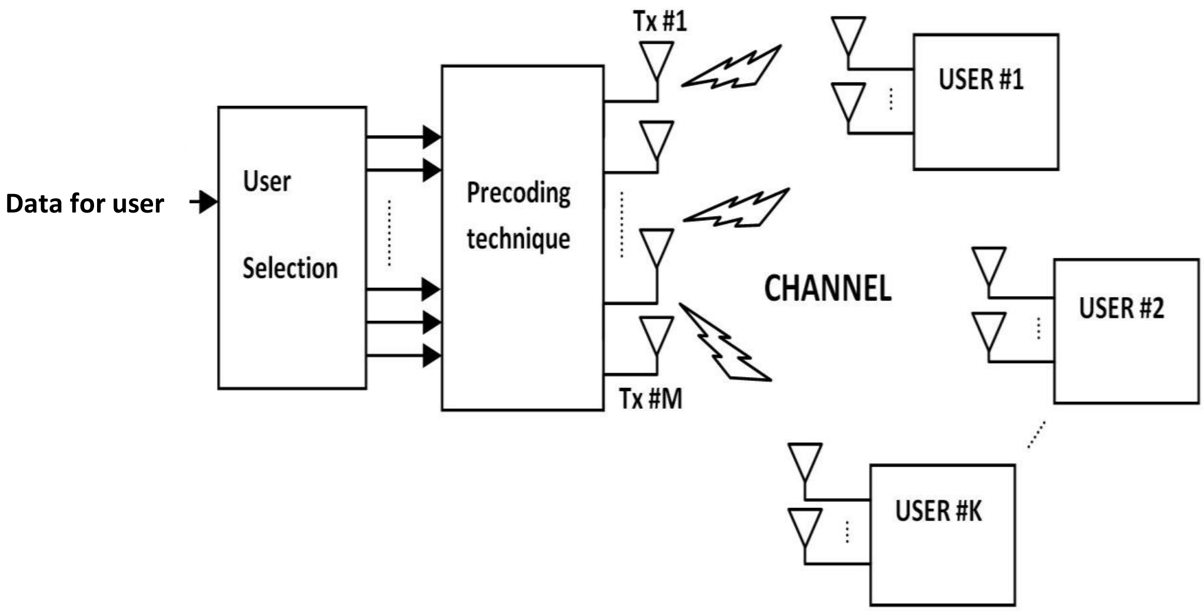


Figure 2. 4: Structure of massive mimo in 5G

2.4.4. Beamforming

Beamforming is a traffic-signaling system for cellular base stations that identifies the most efficient data-delivery route to a particular user, and it reduces interference for nearby users in the process. Depending on the situation and the technology, there are several ways for 5G networks to implement it. Beamforming can help massive MIMO arrays make more efficient use of the spectrum around them. The primary challenge for massive MIMO is to reduce interference while transmitting more information from many more antennas at once. At massive MIMO base stations, signal-processing algorithms plot the best transmission route through the air to each user. Then they can send individual data packets in many different directions, bouncing them off buildings and other objects in a precisely coordinated pattern. By choreographing the packets' movements and arrival time, beamforming allows many users and antennas on a massive MIMO array to exchange much more information at once.For millimeter waves, beamforming is primarily used to address a different set of problems: Cellular signals are easily blocked by objects and tend to weaken over long distances. In this case, beamforming can help by focusing a signal in a concentrated beam that points only in the direction of a user, rather than broadcasting in many directions at once. This approach can strengthen the signal's chances of arriving intact and reduce interference for everyone else [see Figure (2.5)]. Besides boosting data rates by broadcasting over millimeter waves and beefing up spectrum efficiency with massive MIMO, wireless engineers are also trying to achieve the high throughput and low latency required for 5G through a technology called full duplex, which modifies the way antennas deliver and receive data [2].

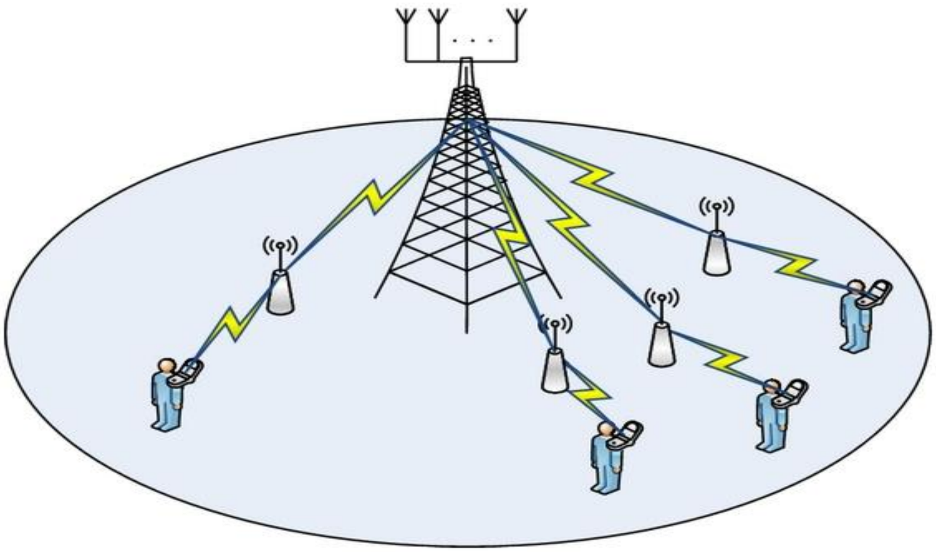


Figure 2. 5: beamforming techniques

2.4.5. Full Duplex

Today's base stations and cell phones rely on transceivers that must take turns if transmitting and receiving information over the same frequency, or operate on different frequencies if a user wishes to transmit and receive information at the same time. With 5G, a transceiver will be able to transmit and receive data at the same time, on the same frequency [see Figure (2.6)]. This technology is known as full duplex, and it could double the capacity of wireless networks at their most fundamental physical layer: Picture two people talking at the same time but still able to understand one another—which means their conversation could take half as long and their next discussion could start sooner. Some militaries already use full duplex technology that relies on bulky equipment. To achieve full duplex in personal devices, researchers must design a circuit that can route incoming and outgoing signals so they don't collide while an antenna is transmitting and receiving data at the same time. This is especially hard because of the tendency of radio waves to travel both forward and backward on the same frequency—a principle known as reciprocity. But recently, experts have assembled silicon transistors that act like high-speed switches to halt the backward roll of these waves, enabling them to transmit and receive signals on the same frequency at once. One drawback to full duplex is that it also creates more signal interference, through a pesky echo. When a transmitter emits a signal, that signal is much closer to the device's antenna and therefore more powerful than any signal it receives. Expecting an antenna to both speak and listen at the same time is possible only with special echo-canceling technology.With these and other 5G technologies, engineers hope to build the wireless network that future smartphone users, VR gamers, and autonomous cars will rely on every day. Already, researchers and companies have set high expectations for 5G by promising ultralow latency and record-breaking data speeds for consumers. If they can solve the remaining challenges, and figure out how to make all these systems work together, ultrafast 5G service could reach consumers in the next five years [2].

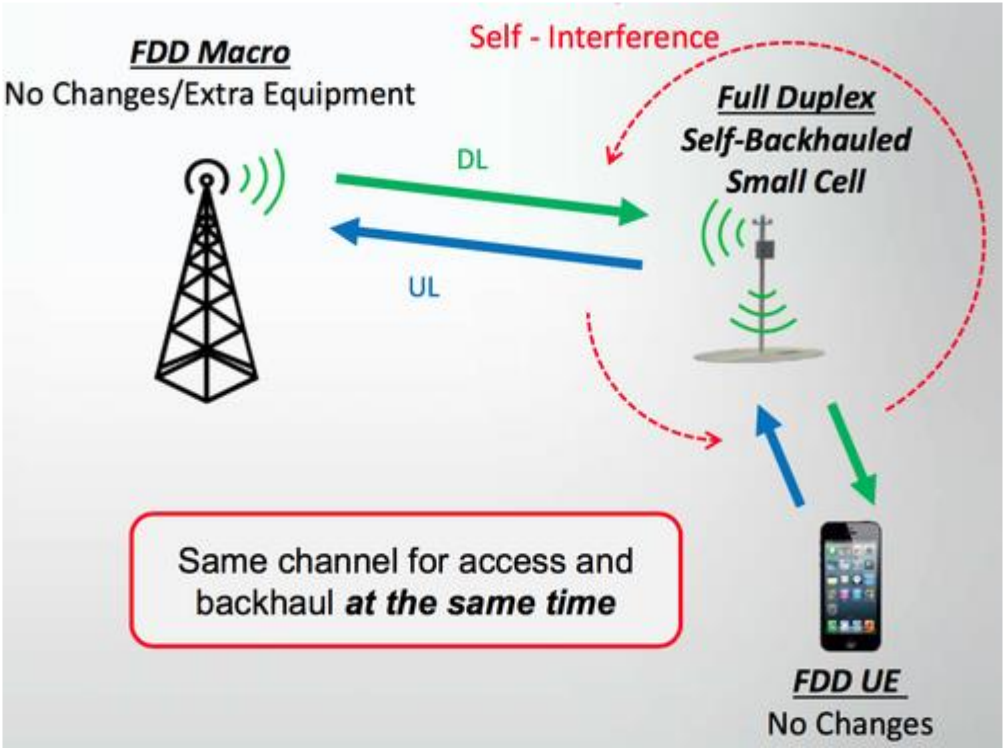


Figure 2. 6: Full - duplex and 5G

2.5. New frequency bands

A key difference between 5G and earlier generations of mobile technology is that the focus of research is on finding the best techniques to improve spectrum utilisation (that is, bits per Hertz per unit area), rather than on improving spectrum efficiency (that is, bits per Hertz). This is because improvements in spectral efficiency are constrained by background noise, meaning that improvements through coding and modulation design become more difficult and less effective (the 'Shannon Limit'). However, new technological approaches can substantially improve spectrum utilisation, defined in terms of bits per Hertz per cell (or area). They can also enable networks to become more flexible and suitable to carry some of the new applications and use cases being foreseen within 5G [4]. Proposed technologies such as massive MIMO, super-dense meshed cells and macro-assisted small cells ('phantom cells') are all possible 5G radio access techniques targeting better spectrum utilisation, higher speeds and lower latency. From the user's perspective, the aim is to provide a better and more-consistent service regardless of location. Many of the technologies being researched are inherently better suited to being deployed in very high frequency bands – in the ‘millimetre’ range of radio spectrum (current 5G researchincludes trials conducted in bands such as 15GHz, 28GHz, 60GHz and 70GHz, for example – substantially higher bands than mobile communications has traditionally used). This spectrum can better support the use of multiple, miniaturised antennas (since the wavelength of higher frequency bands is shorter and antenna spacing is based on wavelength, so more antenna elements can be accommodated). Furthermore, substantially more bandwidth is available in these bands than in the bands below 1GHz, which is beneficial for providing much wider channels and higher speeds as envisaged by 5G, without the need for multiple antennas. However, millimetre-wave bands do not lend themselves to providing wide area coverage for mobile devices (and coverage will be essential for some envisaged 5G services, such as IoT applications such as for the automotive industry). Therefore, further spectrum below 1GHz is expected to be needed in many countries to improve mobile broadband coverage. The spectrum needs for 5G might therefore encompass a range of existing and new bands, which potentially span a wide section of radio spectrum. Different bands will serve different purposes and a key aspect of 5G will be to integrate the various approaches and bands within a harmonised global framework (table 2 summarises examples of different spectrum possibilities). Early indications suggest that spectrum sharing is likely to be used in a far greater way, which may signal an end to further spectrum being reserved for ‘exclusive’ mobile broadband use as 5G is introduced.5G will require new as well as established spectrum bands, but the availability of new bands is not confirmed

Table 2. 2: Comparison of spectrum possibilities for 5G

Band and bandwidth available	Merits	Spectrum packaging/number of licences
700MHz Varies in different markets, from around 2×30MHz to 2×45MHz	Ideal for providing wide area coverage, needed for certain envisaged applications (for example, IoT)	Channel size likely to be similar to other mobile bands in use below 1GHz, for example, multiples of 5 or 10MHz, and spectrum packages will be similar to other bands below 1GHz, for example, 3 or 4 licences of 2×10MHz per operator maximum
3.4–3.8GHz Up to 400MHz either in a paired or an unpaired arrangement	Depending on use by existing services this band could provide substantially more bandwidth than bands below 1GHz (for example, 100MHz and above)	Channel sizes likely to be multiples of 20MHz, meaning 4 or more licences of 50–100MHz could be feasible depending on the available spectrum in the band
5GHz This band is being considered at the ITU World Radio Conference in 2015 (WRC-15) – in total over 300MHz in new spectrum could be allocated	If agreed at WRC-15, a contiguous band from 5150 to 5925MHz would be created using a combination of existing and new spectrum	Channel sizes likely based on current Wi-Fi use, in multiples of 20MHz, and the band is likely to remain as a licence-exempt band in line with current Wi-Fi
15GHz Potentially over 500MHz depending on the sub-band used and sharing with existing uses	Very high speeds are achievable – for example, peak speeds of 5Gbps have been demonstrated already1	Channel sizes could be very wide, for example, multiples of 100MHz Depending on the bandwidth available, the band could accommodate multiple operators, with the opportunity for companies other than established mobile operators to offer some 5G services with an assignment of

		100MHz per operator, or more, depending on national availability and sharing with existing services
28GHz Similar to the 15GHz band, for example, over 500MHz depending on the sub-band used and sharing with existing uses	Similar to the 15GHz band	Channel sizes could be very wide, for example, multiples of 100MHz Depending on the bandwidth available, the band could accommodate multiple operators with the opportunity for companies other than established mobile operators to offer some 5G services with an assignment of 100MHz per operator, or more, depending on national availability and sharing with existing services
60-80GHz Potentially up to 5GHz depending on the selected sub-band (for example, 71–76MHz and/or 81–86GHz)	Similar to the 15GHz and 28GHz bands	Channel sizes could be very wide, for example, multiples of 100MHz Depending on the bandwidth available, the band could accommodate multiple operators with the opportunity for companies other than established mobile operators to offer some 5G services with a 100MHz assignment per operator, or more, depending on national availability and sharing with existing services

2.5.1. Why these frequency bands

New standards in wireless communications are continuously proposed. The reasons are two-fold: First, the number of users are increasing rapidly, and they always ask for better quality-of-service. For example, automobiles/pedestrians would like to get access quickly even with mobility and increasing interferences [see Fig. (2. 7)]. On the other hand, all sub-3 GHz frequencies are already utilized and there is not much left for microwave communications [see Fig. (2.8)]. Thus, there is a need to exploit new and higher frequency bands where more users can be served with higher datarates. The 5G new air interface starts right here: New frequency bands for more users.

Figure 2. 7: Mobility with more connected users

5G operating bands consist of three parts: evolution for existing bands in 4G (below 6 GHz), potentially a few new bands above 3 GHz and new frequency band (6-100 GHz).Based on the relationship between frequency *f* and wavelength $\gamma = \frac{c}{f}$ with *c* being the speed of the light, the new supported bands (above 6 GHz) are also named as mm-wave spectrum. There are lots of special characteristics in mm-wave communications: high path loss, strict peak power limitation, blockage-sensitive signals.These constraints increase the difficulty of the system design remarkably. Moreover, connecting everything is one of the main goals of 5G. Smart home is a typical application. However, more connected users means more interference and lower data speed, which also calls for new techniques to improve it [3].

