# AN ANALYSIS OF ELLIPTICAL SLOTTED PATCH ANTENNA AT 3.7 GHZ USING 3D PRINTED TECHNOLOGY FOR 5G COMMUNICATION SYSTEMS

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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

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**THIS REPORT IS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF ELECTRONIC ENGINEERING WITH HONOURS**

**FACULTY OF ELECTRONIC AND COMPUTER ENGINEERING**
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**2020**

# DECLARATION

I declare that this report entitled "An Analysis of Elliptical Slotted Patch Antenna at 3.7 GHz using 3D Printed technology for 5G Communication System" is the result of my own work except for quotes as cited in the references.



Signature :

Author : AKMAL BAZLI BIN RAHMAD

Date : 1 JULAI 2020

# APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.



| | | |
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| Date | : | 2 JULAI 2020 |

# DEDICATION

Special education to my beloved parents, Rahmad bin Aziz and Rosnah binti Masod, My kind Supervisor, Dr Mohd Azlishah bin Othman, my co. supervisor, PM Dr Abd Majid Bin Darsono and my friends. This thesis is purely about your enormous support and sacrifice. I devote all of this to you. May Allah bless each and every one of you. Thank you for all you care, support and believe in me.

# ABSTRACT

In this project, analysis for the elliptical patch antennas at 3.7 GHz using 3D printing technology for the proposed 5G communications system. The concept of 3D antenna manufacturing has been used in this project as it can save the cost of antenna production and antenna manufacturing process. The elliptical slotted circular shape is a joint antenna between 2 circular slots where an elliptical shape joins the circular and cuts the circle at the top end of the circle to form a crescent moon. The proposed antenna is designed to be elliptical slotted circular with a frequency range of 2.5 GHz – 4.9 GHz and is designed to meet the results using the software: CST Studio Microwaves Suite 17. The shape of the elliptical antenna is widely used in cell phone towers due to some of their advantages such as lowering the frequency cutoff, increase bandwidth, and nominal gain between 12 and 17dBi and 3db beam width between 20 degrees and 43 degrees. Proposed antennas for analysis with simulations located at frequencies of 2.5 to 4.9 GHz to prove design reliability. Return loss, gain, VSWR,bandwidth,radiation patterns at 3.7 GHz used for analysis of the performance of the designed antenna.

# ABSTRAK

Dalam projek ini, analisis untuk antena patch elips pada 3.7 GHz menggunakan teknologi percetakan 3D untuk sistem komunikasi 5G yang dicadangkan. Konsep pembuatan antena 3D telah digunakan dalam projek ini kerana dapat menjimatkan kos pengeluaran antena dan proses pembuatan antena. Bentuk bulat yang berbentuk elips adalah antena bersama antara 2 slot bulat di mana bentuk elips bergabung dengan bulatan dan memotong bulatan di hujung atas bulatan untuk membentuk bulan sabit. Antena yang dicadangkan ini dirancang untuk berbentuk bulat slot elips dengan julat frekuensi 2.5 GHz - 4.9 GHz dan dirancang untuk memenuhi hasil menggunakan perisian: CST Studio Microwaves Suite 17. Bentuk antena elips banyak digunakan di menara telefon bimbit kerana beberapa kelebihan mereka seperti menurunkan pemotongan frekuensi, meningkatkan lebar jalur, dan keuntungan nominal antara 12 dan 17dBi dan lebar balok 3db antara 20 darjah dan 43 darjah. Antena yang dicadangkan untuk dianalisis dengan simulasi yang terletak pada frekuensi 2.5 hingga 4.9 GHz untuk membuktikan kebolehpercayaan reka bentuk. Kerugian pulangan, VSWR, keuntungan, lebar jalur, corak radiasi pada 3.7 GHz digunakan untuk analisis prestasi antena yang dirancang.

# ACKNOWLEDGEMENTS

Without the help and support of kind people around me, it would not have been possible to write this thesis, only to some of whom it is possible to give specific mention here. Above all, I am grateful to Allah SWT for having established me to complete this thesis.