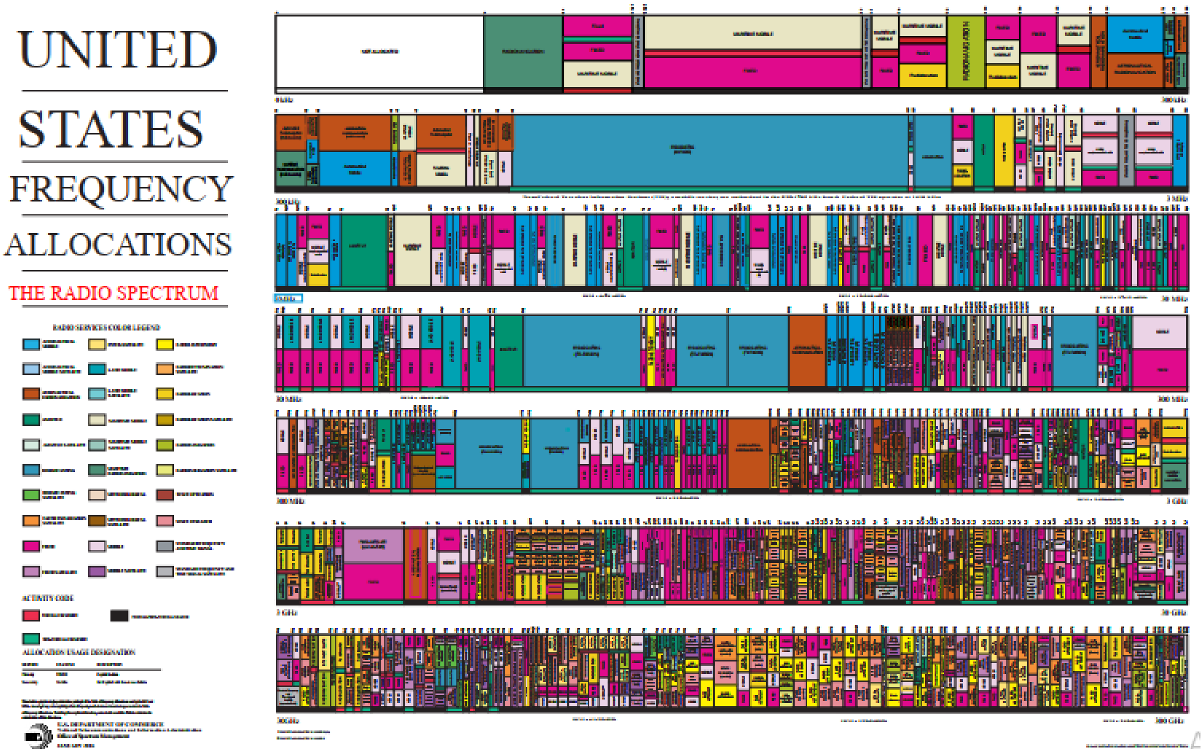


Figure 2. 8: U.S. Frequency Allocation Chart

2.6 Phased array antenna

Phased array antenna is a multiple-antenna system in which the radiation pattern can be reinforced in a particular direction and suppressed in undesired directions. The direction of phased array radiation can be electronically steered obviating the need for any mechanical rotation. These unique capabilities have found phased arrays a broad range of applications since the advent of this technology.Phased arrays have been traditionally used in military applications for several decades. Recent growth in civilian radar-based sensors and communication systems has drawn increasing interest in utilizing phased array technology for commercial applications [5].

2.7. Advantages of using phased array antenna

2.7.1. Spatial filtering

A major advantage of incorporating phased array into communication systems is its capability of spatial filtering. Phased arrays are able to suppress the signals emanating from undesired directions; even if omnidirectional rating elements are used. In general, the ultimate radiation/reception pattern of a phased array is determined by multiplying the received pattern of a single antenna element by the array factor, assuming identical

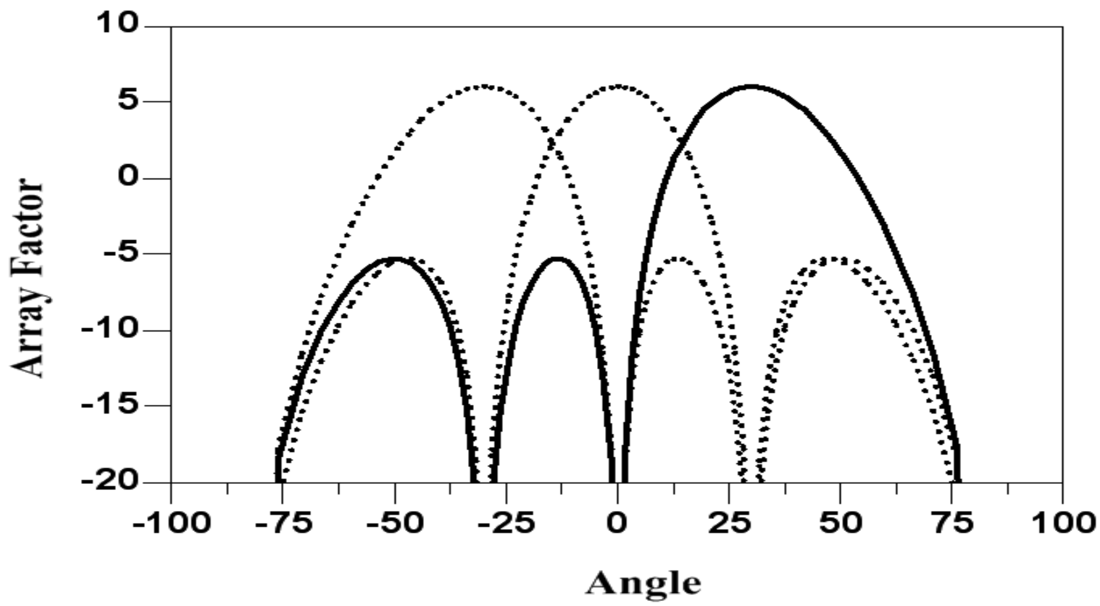


Figure 2. 9: Array factor for a linear 4-element phased array

Antenna elements are used across the entire array. In order to demonstrate the spatial filtering capability of phased arrays, the array factor for a linear 4-element phased array is shown in Fig. [2.9] assuming all the antenna elements are identical and placed $\lambda/2$ apart, where λ is the wavelength. As can be seen, the array radiates/receives signals with a beamwidth 26 degrees centered at 30 degrees while the undesired signals emanating from other angles are significantly attenuated. As mentioned before, the ultimate radiation/reception pattern of a phased array is determined by multiplication of a pattern of each individual antenna with the array factor. Therefore, by different arrangement of antenna elements, various radiation/reception patterns can be achieved to fulfil the required spatial filtering. For instance, array factors for linear 4-elemet phased array having.

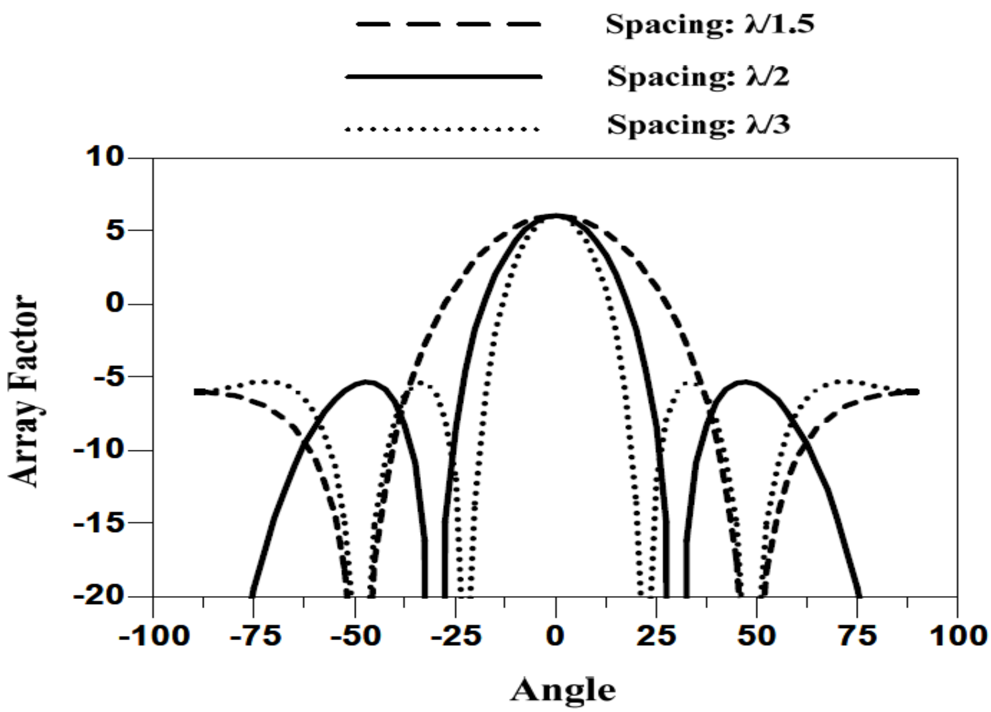


Figure 2. 10: Array factor for 4-elemenet array with different antenna spacings

Different spacings, λ/1.5, λ/2 and λ/3 are compared in Fig. 2.10. As can be seen, by increasing the spacing between the antenna elements the beamwidth of the array radiation pattern decreases. However, increasing the spacing can cause in increase of side lobe level and emergence of grating lobes. Furthermore, in phased-array systems the amplitude excitation of the array elements can be tapered to lower the side lobe levels or to adjust the null positions at directions where the strong interfering signals are emanating from .It should be noted that antenna elements can be placed in two dimensions as well to create spatial filtering in azimuth and elevation. Furthermore, the arrangement of the antenna elements and their feeds can be changed in conjunction with the associated circuitry to allow for the multiple beams to be created and steered independently.Spatial filtering of phased arrays not only allows for suppressing the interfering signals emanating from undesired sources, but, it also can alleviate the problem of fading and multi-channel interference [9]. Fading is caused when the signal travels along multiple paths before arriving at the receive antenna. Therefore, although all of these signals have been emanated from a single transmitter, the phases of these signals arriving at the receive antenna are different and can even cancel out each other. Therefore, it ismdesired to receive the signal from a specific path while suppressing the others propagating along other directions. Spatial filtering of phased array can be exploited to alleviate this problem.

2.7.2. Gain boosting in transmit phased array

In general, the maximum distance that reliable communication between a transmitting and receiving system can occur is determined by the maximum power transmitted in the direction of receiver. For a given receiver sensitivity, the power transmitted in the direction of receiver can significantly affect the maximum range of communication. In radars, also, the maximum transmit power determines the maximum range that radar would be able to detect a target with a given radar cross section.

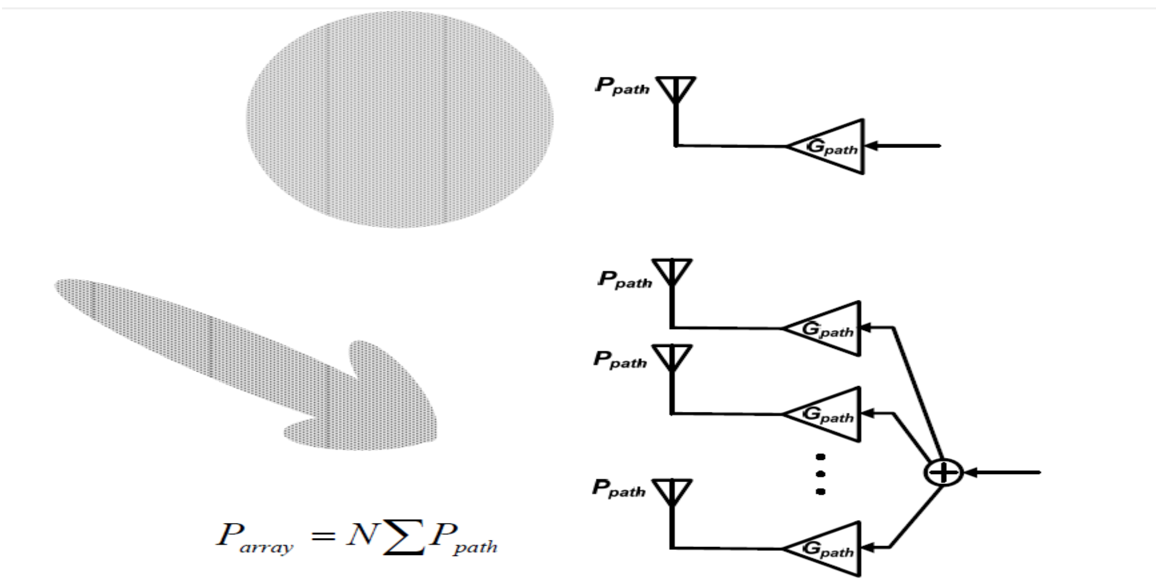


Figure 2. 11: Phased array transmitter can boost the gain in a desired direction

By implementing transmitter antennas using phased arrays one can boost the transmit power level in a desired direction while the total power transmitted remains the same. Therefore, compared to omnidirectional transmitter, phased array transmitter are capable of communicating over longer distance for a given receiver sensitivity (Fig. 2.11). An omnidirectional transmitter radiates electromagnetic power in all directions, and only a small fraction reaches the intended receiver. Not only is a major fraction of this power wasted, but it also causes interference for other users.

With ever-increasing wireless applications and the rapid growth of number of wireless users, data-rates currently.

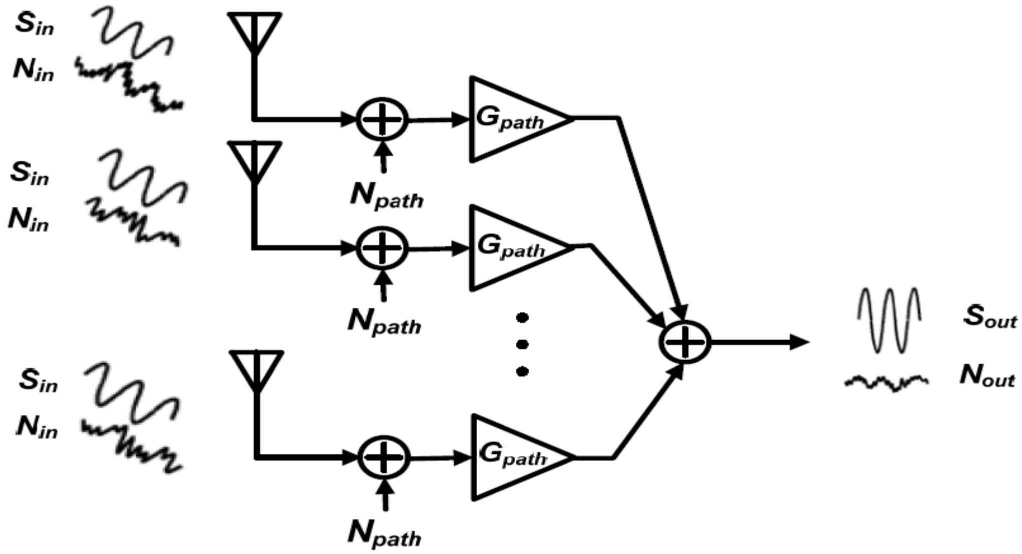


Figure 2. 12: Phased array receiver can improve the noise performance of the system

Achievable in available wireless communication networks are in general limited by the interference rather than noise. An increase in transmit power for all users to increase the achievable range and data rate increases the interference level as well and therefore does not provide any benefit to the system overall capacity (see Fig. 2.12).

2.7.3. Sensitivity improvement in receive phased array

Sensitivity of a receiver can be directly obtained from the signal to noise ratio at the output of the receiver's front end. In general, a signal to noise ratio above a certain level is required to detect the signal with a target error probability in mind. The minimum signal to noise ratio possible would determine the minimum detectable signal at the antenna element. Therefore, the noise figure of the receive systems is improved and the overall sensitivity of receive systems is enhanced. Having the noise figure *NFchannel* and minimum acceptable signal to noise ratio at the output *SNRout*, the signal to noise ratio at the input of a single path receiver is given in Eqn. 2.1.

$$SNRIn(dB) = SNRout(dB) + NFchannel \qquad (2.1)$$

In a receiver based on using phased array, the signals at the output of phased array are combined coherently for transmit signal coming from the desired direction. Assuming the current from the antenna elements are combined coherently, the current at the output will be *N* times larger than the current at each individual antenna; therefore, the signal power level at the output will be *N*^2 times larger than the received signal.

S out = N^2 Sin (2.2)

Here, N is the number of antenna elements the noise contributed by the receive channels are not coherent, therefore, at the output of the phased array, the power of noise from different channels are combined.

Output noise level, therefore, will be *N* times larger than the noise contribution of each channel *N*. As a result, the noise figure of the entire system can be calculated as shown in Eqn. 2.3.

$$NF_{array} = \frac{nP_N}{n^{\wedge}2P_S} = n\frac{P_N}{P_S} = \frac{NF_{channel}}{N} \qquad (2.3)$$

Therefore, the minimum acceptable SNR at the input of phased array can be shown as Eqn. 2.4. Assuming the noise performance of the channels remains the same as when used alone.

$$NSNR_{in}\ (dB) = NSNR_{out}\ (dB) + \frac{NF_{channel}}{N} \qquad (2.4)$$

Thus, compared to the output SNR of a single-path receiver, the output SNR of the array is improved. This improvement can be more significant if number of antenna elements is increased. In general, the improvement in sensitivity of receiver by using phased array is given in Eqn. 2.5. For instance, a 16-path phased-array can improve receiver sensitivity by 12dB.

$$Sensitivity_{array}(dB) - Sensitivity_{channel}(dB) = 10\log_{10} N \qquad (2.5)$$

2.8. Phased Array Architecture

2.8.1 Phased Arrays based on feed network design

Phased arrays are usually composed of a feed network and a number of phase shifters. Feed networks are used to distribute the output signal of the transmitter to the radiation elements and phase shifters control the phase of the signals at each radiating element to form a beam at the desired direction. There are almost as many ways to feed arrays as there are arrays in existence. In general, array feed networks can be classified into three basic categories: constrained feed, space feed and semi constrained feed which is a hybrid of the constrained and the space feeds.

In a space feed network, the array is usually illuminated by a separate feed horn located at an appropriate distance from the array [7]. Due to the free space existing between the feed and radiating elements, this type of feed network is not a good candidate for planar arrays. The constrained feed, which is usually the simplest method of feeding an array, generally consists of a network which takes the power from a source and distributes it to the antenna elements with a feed line and passive devices. The constrained feed itself can be categorized into two basic types: parallel feeds and series feeds. The architectures based on these two types of feed network is the most common approach to design phased arrays.

2.8.1.1. Parallel-fed Arrays

In parallel feed networks, which are often called corporate feeds, the input signal is divided in a corporate tree network to all the antenna elements as shown in Fig. [2.13].

These networks typically employ only power dividers [11]. Therefore their performance critically depends on the architecture of the power splitter/combiner used. 2^N number of radiation elements is preferred for these types of arrays, where N is the number antennas in the phased array.

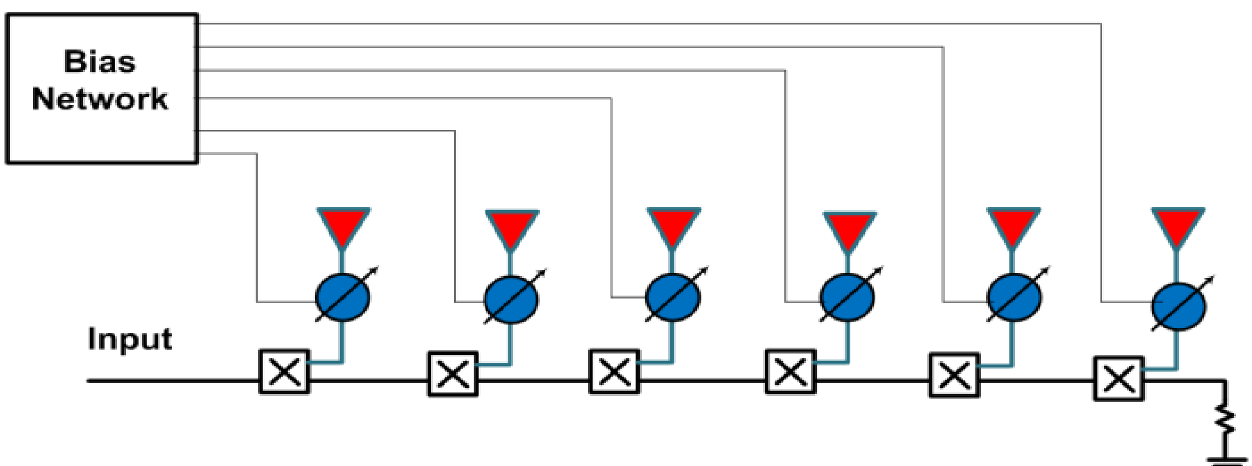


Figure 2. 13: General diagram of parallel fed phased array

2.8.1.2. Series-fed Arrays

In a series-fed array the input signal, fed from one end of the feed network, is coupled serially to the antenna elements as shown in Fig. 2.14. The compact feed network of series-fed antenna arrays is one of the main advantages that make them more attractive than their parallel-fed counterparts. Beside compactness, the small size of series-fed arrays results in less insertion and radiation losses by the feed network.The cumulative nature of the phase shift in series arrays also relaxes the design constraints on the phase tuning range of the phase shifters. In an N-element series-fed array, the required amount of phased shift is smaller than parallel fed arrays by a factor of *(N-1)*. However, the cumulative nature of phase shift through the feed network results in an increased beam squint versus frequency [14], which is one of the main limitations in series-fed designs. The loss through the phase shifters is also cumulative in series fed arrays which can be an issue in the design of arrays with a large number of array elements.

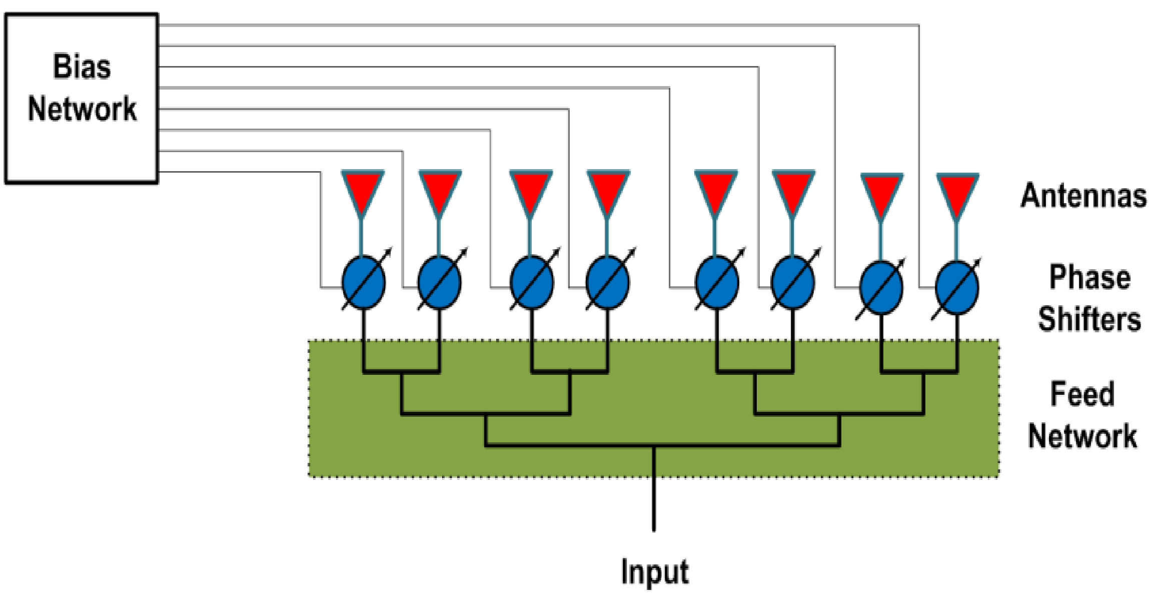


Figure 2. 14: General diagram of series fed phased array

2.9 Why at 28 GHz?

Unused or underutilized Local Multipoint Distribution Service (LMDS) broadband spectrum exists at 28 GHz, and given the low atmospheric absorption, the spectrum at 28 GHz has very comparable free space path loss as today's 1-2 GHz cellular bands. In addition, but the rain attenuation and oxygen loss does not significantly increase at 28 GHz, and, in fact, may offer better propagation conditions as compared to today's cellular networks when one considers the availability of high gain adaptive antennas and cell sizes on the order of 200 meters [7] .

As shown in Figure (2.15) atmospheric absorption at 28 GHz is the negligible

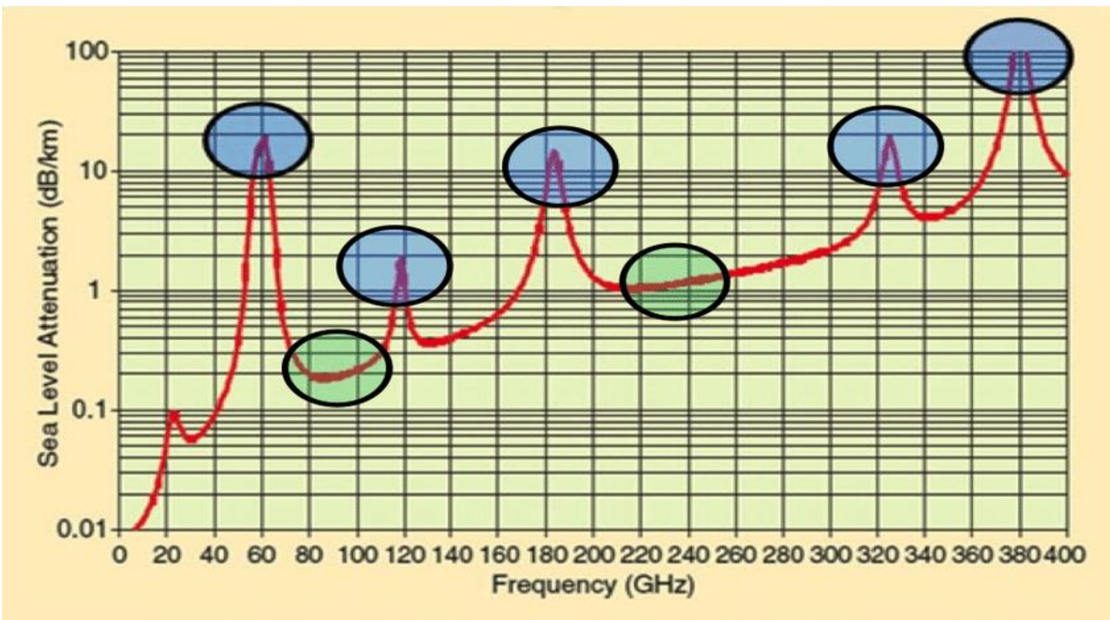


Figure 2. 15: Air attenuation at different frequency bands

2.10. N – element base station

Multi-antenna technology has been applied to a variety of wireless communication systems such as 3G system, LTE, LTE-A, WLAN and so on as an effective means to improve the system spectrum efficiency and transmission reliability. According to the information, the more the number of antennas, the more obvious the spectral efficiency and reliability. In particular, when the number of transmit and receive antennas is large, the MIMO channel capacity will grow linearly with the minimum of the number of transmit and receive antennas. Therefore, the use of a large number of antennas, to greatly improve the capacity of the system provides an effective way. Due to the space occupied by the multi-antenna and the complexity of the technical conditions, the number of antennas in the current wireless communication system is not large. For example, up to four antennas are used in the LTE system. In the LTE-A System with up to eight antennas, due to its huge capacity and reliability gain, research on MIMO related technologies for large antennas has attracted the attention of researchers, where the base station is equipped with a much larger number of mobile stations than in the case of a single cell in 2010, Bell Labs Marzetta studied multi-cell, TDD (time division duplexing) case, the base station configuration of an unlimited number of antennas in the extreme situation of multi-user MIMO technology, proposed by the multi-user MIMO system of the antenna, the concept of large-scale MIMO (large scale MIMO, or Massive MIMO) has found some different characteristics with single-cell, finite number of antennas.

After a large number of researchers on the basis of the study of the number of base stations configured limited antenna in the large-scale MIMO, the base station configuration is very large (usually tens to hundreds of root, the number of existing system antenna 1 ~ 2 Above the order of magnitude) of the antenna, in the same time-frequency resources at the same time a number of users. In the arrangement of the antenna, these antennas can be centrally located on a base station, forming a centralized large-scale MIMO, or distributed in a plurality of nodes to form a distributed large-scale MIMO. It is worth to mention that our scholars in the research of distributed MIMO has been at the forefront of the international. The benefits of large-scale MIMO are mainly reflected in the following aspects: First, the spatial resolution of largescale MIMO is significantly enhanced compared with the existing MIMO, and the spatial dimension resources can be excavated in depth so that multiple users in the network can The same time-frequency resource utilizes the spatial degrees of freedom provided by large-scale MIMO to communicate with the base station at the same time, thus greatly improving the spectral efficiency without increasing the base station density and bandwidth. Second, large-scale MIMO can focus the beam in a very narrow range, thus greatly reducing the interference. Fourth, when the number of antennas is large enough, the simplest linear precoding and linearity detectors tend to be optimal, and noise and uncorrelated disturbances are negligible.

2.11. 2x2 and 4x2 MIMO in Wireless Networks

Wireless data demands continue to grow as consumers drive usage levels ever higher. Given constraints on operating and capital budgets, every effort is being made to utilize existing assets more efficiently. The technique that wireless operators utilize for adding capacity is MIMO (multiple input/multiple output). MIMO systems are already commonplace for 5G networks with 2x2 MIMO being table stakes now. (2x2 MIMO is essentially two streams of data for transmit and receive pathways; 4x2 MIMO is four streams) [8].4X2 MIMO will further improve the traffic carrying capability of the RF path and increase the capacity of the link from the base station to the mobile. The 4-way receive configurations will also ease the transition to 4X2 downlink MIMO because the same number of antenna ports are needed for 4-way receive as are needed for 4X2 MIMO. Going to 4X2 MIMO often also requires additional equipment to share paths and keep the number of antennas on the tower to a minimum number. These methods of improving the capacity of a wireless network improve spectral efficiency without adding more sites. They are one tool in the toolkit of the radio engineer working to efficiently add more data handling capability.Massive MIMO has been widely recognized as a promising technology in the next generation of mobile communication systems due to its potential to meet the future high demands of data rate [10]. In a massive MIMO system, a base station (BS) is generally equipped with tens or even hundreds of antennas. This feature makes the channel vectors for different users almost orthogonal. Hence, many advantages, such as low decoding complexity, high spectral efficiency, and high transmission reliability, can be exploited. In practice, due to the physically limited space the hundreds of antennas are not possible to be separated far away, the correlation among antennas cannot be avoided. However, the correlation among the antennas offer a benefit of beamforming gain.

CHAPTER THRE

Problem Statement

3.1 Introduction

In the next decade, its envisioned media-rich mobile applications such as tele-presence and 3D holography will require data rates simply not possible with fourth generation (4G) networks so that we need to improve the problem that phased 4G to solve it by 5G to perform the demands that need to be addressed are increased capacity, improved data rate, decreased latency and better quality of service.

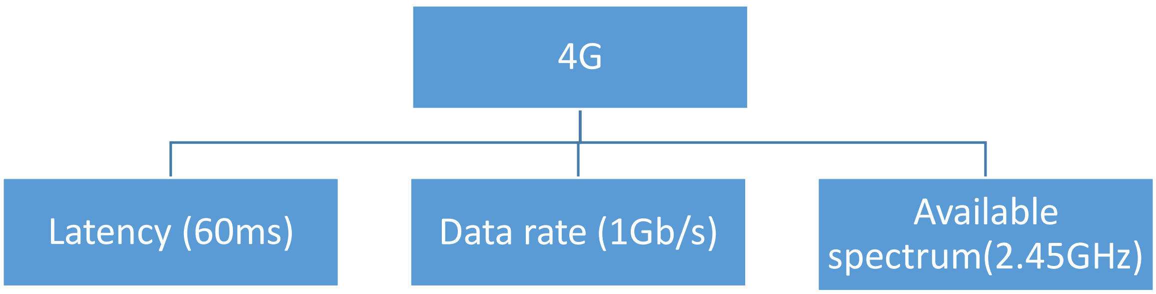
3.2 Existing Model

Exist model has disadvantage there are still limitations that must be addressed. Some major limitation are low capacity, low data rate and less quality of service.The data rate that we have in 4G network is about 1Gb/s.

Latency is one of the limitation of 4 generation and it has around 60 milliseconds.

Some limitations of existing model

- The data rate is low
- low capacity
- Less quality of service



3.3 Proposed model

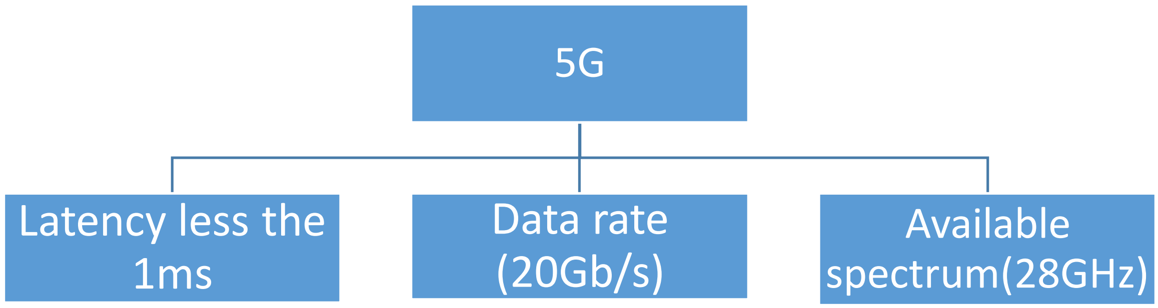
This study focused on the proposed solution of 5G networks. In proposed model increased the frequency, bandwidth and gain; so that lead to get high capacity, low latency and improved data.

5G networks improved the problem of 4g networks such as increased capacity, improved data rate, decreased latency and better quality of service.

Some major advantage are increased capacity, improved data rate, reduced latency and batter quality. The data rate is a term to denote the transmission speed and transmission speed in 5G will be around 20Gb/s. The latency is how long it takes the network to respond to a request, which could be you trying to play a song or video or load a website for example. It has to respond before it even starts loading, which can lead to minor but perceptible lag and is especially problematic for online games, as each input has a new response time. Over 4G those response times are typically around 60 milliseconds and on 5G response times will drop to just 1 millisecond, which will be completely imperceptible.