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Last but not least, my sense of gratitude to one and all who had been directly and indirectly associated with realizing this project.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| 5G | Fifth generation |
| 4G | Fourth generation |
| WRC | World Radio Communication Conference |
| Mmtc | Machine Type Communication |
| eMBB | Enhanced Mobile Broadband |
| URLLC | Ultra Reliable Low Latency |
| WRC | World Radio Communication Conference |
| IoT | Internet of Things |
| CST | Computer Simulation Technology |
| 3D | Three dimension |
| CST | Computer Simulation Technology |
| VSWR | Voltage Standing Wave Ratio |
| USB | Universal Serial Bus |
| PCB | Printed Circuit Board |

# CHAPTER 1

# INTRODUCTION



## 1.1 Introduction

Antennas radiate and receive electromagnetic waves by converting guided waves supported by a guiding structure into radiating waves propagating in free space and vice versa. This function has to be accomplished by fulfilling specific requirements which affect the antenna design in different ways. In general, a number of antennas are installed in a satellite and their requirements vary depending on the application and on the mission. It is also a transducer which converts RF fields to alternate actual or bi - directional RF fields. Two receiving mediums and antenna transmissions can be transmitted or received through antennas. Antennas have an important role to play in the operation of all radio equipment. It is used in the network of local wireless and mobile phones as well as in satellite communications.

Frequency or bandwidth when the antenna has a wide or wide transmission function (as for an antenna with a log-period antenna); when an antenna with an impedance is not available, the transmission line and the transmitter (or receiver) are not well adapted. The antenna is also not well connected. The use of antennas which exceed the frequency of their construction affects their radiation pattern and decreases the gain in each way.

The corresponding network is normally the base of the antenna terminal and the power transmission to the antenna is increased by the transmission line. The bandwidth of the antenna system may likely be limited by similar networks. Some small wires can also be grouped in cages to simulate thick components. Alternatively, this extends the bandwidth of the resonance.

The radiation mechanism comes from interruptions of the transmission line at each truncated edge. Radiation at the rim leads to an antenna acting electrically slightly larger than its physical measurements, so a microstrip transmission line length slightly shorter than half the wavelength is applied at the frequency to ensure that the antenna resonates. The patch antenna is normally made from the same lithographic material and processes used to produce printed circuit board material on a dielectric substrate.



It was realized to be possible to radiate circular polarized waves in the elliptical microstrip antenna that only require coaxial feeding, and design is simple enough to calculate in standard co-ordinate systems. But it is main point of this paper to detect the output and behaviour, with different coaxial ports.

There are many ways to test antennas (called AUTs, or antennas under test), and many parameters can be tested according to their characteristics and specifications. Measurement parameters can also be used in several ways including radiation pattern, directivity, gain and polarization. Based on the 3D printed that will be used later the measurement must be through the terminal antenna input to get the ratio of power actual radiation. This can prove the analysis of the elliptical antenna patch at 3.7 GHz using 3D printing technology for 5G communications systems.

## 1.2 Background study of 5G communication system

The fifth evolution of smart communications networks (5G) comes from the fact that the user wants to be able to remain connected in a more secure, low latency, reliable and battery-saving way. Given the evolution of our mobile devices and growing demand for connectivity, 5G will have to confront the high volumes and the number of new devices in the network that multiply by 1000. Following the fall in voice phone revenue and the rise in data content and online service, this new technology has not only been developed to meet customer needs, but also to improve performance in services such as remote operations, offer a safer and more sustainable technology, test new business models and financial formulas amongst other things. This will also help to restructure the band by closing the holes that a increasing digital divide would create, as new demands emerge and new allocation needs to be made to fill empty spaces. We need to take a look at standardization organizations and regulatory bodies involved in the deployment of 5G in order to be able to analyze how 5G is developed and how this will affect us in a socio-economic way.

The 3GPP is a group of telecommunications association that work together to develop different generations of mobile communication systems starting with the Third Generation (3G) of mobile phone system specification that came after the

Second Generation (2G) known as the Global System for Mobile Communications (GSM). Moreover 3G was developed into the Universal Mobile Telecommunications System (UMTS) and finally to the technology that is in use nowadays Long-Term Evolution (LTE) [1]. This organism plays a very important role in the deployment of the fifth generation as it puts together all the ideas and developments that are being produced worldwide. Additionally the "ETSI which is the European Telecommunications Standards Institute is in charge of producing standards for Information and Communications Technologies (ICT) including fixed, mobile, radio, converged, broadcast and Internet technologies" [2], and will be in charge of the standardisation needed for 5G in terms of technology, security and so on.