Some advantage of proposed model

- Increased capacity
- Improved data rate
- Reduced Latency
- Better quality of service



CHAPTER FOUR

METHODOLOGY

4.1. Introduction

Simulation models are conceptual representation of real time world phenomena; they must adequately replicate systems behavior over span of time. It is often needed in complex situations that cannot be dealt with adequately by analytical and mathematical models or for performing sampling experiments on the model rather than on the real system because the latter would be too inconvenient, expensive or time consuming. In this chapter, the design and computer simulations of the proposed simple management spectrum in phased array antenna design for mobile networks is presented. The flow charts used are also depicted. The simulation software has done by using CST software. The electromagnetic simulation software CST MICROWAVE STUDIO is the culmination of many years of research and development into the most accurate and efficient computational solutions for electromagnetic designs. It comprises CST's tools for the design and optimization of devices operating in a wide range of frequencies - static to optical. Analyses may include thermal and mechanical effects, as well as circuit simulation. CST MICROWAVE STUDIO benefits from an integrated design environment which gives access to the entire range of solver technology. System assembly and modelling facilitates multi-physics and co-simulation as well as the management of entire electromagnetic systems. CST MICROWAVE STUDIO can offer considerable product to market advantages such as shorter development cycles, virtual prototyping before physical trials, and optimization instead of experimentation. The antenna design tool Antenna Magus was used to design 2x2 notched circular array patch antenna and then exported to CST MICROWAVE STUDIO for further analysis and optimization, then the 2x4 notched circular array patch antenna was designed using CST expanding 2x2 patch antenna to become 8 elements. Antenna Magus is a new software tool to help engineers accelerate the antenna design and modelling process. It has a huge database of designed antennas which can be exported to CST MICROWAVE STUDIO for further analysis and optimization. This simplifies the day-to-day work of antenna designers and modellers ensuring that more projects are completed within specification and on time.

Antenna Magus offers an extensive database of antennas which is easily searchable. It not only highlights the unique characteristics of an antenna, but also gives other general information. This helps engineers find and select antennas according to given requirements as well as compare relevant information between antennas. Its feature set is targeted at aiding engineers to get to the customization phase of an antenna design quickly and reliably. Validated, parametric models of the initial design are exported seamlessly into CST MICROWAVE STUDIO, where in-depth analysis and optimization can be performed. It is expected that Antenna Magus will become an invaluable aid to antenna design engineers, to EMC engineers requiring antenna models and to system integrators who require antenna models for antenna placement studies.

4.2. Project flow chart

In order to design the proposed antenna, a flow chart is created. This project is started by defining the problem which is about having a phased array antenna that can applied for 5G generation. Then the study about 5G and basic phased array antenna is made by doing literature review. Hence the gather information from literature review is used for the designing 2 by 2and 2 by 4 notched circular array patch antenna at the operating frequency of 28GHz with design specification shown in Table 3.1. The bandwidth, gain and directivity are set to be greater than 4 GHz, 10 dB and 10 dBi respectively as there is still no official standards value for requirements of 5G in the real world. The simulation is done and analyzation of the data is made from it. The flow chart is illustrated as in Figure 4.

Table 4. 1: Design Specification

Parameter	**value**
Operating frequency(GHz)	**28**
Bandwidth(GHz)	**>4**
Gain(dB)	**>10**
Directivity(dBi)	**>10**

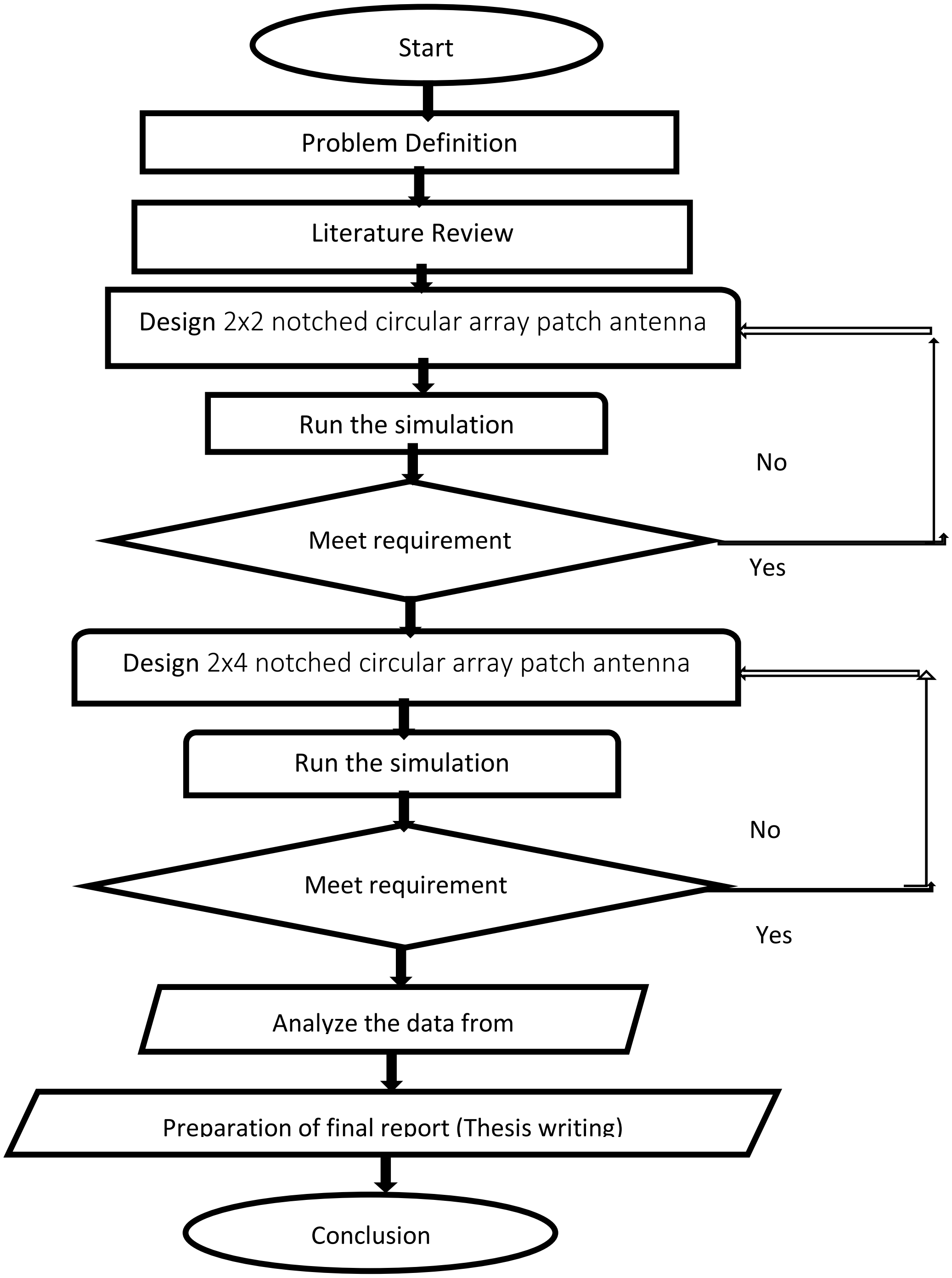
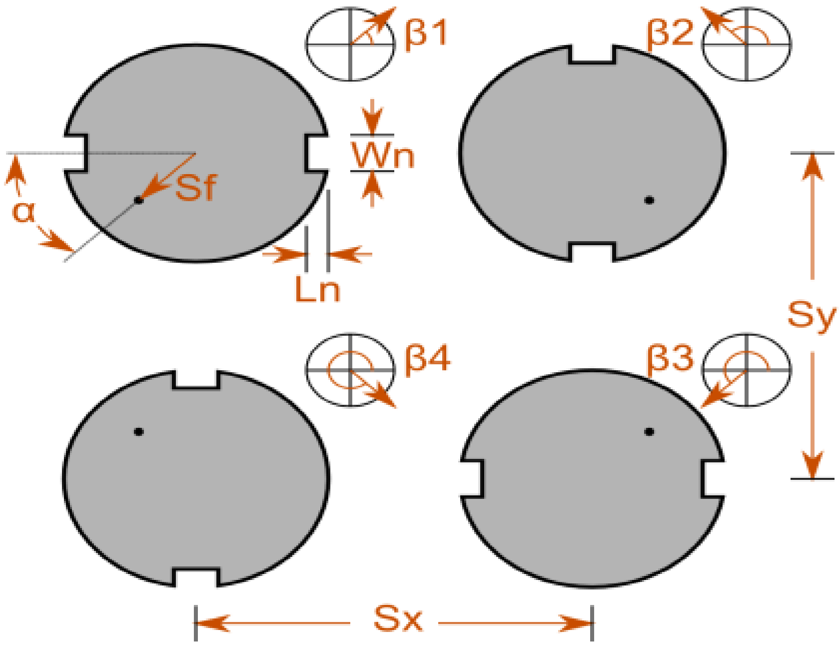


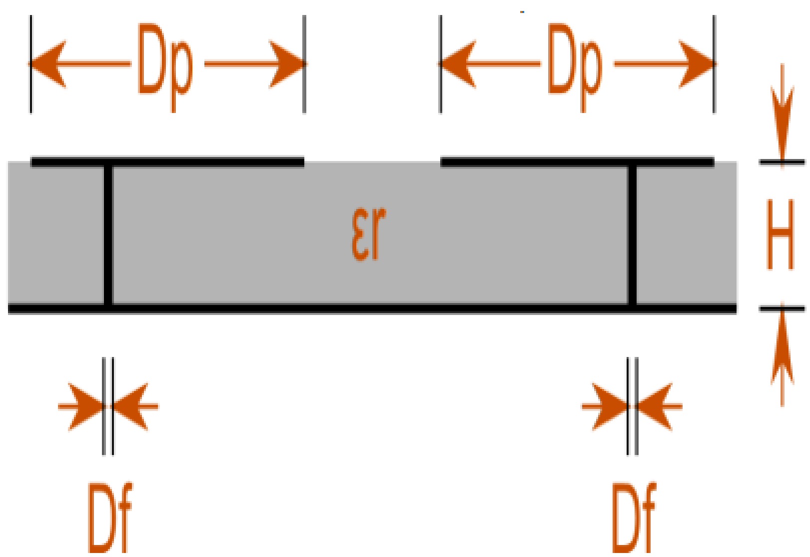
Figure 4. 1: Project flow chart

4.3. Notched Circular Patch Antenna

The notched circular patch and other circularly polarized antennas tend to suffer from high cross-polarization levels, especially away from resonance and off broadside. One way of improving the axial ratio is to use a number, say N, of these antennas, identical within the limits imposed by the manufacturing tolerances, together in an array, and rotate them in sequence. The differential physical rotation angle and phase shift are both $p\pi/N$, where p is an integer such that $0<p<N$. The elements are excited with equal amplitude which results in the polarization ellipses of the individual elements being superimposed to yield near perfect circular polarization on boresight at the centre frequency. In the simplest case of a two element array, the elements are rotated by 90 ° and excited with relative phases of +90° or -90°s, depending on the required polarization sense, i.e. LHC or RHC. In many cases, a sequentially rotated sub-array may be used as a building block for a much larger array. There are many possible arrangements of sequentially rotated arrays, especially if more than four elements are used. Different configurations can be used to reduce the cross-polarization from various sources, such as multiple reflections, feed phase errors and higher order modes.Each patch element uses only a single feed pin which is fed from behind the ground plane. A feed network which incorporates all the necessary phasing and impedance transformations may be integrated onto the back of the ground plane. For the design used in Magus, no feed network is used and each element is fed directly with the appropriate phase. Fig 4.2 shows the typical orientation of 2x2 notched circular array patch antenna with coaxial feeding. Table 4 shows the dimensional characteristics of the antenna in mm. The design guidelines for the patch dimensions are the same as for a single patch element. The spacing between array elements is typically of the order of a free-space wavelength, but this may rather be determined by the pattern requirements of the overall array. To switch polarization, the polarization of the individual patch should be modified (in this case by changing the sign of the feed rotation angle) and changing the sign of the relationship between the element rotation angle and port phase.



a) Top View



Side View

Figure 4. 2: 2X2 Circular Array Patch, (a) Top View, (b) Side View

Table 4. 2: Antenna Parameters

No	Parameter	Notation	Dimensions	No	Parameter	Notation	Dimensions
1	Patch Diameter	Dp	3.5715 mm And 3.746	11	Element 1 rotation angle	β 1	0^0
2	Notch length	Ln	0.1918 mm And 0.832	12	Element 2 rotation angle	β 2	-90^0
3	Notch width	Wn	0.3836 mm And 0.42	13	Element 3 rotation angle	β 3	-180^0
4	Diameter of feed pin	Df	0.0964 mm And 0.666	14	Element 4 rotation angle	β 4	-270^0
5	Offset of feed pin	Sf	0.5475 mm And 0.107	15	Element 1 port phase	Φ1	0^0
6	Feed pin rotation angle	α	45^0	16	Element 2 port phase	Φ2	90^0
7	Permittivity of substrate	εr	2.2	17	Element 3 port phase	Φ 3	180^0
8	Height of the substrate	H	0.5357 mm	18	Element 4 port phase	Φ 4	270^0
9	Patch spacing (X)	Sx	10.714 mm	19	Centre Frequency	f_0	28 GHZ
10	Patch spacing (Y)	Sy	10.714 mm				

4.3.1. Physical Description

The array consists of four circular notched patches with feed pins orientated at 45 ° to the position of the notches. The array is typically fabricated by etching a metallized dielectric substrate.

4.3.2. Feed Method

Each patch element uses only a single feed pin which is fed from behind the ground plane. A feed network which incorporates all the necessary phasing and impedance transformations may be integrated onto the back of the ground plane. For the design used in Magus, no feed network is used and each element is fed directly with the appropriate phase.

4.3.3. Operation Mechanism

Consider the broadside radiation of two elliptically polarized antenna elements excited with equal amplitude, where the second element has been rotated by 90° and driven at –90° with respect to the first element. The polarization ellipses of the elements then lie at 90° with respect to one another. The quadrature feed phasing then ensures that the instantaneous E-field vectors combine such that the two ellipses add to form a circle, thus producing perfect circular polarization at broadside. This will be the case even if the antenna elements are linearly polarized.

4.3.4. Antenna Substrate

The radiation characteristics of a patch antenna is determined by the thickness and type of substrate used. The impedance bandwidth and efficiency (η) of a patch antenna varies inversely to one another. The parameters of dielectric constant (εr) and thickness (h) can be varied to obtain different η, which will ultimately increase impedance bandwidth decrease in the substrate dielectric constant and increase in the substrate thickness increases the bandwidth of the antenna. However, thick substrates with high dielectric substrates would result negatively on the radiation efficiency. Poor radiation efficiency will turn out by the increase of surface wave propagation power and the poor impedance matching problem.

4.3.5. Ground Plane

As part of the antenna, the ground plane should be infinite in size as for a monopole antenna but in reality this is not easy to apply besides a small size of ground plane is desired. In practice, it has been found that the patch impedance with finite ground plane width (Zo) is practically equal to the impedance value with infinite width ground plane (Zi), if the ground width Wg is at least greater than 3*W. The radiation of a patch antenna is generated by the fringing field between the patch and the ground plane, the minimum size of the ground plane is therefore related to the thickness of the dielectric substrate. The size of the ground plane in 2 by 2 and 2 by 4 antenna array was chosen as 10.7145$mm\ length\ by$ 10.7145$mm\ width$ and 11.2379$mm\ length\ by$ 11.2379mm $width$ respectively.

4.4. Antenna Design and Simulation

Based on Figure 4.1, methodology part one is started by designing a 2x2 notched circular array patch antenna. Some of the journal papers and books are referred and discussed in this study. At design stage, the antenna design tool Antenna Magus is first used for the 2x2 notched circular array patch antenna, then it exported in to CST MICROWAVE STUDIO as shown in Figure 4.3. In this study, 2-by-2 circular patch array with stubs is operated at 28 GHz.

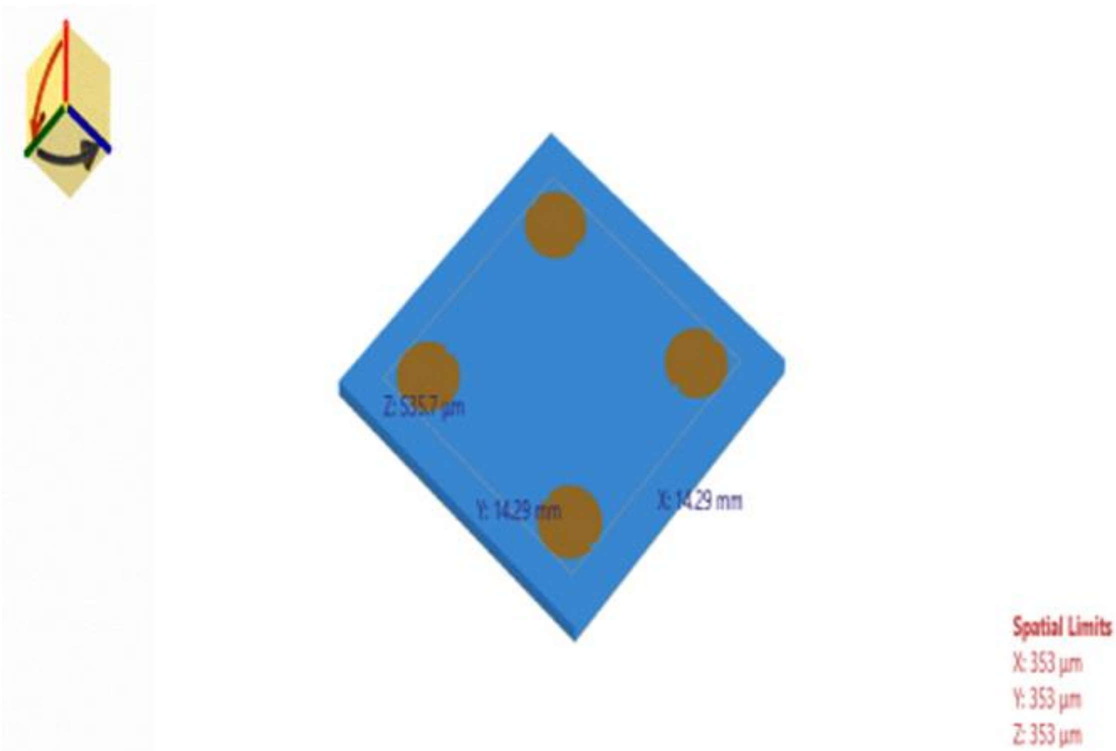


Figure 4. 3: Element patch antenna in antenna magus

Before exportation it easy to change some variables to a suitable values like frequency, diameter of the patch and etc. as shown in Fig (4.3) above.

Antenna Magus' export functionality allows more time to be spent on antenna design and less time on mastering simulation software.

Antenna Magus generates a parametric and "ready to run" model of the user's designed antenna which can be exported in CST MICROWAVE STUDIO. The exported model Figure (4.3) contains all the parameter values within the EM schematic.

The mesh settings are defined to give accurate results in a reasonable time. Certain general graphs and measurements, such as S11 vs. frequency, etc., are predefined. The project is therefore ready to run and all parameters are available if changes are necessary. Because all parameters are defined in CST MICROWAVE STUDIO, the feed spacing, for instance, can be directly edited in the CST Design Environment model definition to try and achieve a higher input resistance. and the simulation started using Time domain solver.

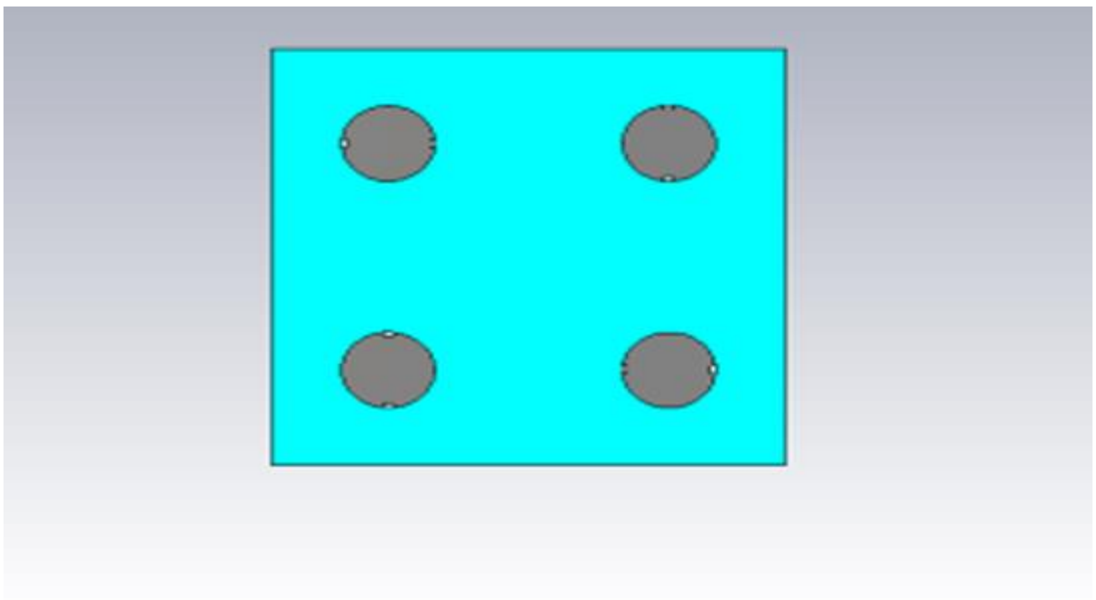
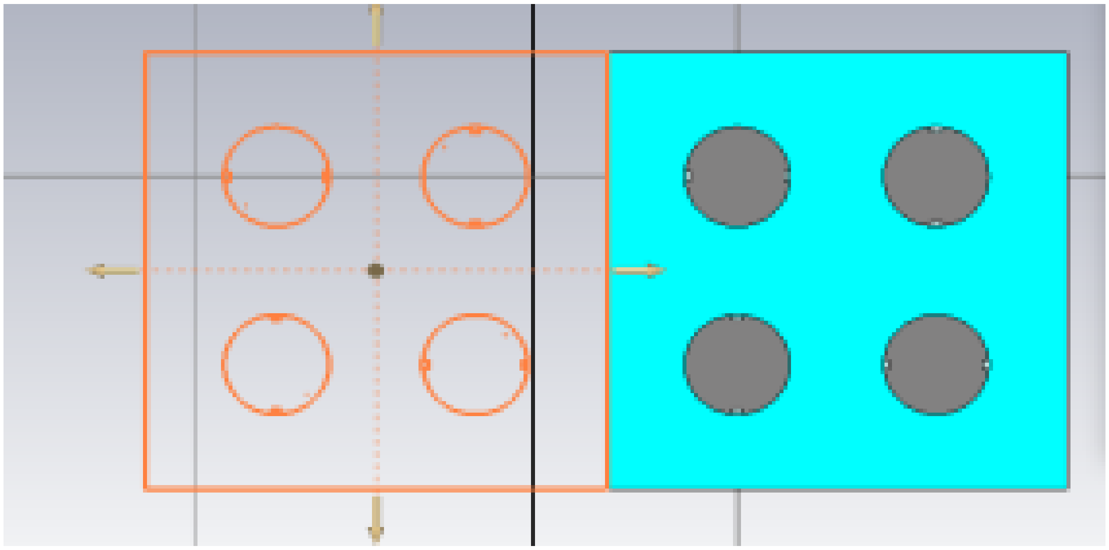


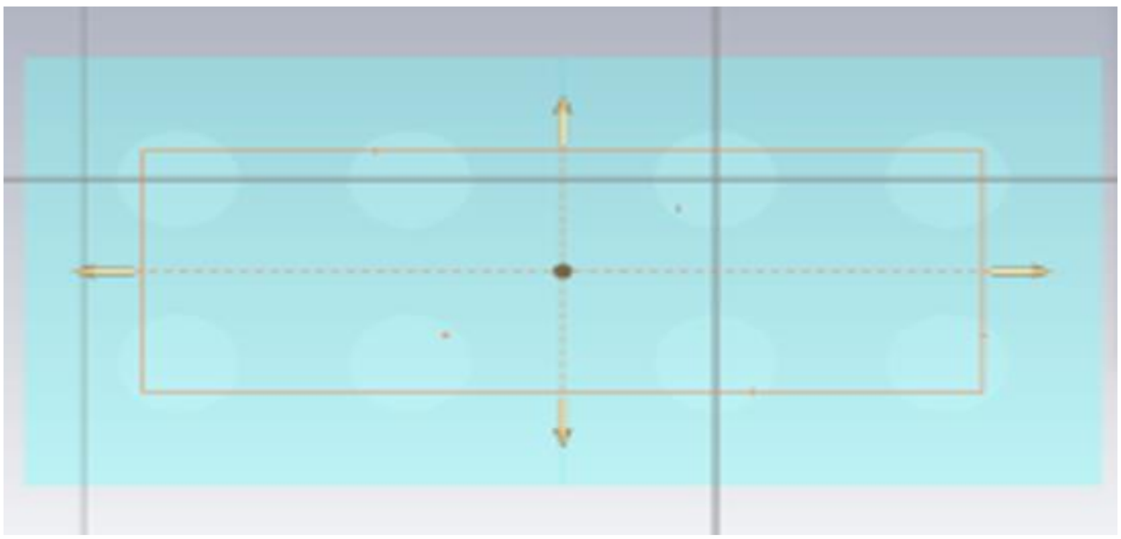
Figure 4. 4: four Elements patch antenna in CST work space

Methodology part two is started by designing a 2x4 notched circular array patch antenna. At design stage, the antenna design tool Antenna Magus is first used for the 2x2notched circular array patch antenna, then it exported in to CST MICROWAVE STUDIO.

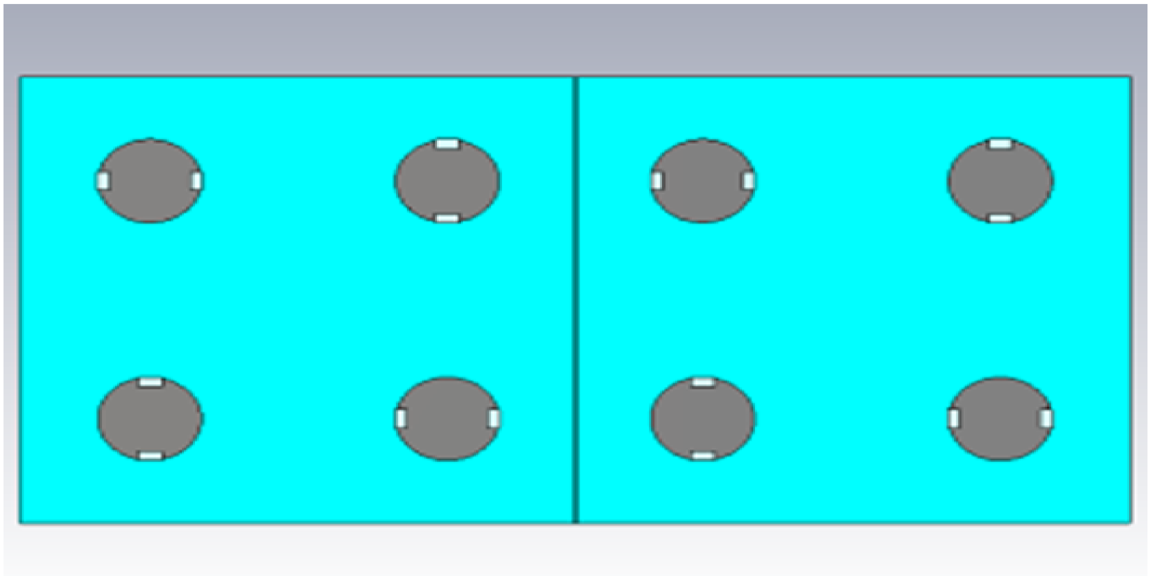
It then copied the 4 elements to become 8 using the transform operation in the CST work space. It also copied the antenna ports to get 8element which has 8 ports as shown in Fig (4.5. a, b and c) and the simulation started using Time domain solver.



A) transforming four elements into eight elements



B) transforming the ports of the antennas



C) complete eight element antennas.

Figure 4. 5: Eight Elements patch antenna in CST work space

(a) transforming four elements into eight elements

(b) transforming the ports of the antennas and

(c) the complete eight element antennas.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1. Introduction

In this chapter, the results for simulation of phased antenna array as proposed is presented. The performance of the antenna is studied and analyzed by using CST Software. The results are divided into2 parts, which is, four patches and eight patches. The CST simulation results will be discussed. The main focus of the discussion of the antenna result will be on the return loss (S11), gain, bandwidth and radiation pattern in order to determine and fulfil the specification design of phased array antenna for 5G communication systems.

5.2. The Metal and Substrates used in this final project

Throughout the project metal is design as a perfect electric conductor (PEC). The PEC simulates faster with the 3D electromagnetic software as compared when a 1 oz. Copper is used as it requires less mesh cells. For the substrate, usually a dielectric with a low permittivity close to 1 would enable the element to radiate the most. Rogers of εr 2.2 (Rogers RT5880) is used as the dielectric substrate because a low dielectric substrate close to air or close to 1 will allow a higher radiation pattern as compared to much higher permittivity value. RT/Duroid 5880 is a glass microfiber reinforced PTFE composite where the glass reinforcing microfibers are randomly oriented to maximize the benefits of fiber reinforcement. The dielectric constant of the RT/Duroid 5880 laminate is uniform from panel to panel and is constant over a wide frequency range. Its low dissipation factor extends the usefulness to the Ku-band and above. Moreover, Roger's laminates are easily cut, sheared and machines to shape. They are resistant to all solvents and reagents, hot or cold, normally used in etching printed circuits or in plating edges and holes. These characteristics are useful as the substrate needs to allow the antenna element to perform under environmental conditions where temperature or humidity can vary. The Rogers substrate is commonly obtained, reliable, popular and intensively used in the literature along with the substrate Rogers RT6010 of εr 10.2 which is used to design the phase shifters. RT6010 has an εr that is high enough to be used as a phase shifter and is commonly available and must not specially be made. Moreover, the substrate used in this project is maintained to be Rogers to maintain uniform humidity, temperature influences when the phased array is placed outdoors.

5.3. Which Solver to used?

Time Domain or Frequency domain?

CST microwave is a software focused on 3D electromagnetic simulation. It has two main solvers, the frequency domain solver and the time domain solver. The choice of the solver depends on the application. Table 5 shows summarizes the choice criteria to select the correct solver.

Table 5.1 the characteristics for the solver choice

Characteristics	**Solver choice**
Bandwidth	The time domain solver is preferred for a large continuous bandwidth while the frequency domain is more for a narrowband application or for a single frequency.
Resonances	The frequency domain solver is more suitable when the project has strong resonances.
Project Size	The time domain solver is more suitable when the total design size > 20 to 30 λ while the frequency domain is preferred when the project is < λ.

In all the cases presented here, the time domain solver is the ideal choice. The transient or time domain solver utilizes the fast and memory efficient finite integration technique. It calculates the S-parameters by applying Fourier transform to time signals. It allows the calculation of the far-field gain as well as beam directions for a broadband range of frequencies. In order to allow faster computation time, the GPU is supported and hardware acceleration is possible. The time domain solver uses hexahedral meshing.

The frequency domain solver, on the other hand, uses a tetrahedral or hexahedral meshing. It also allows the calculation of S-parameters as well as the calculation of the far-field gain and the beam directions. However, neither the GPU nor the hardware acceleration can be used.

5.4. Reflection Coefficient and Bandwidth

Consider the broadside radiation of two elliptically polarized antenna elements excited with equal amplitude, where the second element has been rotated by 90° and driven at –90° with respect to the first element. The polarization ellipses of the elements then lie at 90° with respect to one another. The quadrature feed phasing then ensures that the instantaneous E-field vectors combine such that the two ellipses add to form a circle, thus producing perfect circular polarization at broadside. This will be the case even if the antenna elements are linearly polarized. Fig 4.2 shows the return loss curve for the 2 by 2 patch antenna. It has been observed that the antenna is showing bandwidth of 5.6 GHz between (25.2 to 30.8 GHz). Depending on the feed network used, the array may have a lower input reflection coefficient than that of a single patch, and a significantly greater impedance bandwidth. The patch diameter, notch width and notch length were 0.33335λ, 0.017865λ and 0.0358λ respectively. The Fig 5.1 is for a 2 by 2 circular patch designed for a substrate with a εr of 2.2 and substrate height of 0.5357mm.

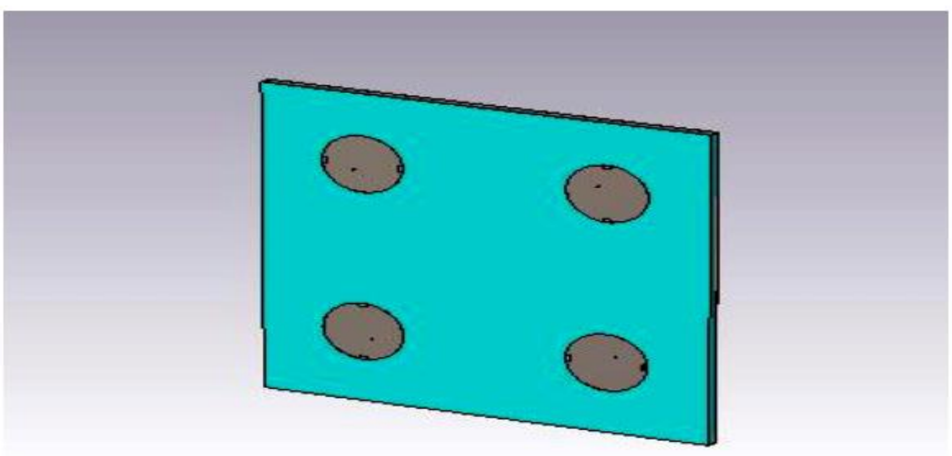


Figure 5. 1: 2 by 2 circular patch antenna in CST work space

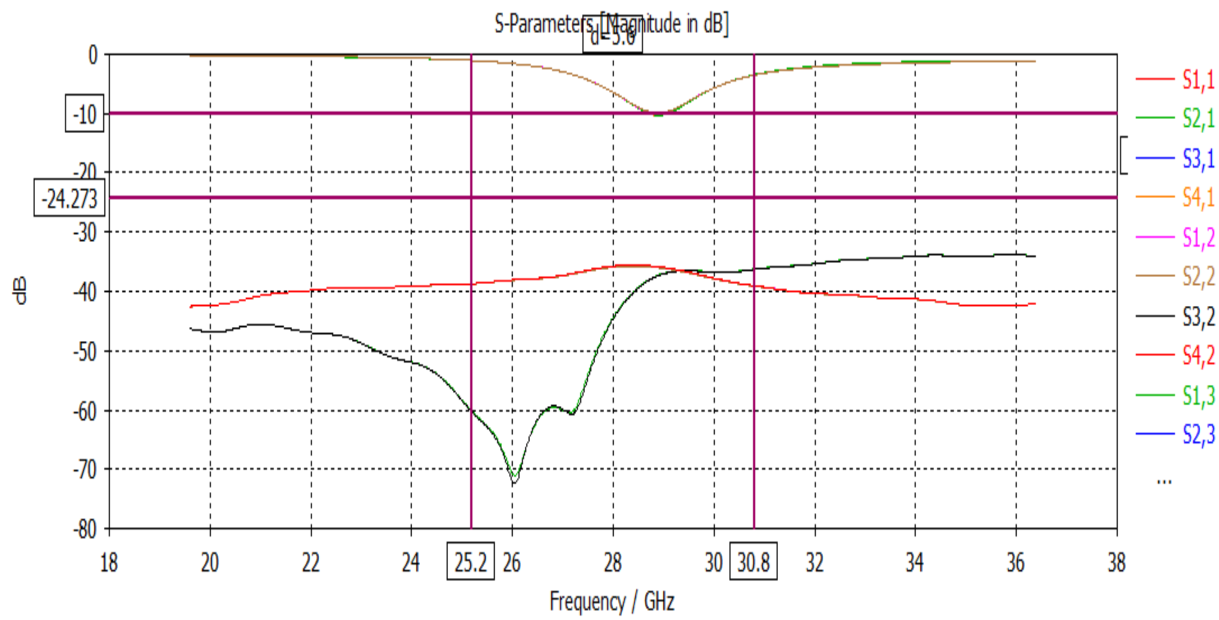


Figure 5. 2: Return-loss Vs Frequency 2 by 2 circular patch antenna

Bandwidth = $\frac{F_{upper} - F_{lower}}{F_{centre}} \times 100\%$

whereF_{upper} is the upper operational frequency i.e. 30.8 GHz in the studied case and F_{lower} is the lower operation frequency, here, 25.2 GHz and F_{centre} is the centre frequency where F_{centre} = (F_{upper} - F_{lower})/2. Here F_{centre} is 28 GHz.

Even though 2x2 patch antenna array already achieves the design requirement, eight elements patch antenna array is designed based on Table 4. in order to investigate the effect of gain and directivity and varying the patch diameter, notch width and notch length.

The patch diameter, notch width and notch length were 0.3436λ, 0.07762λ and 0.0388λ respectively. The Fig 4.3 is for a 2 by 4 circular patch designed for a substrate with a εr of 2.2 and substrate height of 0.5357mm Fig 4.4 shows the return loss curve for the 2 by 4 patch antenna. It has been observed that the antenna is showing bandwidth of 5.6 GHz between 25.2 to 30.8 GHz).

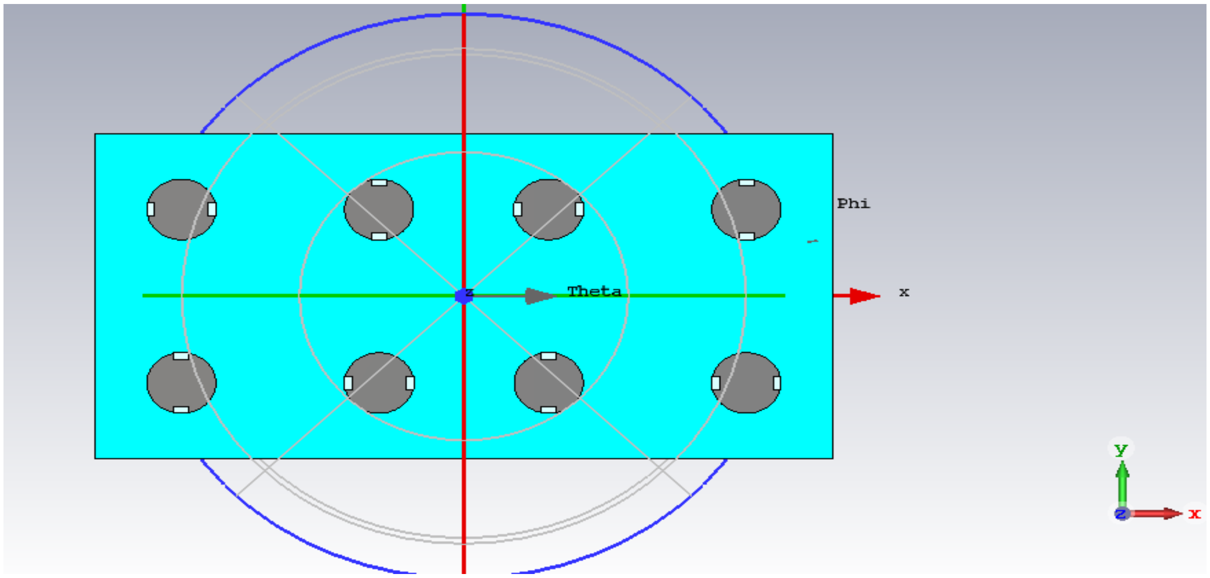


Figure 5. 3: 2 by 4 circular patch antenna in CST work space

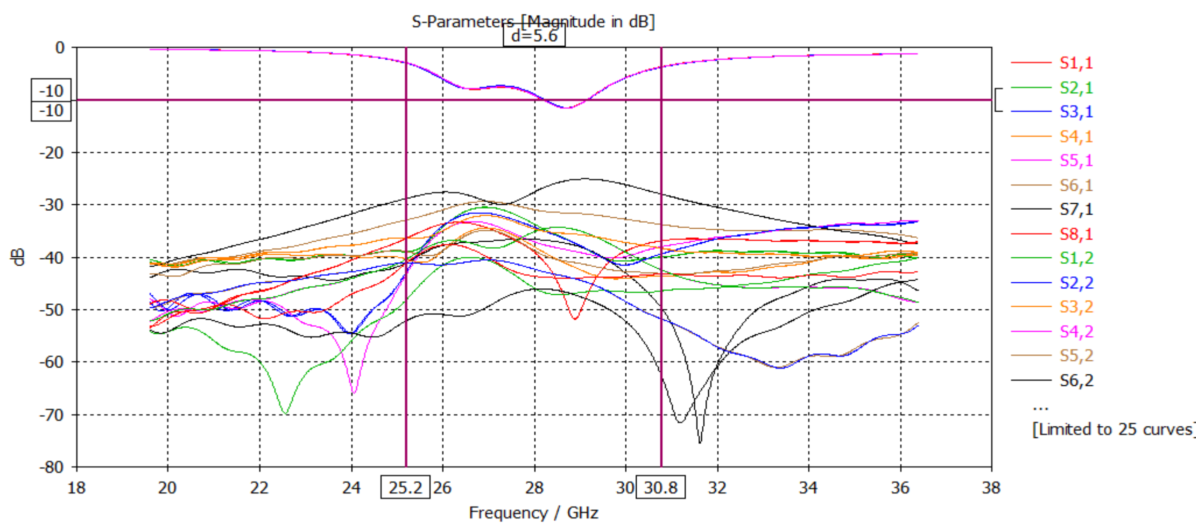
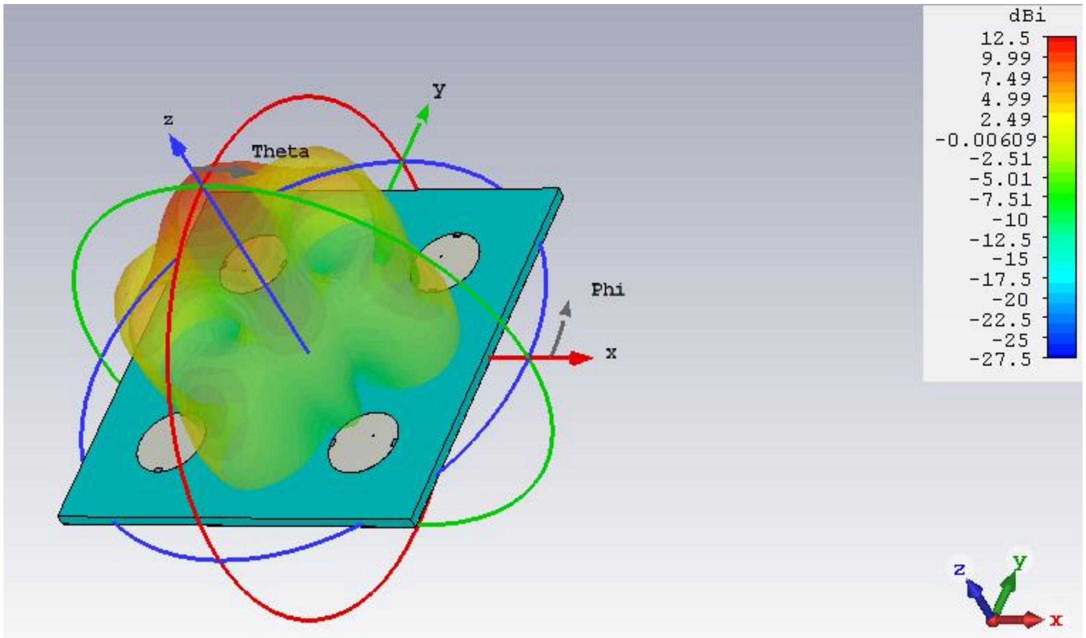


Figure 5. 4: Return-loss Vs Frequency in 2 by 4 circular patch antenna

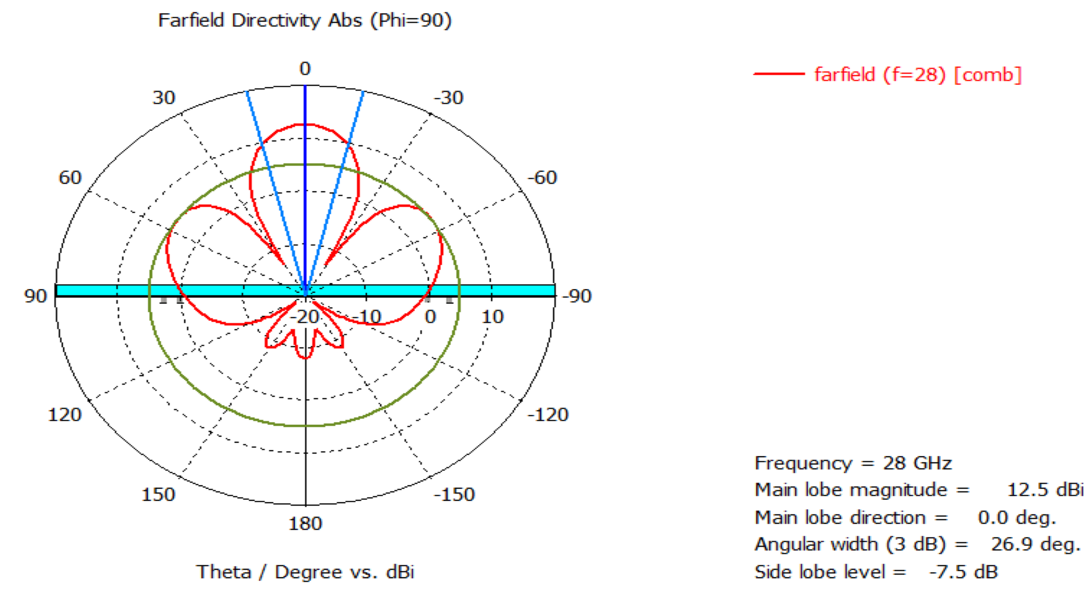
5.5. Radiation patterns

For ideal element phasing, the broadside radiation should in theory have perfect circular polarization. At the center frequency, the polarization purity is high over a wide angular range about broadside. When looking at radiation pattern parallel to the array axes, the angular range of good axial ratio decreases slowly on either side of the resonant frequency. However, for the pattern at 45° to the main axes, this angle decreases fairly rapidly. However, compared with a single patch, the axial ratio is improved and this is done over a greater frequency range and angular range.

Fig (5.5. 'a' and 'b') shows the directivity of the antenna in three dimensional view and the polar coordinates for the 2 by 2 patch antenna



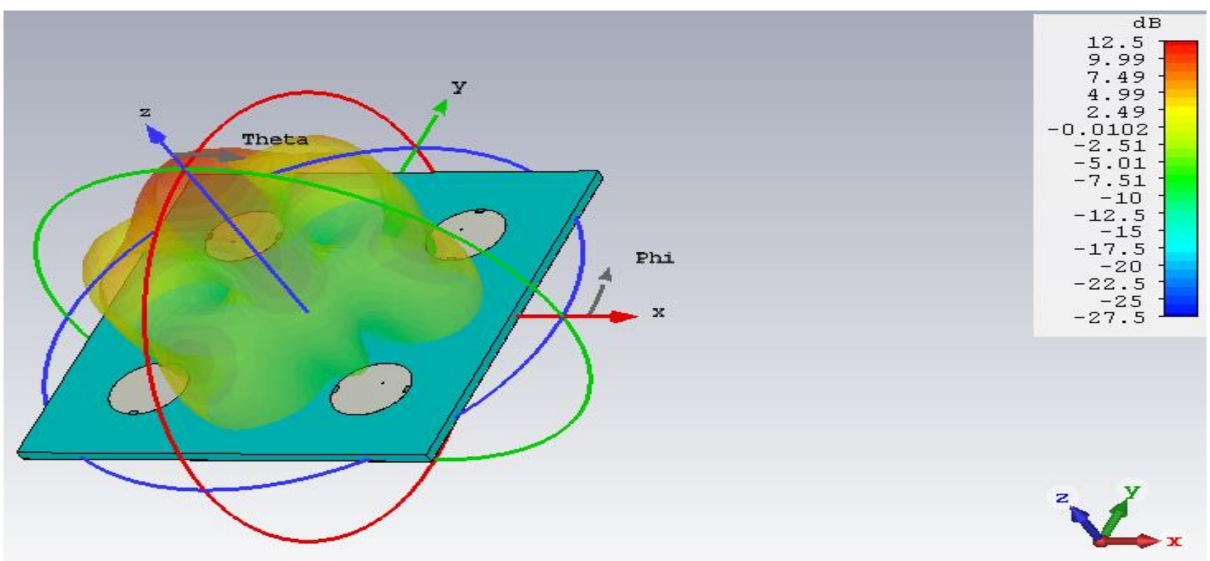
a) directivity



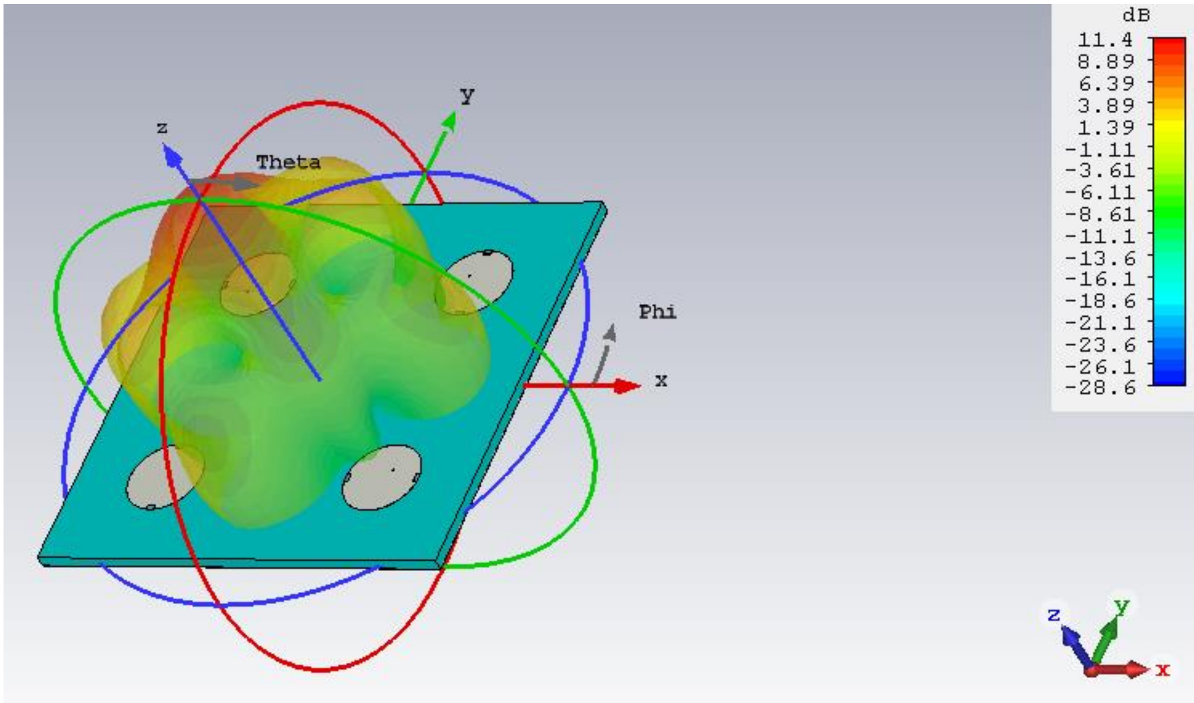
b) polar form at 28 GHz

Figure 5. 5 Simulation results of (a) directivity and (b) polar form at 28 GHz for four patches

Fig 5.6.a shows the antenna IEEE Gain and it is around 12.5 dB at the operating band and Fig 5.6.b shows the realized gain of 11.4 dB at desired frequency for the 2 by 2 patch antenna.



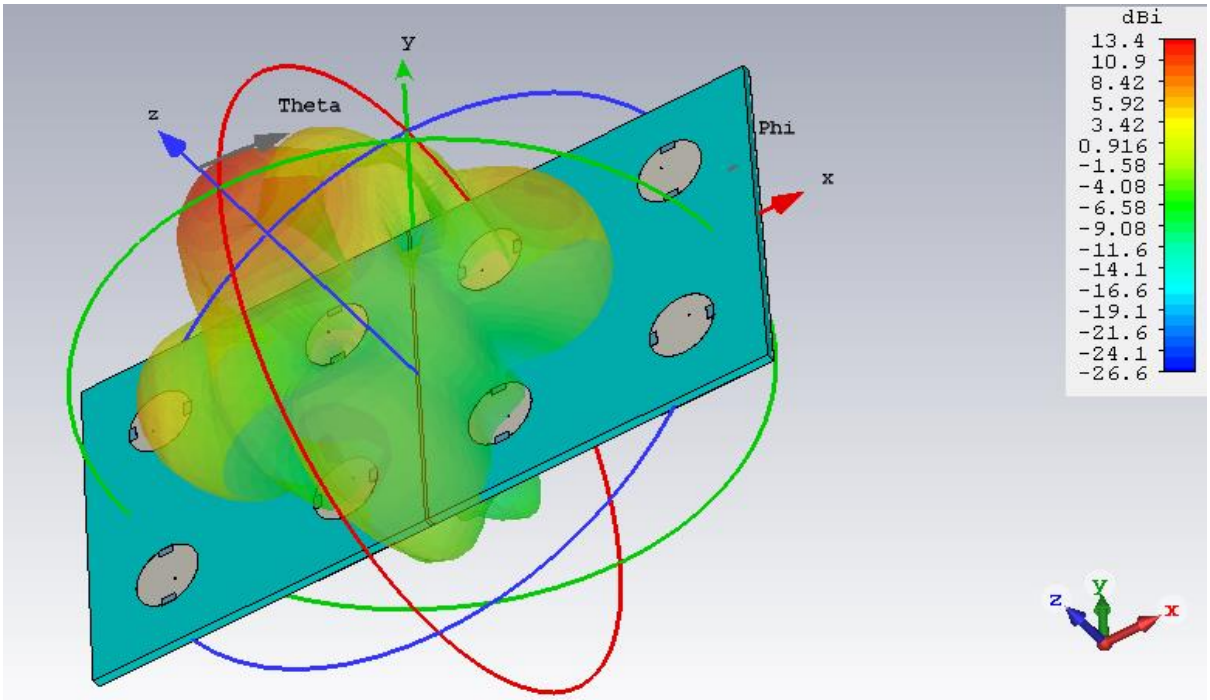
a)



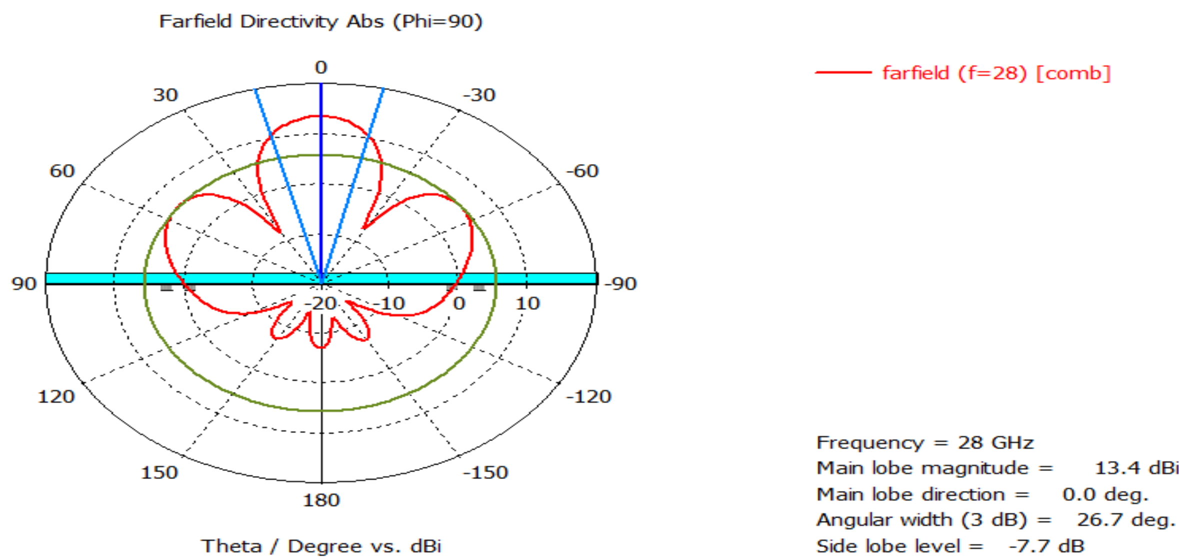
b)

Figure 5. 6: Simulation results of (a) IEEE Gain and (b) Realized gain 28 GHz for four patches

Based on the results of the previous 2x2 array, a new array of 2x4 is design and simulated Figure (5.7 a & b) presents the directivity of the antenna in three dimensional view and the polar coordinates for the 2 by 4 array respectively.



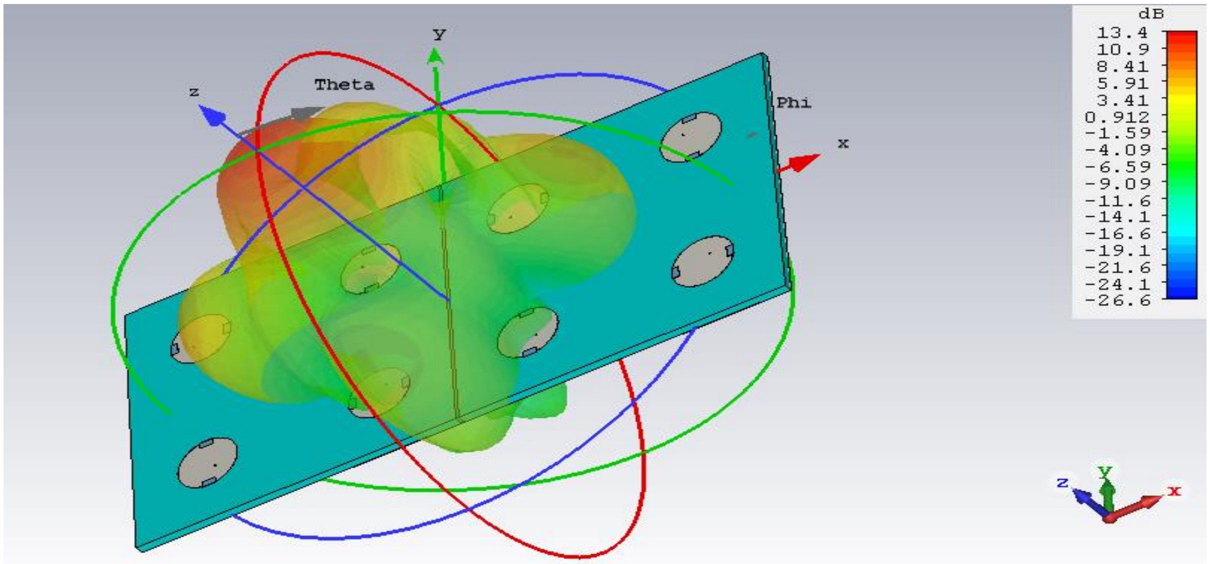
a)



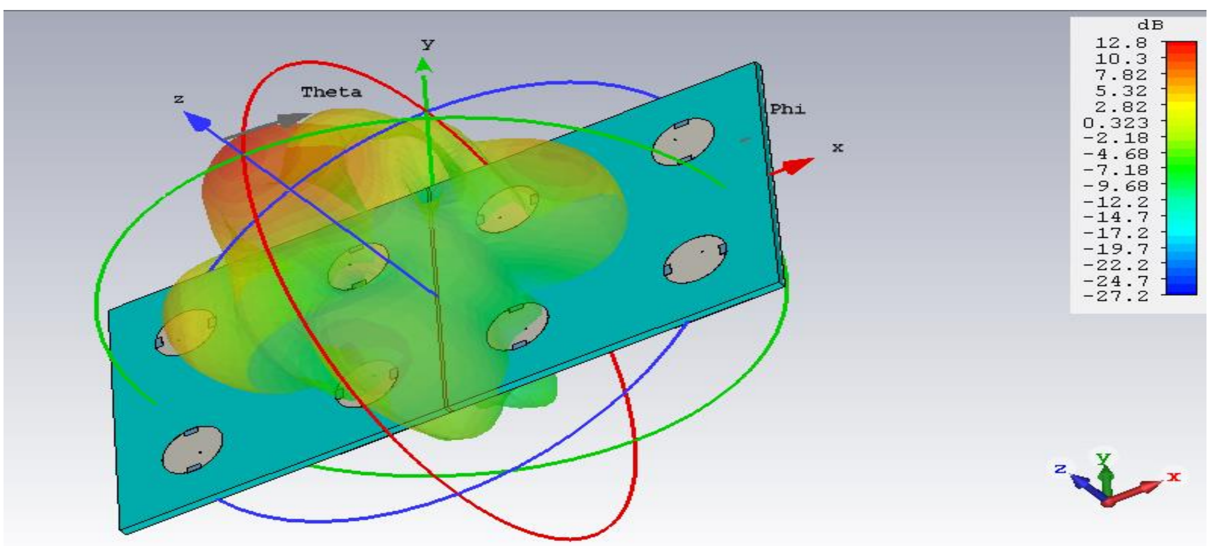
b)

Figure 5. 7: Simulation results of (a) directivity and (b) polar form at 28 GHz for eight patches

The 8- element array has a gain which greater than the 4 array. Figure (5.8 a & b) presents the IEEE Gain of the antenna in three dimensional view and the realized gain for the 2 by 4 array around 14db and 13db respectively.



a)

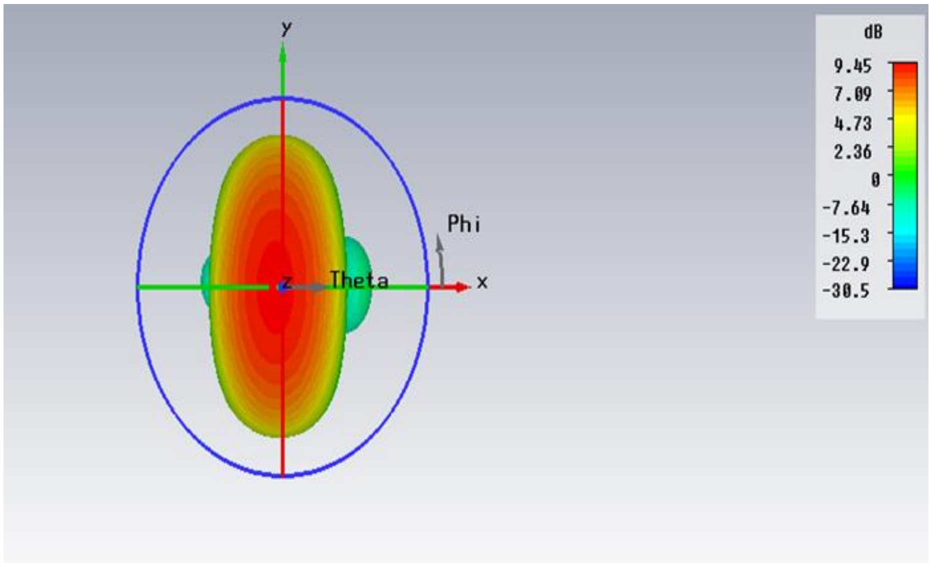


b)

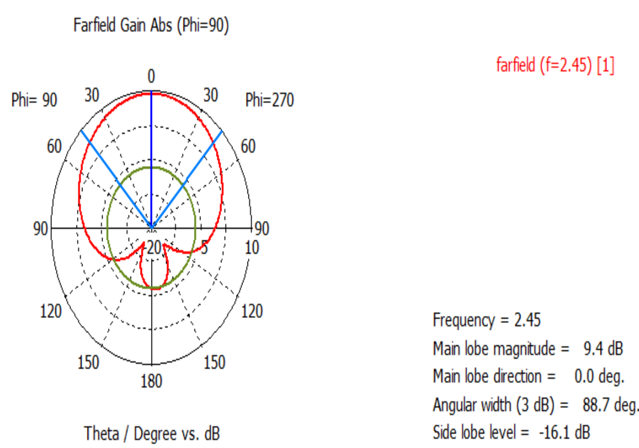
Figure 5. 8: Simulation results of (a) IEEE Gain and (b) Realized gain 28 GHz for eight patches

5.6 Simulated radiation patterns of the 2x1 Array patch antenna

The 2 elements array has gain less than 4 array and 8 array as we have seen previously on the proposal model. The gain 2x1 array around 9.45 dB as shown in the Figure below



a)



b)

Figure 5. 9: Simulation results of (a) Gain and (b) polar from at 2.45GHz for two patches

5.7 Return loss

The simulated return loss of the exiting antenna is shown in the figure below. It can be observed that the optimum antenna has -10 dB

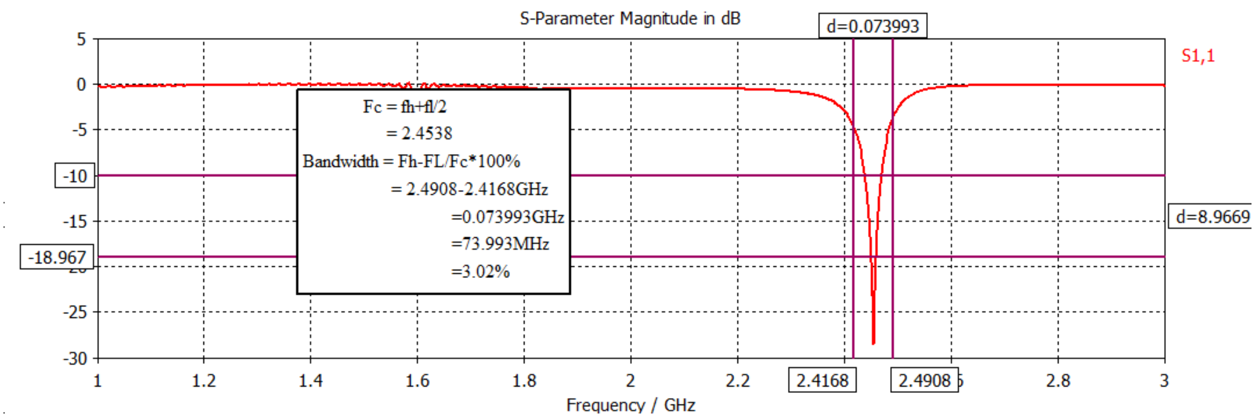


Figure 5. 10: Simulated return loss by 2x1 circular patch antenna

5.8 Sample for each 2, 4 and 8 elements

Comparison between the three designs show that there are increasing value for Gain as the number of patch increases. Table blow shows the comparison between the three designs in terms of Gain. The value of Gain for proposal frequency 28 GHz has increase when number of patches increase from 4 patches to 8 patches. While the exiting model is 2 patches.

Table 5. 1: Comparison between the three designs in terms of Gain

No of Patches	Two	Four	Eight
Gain (dB)	9.45	12.5	13.4

CHAPTER SIX

ANALYSIS

6.1 Introduction

In this chapter will present an analysis of the existing model and proposed model.

Therefore we will compare for frequency, gain, bandwidth and return loss and we will find a better performance in terms of capacity, data rate and quality of service.

The following table shows the parameters.

To understand how 5G will differ from today's 4G networks, we have to compare the existing model and proposed model

Low latency is one of 5G's most important attributes, making the technology highly suitable for critical applications that require rapid responsiveness, such as remote vehicle control. 5G networks are capable of latency rates of under a millisecond in ideal conditions. 4G latency varies from carrier to carrier and cell to cell. Still on the whole 5G is faster than average 4G latencies.

Over time, 5G is expected to advance wireless networking by bringing fiber-like speeds and extremely low latency capabilities to almost any location. Generally speaking, fixed site users, such as offices and homes, will experience somewhat higher speeds than mobile users.

Table 6. 1: parameters

Parameters	4G	5G
Frequencies fr	2.45GHZ	28GHZ
Gain	9.45	13.4
Bandwidth	2.5	4
Return loss	-10	-10

6.2 Gain at frequency 28GHz

The gain of the antenna is determined by the antenna design. Gain is the ability of an antenna to focus energy in a particular direction when transmitting or to receive energy better from a particular direction when receiving. At frequency 28GHz the gain equals about 13.4 dB and this performance is better by the proposed model.

6.3 Gain at frequency 2.45GHz

The existing model shows that the gain is equal to 9.45 dB as shown in the previous chapter and therefore the existing model performed less than the proposed model

6.4 Bandwidth at frequency 28GHz

A higher bandwidth Increased data transfer capability and allows your upload and download larger amounts of data. In proposed we have bandwidth that more than the existing model. The proposed model at frequency 28 GHz has a bandwidth equal to about 4 this proposed model is curious by the existing model.

6.5 Bandwidth at frequency 2.45GHz

In existing model the bandwidth is less than for proposed model that is around 2.5GHz

6.6 Return loss proposed model vs existing model

Return loss is the amount of signal that is reflected back toward the signal source by a device, due to an impedance mismatch. In this section the rerun loss at proposal and existing model and I get they have a standard number that equal to -10dB.

As we mention above the increasing bandwidth, and frequency reducing of return loss and efficiency of power gain it may lead to get quality of service and speed of data transfer and reduce of latency. 5G is better than 4G for data transfer and latency. Proposed Model resulted in an improvement than existing model. The blue line stands on existing Model and the orange line stands on proposed model. That means Proposed Model has better performance than existing model.

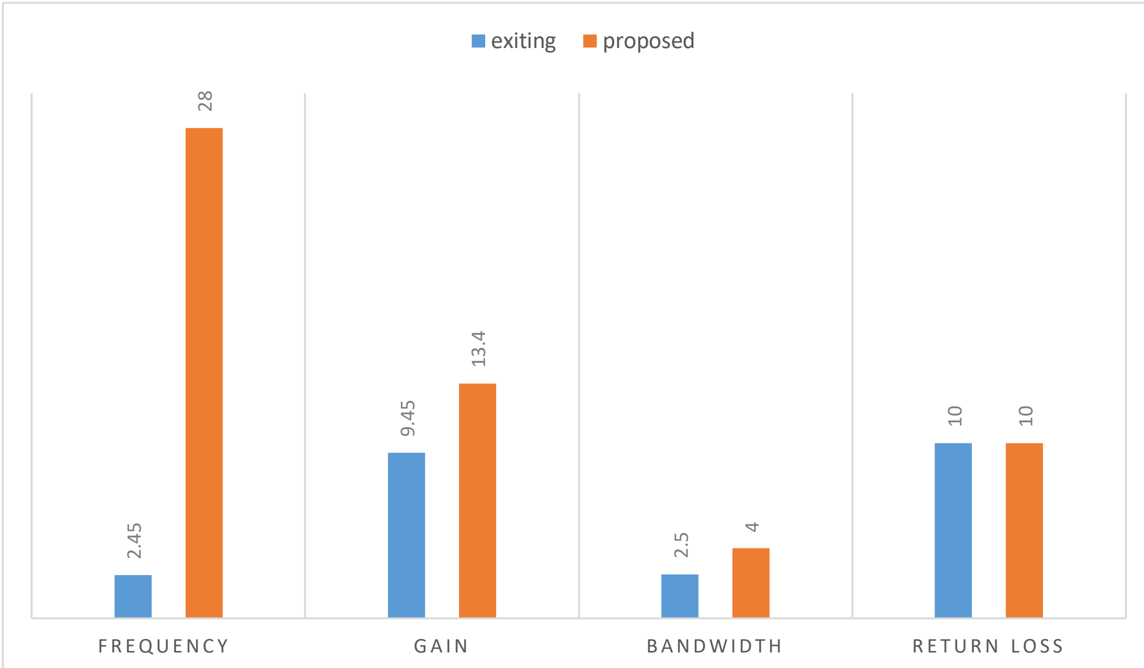


Figure 6. 1 Proposed model vs Exiting model

CHAPTER SEVEN

7.1 Conclusion

A circularly polarized 2x2 and 2x4 array notched circular patch antenna is designed to operate at 28 GHz band. Extensive optimization process for optimum antenna performance is generated besides analysing the beam forming pattern of the antenna for 5G antenna using CST software. Several methods are used throughout the design procedure, such as The antenna design tool Antenna Magus. Antenna Magus is a new software tool to help engineers accelerate the antenna design and modelling process. It has a huge database of designed antennas which can be exported to CST MICROWAVE STUDIO for further analysis and optimization. This simplifies the day-to-day work of antenna designers and modelers ensuring that more projects are completed within specification and on time. Rogers of εr 2.2 (Rogers RT5880) is used as the dielectric substrate because a low dielectric substrate close to air or close to 1 will allow a higher radiation pattern as compared to much higher permittivity value and also a substrate thickness of 0.5357mm is used. The time domain solver is used to run the simulation. The simulation is successfully completed for getting the results that fulfil the design specification which has return loss of -10. The gain and directivity at the operating frequency is greater than 10dB and 10dBi.The bandwidth is greater than 4 GHz.

7.2 Future work

The new 5G network will be able to handle the billions of IoT devices is not the most exciting part of 5G technology. Its ability to simultaneously process and manage that data promises to create new opportunities in virtual reality, I will present some areas here:

Autonomous Driving (and Flying)

5G be the technology that finally pushes autonomous cars and drones into the public sphere, it will be able to connect to other vehicles-people-buildings-and street lights in ways.

Remote Robotic Surgery

5G allows physicians to take that technology on the road—performing surgeries from hundreds of miles away. Because it's so reliable, surgeons know there will be no unexpected glitches or down-times during their procedures. This could revolutionize healthcare for people living in more remote area.

Smarter Factories

Clearly, we've been innovating factories for quite some time. But with 5G technology—which is 100 times faster than 4G and 10 times faster than broadband—the world is our oyster in terms of creating new models of factories themselves.

Immersive Gaming and Augmented Reality

The gaming community is celebrating the launch of 5G more than any other. Because of it's speed, it will allow for the develop of truly immersive, real-time gaming.

Supply Chain Management

Given the huge role the IoT is set to play in the industrial sector, it stands to reason the entire supply chain will benefit from 5G and its ability to connect and communicate among a widely disparate group of connected things. This will provide even greater efficiencies—even higher quality—and even greater transparency for customers—all goals of digital transformation.

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APPENDIX A

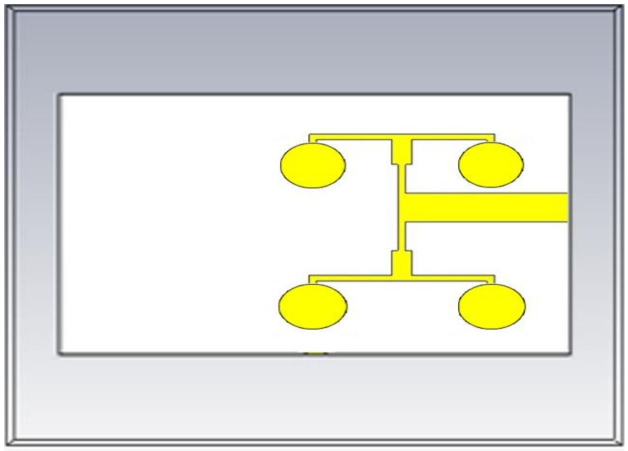
LIST OF ABBREVIATIONS

5G	Fifth Generation
4G	Fourth Generation
CST	Computer Simulation Technology
MIMO	Multi Input Multi Output
IOT	Internet of Things
LTE	Long Term Evolution
WLAN	Wireless Local Area Network
LTE-A	Long Term Evolution-Advanced
TDD	Time Division Duplexing
BS	Base Station
Dp	Patch Diameter
Ln	Notch Length
Wn	Notch Width
Df	Diameter of Feed Pin
Sf	Offset of Feed Pin
PEC	Prefect Electric Conductor

APPENDIX B

Source code

2 by 2 circular patch antenna in CST



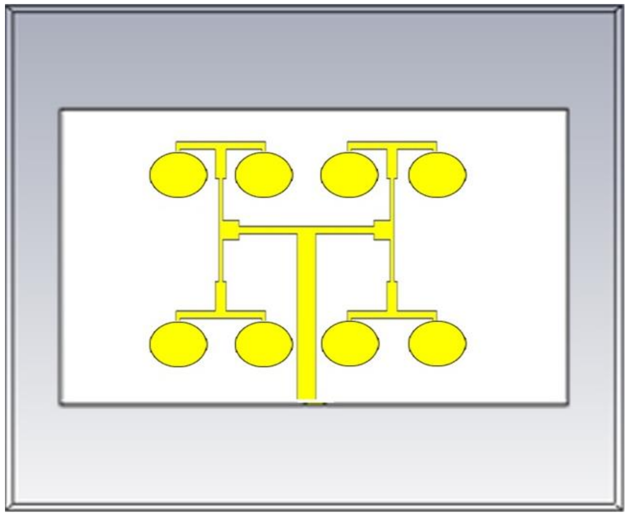
Four elements patch antenna in CST code

3D | Schematic

Parameter List

Name	Expression	Value	Description	Type
wavelength_centre	= c0/frequency_centre	10.7068735		Undefined
tan_delta	= 0	0		Undefined
substrate_width	= patch_spacing_y+patch_diameter*2.5	19.64275		Undefined
substrate_length	= patch_spacing_x+patch_diameter*2.5	19.64275		Undefined
substrate_height	= 0.5357	0.5357	Substrate height	Length
relative_permittivity	= 2.2	2.2	Relative permittivity of substrate	None
pin_position_y	= -feed_pin_offset*sind(feed_rotation_angle)	-0.387140962699635		Undefined
pin_position_x	= -feed_pin_offset*cosd(feed_rotation_angle)	-0.387140962699635		Undefined
patch_spacing_y	= 10.714	10.714	Patch spacing (Y)	Length
patch_spacing_x	= 10.714	10.714	Patch spacing (X)	Length
patch_diameter	= 3.5715	3.5715	Patch diameter	Length
num_ff_monitors	= 13	13		Undefined
notch_width	= 0.3836	0.3836	Notch width	Length
notch_length	= 0.1918	0.1918	Notch length	Length
metal_thickness	= wavelength_centre/1000	0.0107068735		None
groundplane_width	= patch_diameter*3	10.7145		Undefined
groundplane_length	= patch_diameter*3	10.7145		Undefined
frequency_minimum	= frequency_centre*0.7	19.6		Undefined
frequency_maximum	= frequency_centre*1.3	36.4		Undefined
frequency_centre	= 28	28	Centre frequency	Frequency
ff_monitor_frequency_min	= frequency_centre*0.975	27.3		Undefined

2 by 4 circular patch antenna in CST



Eight elements patch antenna in CST code

Parameter List

Name	Expression	Value	Description	Type
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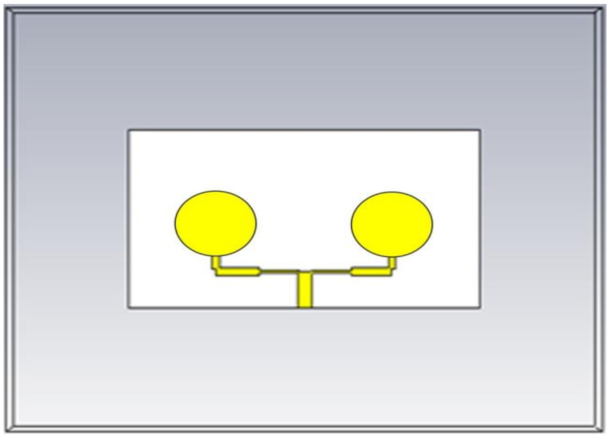
tan_delta	= 0	0		Undefined
substrate_width	= patch_spacing_y+patch_diameter*2.5	20.0788912722893		Undefined
substrate_length	= patch_spacing_x+patch_diameter*2.5	20.0788912722893		Undefined
substrate_height	= 0.5357	0.5357	Substrate height	Length
relative_permittivity	= 2.2	2.2	Relative permittivity of substrate	None
pin_position_y	= -feed_pin_offset*sind(feed_rotation_...	-0.470652991792403		Undefined
pin_position_x	= -feed_pin_offset*cosd(feed_rotation_...	-0.470652991792403		Undefined
patch_spacing_y	= 10.714	10.714	Patch spacing (Y)	Length
patch_spacing_x	= 10.714	10.714	Patch spacing (X)	Length
patch_diameter	= 3.74595650891573	3.74595650891573	Patch diameter	Length
num_ff_monitors	= 13	13		Undefined
notch_width	= 0.831602091812889	0.831602091812889	Notch width	Length
notch_length	= 0.415801045906445	0.415801045906445	Notch length	Length
metal_thickness	= wavelength_centre/1000	0.0107068735		None
groundplane_width	= patch_diameter*3	11.2378695267472		Undefined
groundplane_length	= patch_diameter*3	11.2378695267472		Undefined
frequency_minimum	= frequency_centre*0.7	19.6		Undefined
frequency_maximum	= frequency_centre*1.3	36.4		Undefined
frequency_centre	= 28	28	Centre frequency	Frequency

2 by 1 circular patch antenna in CST



Two elements patch antenna in CST code

3D | Schematic

Parameter List

Name	Expression	Value	Description	Type
wavelength_centre	= c0/frequency_centre	10.7068735		Undefined
tan_delta	= 0	0		Undefined
substrate_width	= patch_spacing_y+patch_diameter*2.5	19.64275		Undefined
substrate_length	= patch_spacing_x+patch_diameter*2.5	19.64275		Undefined
substrate_height	= 0.5357	0.5357	Substrate height	Length
relative_permittivity	= 1.6	1.6	Relative permittivity of substrate	None
pin_position_y	= -feed_pin_offset*sind(feed_rotation_angle)	-0.387140962699635		Undefined
pin_position_x	= -feed_pin_offset*cosd(feed_rotation_angle)	-0.387140962699635		Undefined
patch_spacing_y	= 10.714	10.714	Patch spacing (Y)	Length
patch_spacing_x	= 10.714	10.714	Patch spacing (X)	Length
patch_diameter	= 3.5715	3.5715	Patch diameter	Length
num_ff_monitors	= 13	13		Undefined
notch_width	= 0.3836	0.3836	Notch width	Length
notch_length	= 0.1918	0.1918	Notch length	Length
metal_thickness	= wavelength_centre/1000	0.0107068735		None
groundplane_width	= patch_diameter*3	10.7145		Undefined
groundplane_length	= patch_diameter*3	10.7145		Undefined
frequency_minimum	= frequency_centre*0.7	19.6		Undefined
frequency_maximum	= frequency_centre*1.3	36.4		Undefined
frequency_centre	= 2.45	2.45	Centre frequency	Frequency
ff_monitor_frequency_min	= frequency_centre*0.975	27.3		Undefined