The ETSI is part of the 3GPP and in mobile communications; it standardizes what the 3GPP proposes. Moreover we will have to take into consideration the International Telecommunications Union (ITU) that will also play an important role in the standardization and regulation involved in 5G technology. "In the world radiocommunication conferences (WRC), that are held every three or four years a review is done to revise the radio regulations, the 10 international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. This reviews are made based on the ITU council and it takes into account recommendations made by previous world radiocommunication conferences" [3].

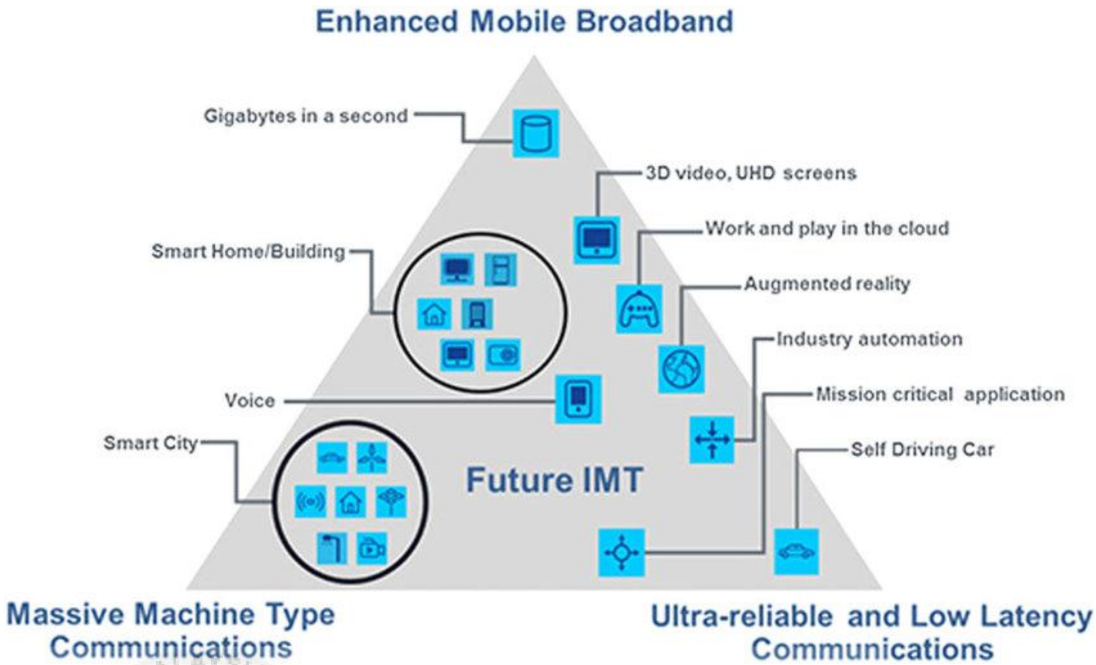



**Figure 1.1 shows the usage scenarios of IMT for 2020 and beyond [4].**

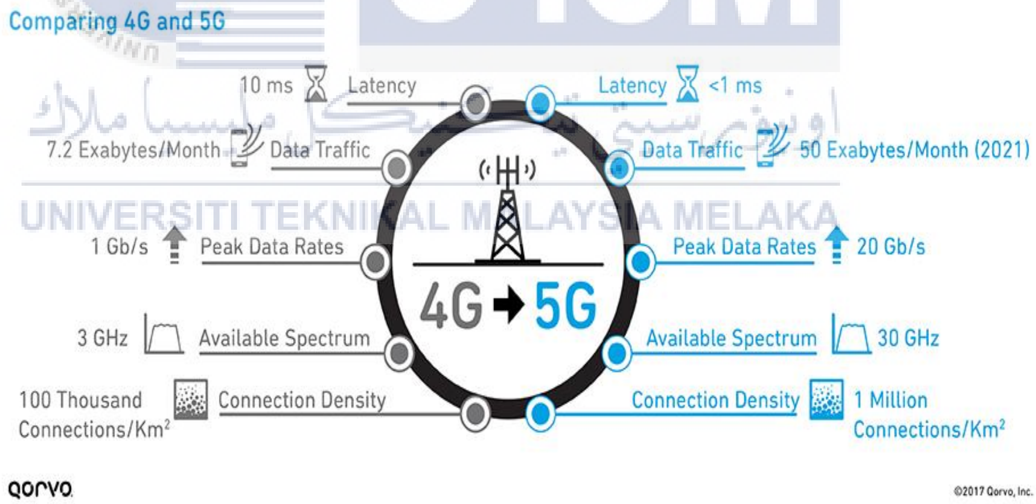



**Figure 1.2 shows comparison of 4G and 5G requirement**

Microstrip antenna is a good candidate for 5G base station antenna designs due to its attractive features of low profile and light weight, easy fabrication, and conformability to mounting hosts. So in this project, I have been focused on the development of low-profile and wideband microstrip antenna using the FR4 (flame resistance 4) heated on 3D printer to achieve half wavelength mode operating at 3.7 GHz during fabrication to this project. There were a few types that have been used in determining the multilayer PCB material comparison before which are:

**Table 1.1 Shows advantage of PCB material**

| | **PCB MATERIAL** | **ADVANTAGES** | **JOURNAL** |
|---|---|---|---|
| **1)** | FR4 | • Handling is easy<br>• Availability is high<br>• The cost is very low<br>• Measured insertion loss is higher | Chirap, A., & Popa, V. (2016). Insertion loss measurement of a lowpass microwave filter manufactured on FR4 laminate. 2016 International Conference on Development and Application Systems (DAS). doi: 10.1109/daas.2016.7492578 [5]. |
| **2)** | 3D printer | • smaller form-factor<br>• lighter weight<br>• lower cost<br>• Being more bio-friendly. | Nayeri, P., M. Liang, R. A. Sabory-Garcia, M. Tuo, F. Yang, M. Gehm, H. Xin, and A. Z. Elsherbeni, “3D printed dielectric reflectarrays: Low-cost high-gain antennas at submillimeter waves,” IEEE Trans. Antennas Propag., Vol. 62, No. 4, 2000–2008, Apr. 2014 [6]. |

## 1.3 Problem statement

Low-profile microstrip antennas with stable radiation patterns within a relatively broad band have been presented for today's 5G operations. However, frequency output may be inaccurate as output from PCB boards differs from software and theory. In addition, the FR4 design must adhere to the existing features to transmit maximum data transfer at a frequency of 3.7 GHz. Therefore, we created a form of elliptical antenna that covers a wide range of areas with 5G applications to meet the needs of the users. This project requires accurate design of the FR4 microstrip length and width to easily receive and transmit signals. The advantages of this antenna are that the user can increase the capacity and speed of the internet to transmit more data with using low cost.

The conversion from FR4 to 3D antenna printers offers many new ways of building complex products. Such developments demonstrate that the quality of the commodity in a variety of ways can be accomplished.



This project aims at both FR4 manufacturing and a 3D printed elliptical antenna consisting of low price miniaturization. Then the antenna output is measured so that 5 G applications can run at frequency 3.7 GHz.

## 1.4 Objective

The main objective of this project is to analyze the 3D elliptical form antenna at 3,7 GHz for 5G. The following objectives support this project goal:

1. To develop an elliptical antenna with operating frequency of 3.7GHz that capable for 5G communication system.
2. To design an antenna using FR4 method and 3D print technology with copper spray.
3. To analyze the simulated S-Parameters of elliptical antenna specifically on $S_{11}$ reflection.
4. To analyze computed radiation pattern 2D view of E and H plane of the single antenna at the operating frequency of 3.7GHz.
5. To develop a prototype of elliptical antenna.

## 1.5 Scope of work

The scope of work in this project is to design an elliptical antenna at 3.7 GHz for 5G application an analysis the behavior of elliptical antenna parameter such as S-parameter S11, gain, radiation pattern, and efficiency and bandwidth. Lastly, develop an elliptical antenna using FR4 fabrication and 3D printing technologies.



The frequency range from 2.5 GHz to 4.9 GHz for the simulation and optimization of an elliptical antenna is defined. Moreover, the operating bandwidth is enough for practical operation. The software that we used to design an antenna is CST studio software 2017.CST software is able to analysis and simulated the antenna that already designed. Hence, all the parameter of the antenna will be shown based on the frequency stated.

Lastly, we analyze the effect of elliptical antenna design specification on the characterization and functionality of the antenna fabrication.

## 1.6 Brief explanation on methodology

Methodology is a method used to collect any data and flow process used in the thesis to show the project is running successfully. At an early stage, beginning with a literature review on elliptical antenna development. Literature review is very important to discuss all project information at various points so researchers can understand in depth how the project works. All information collected is processed through the IEEE journal, books, and articles and also from established websites.

Then, design and simulation will be done using CST software. Observation and measurement of antenna parameters will be recorded. For the FR4 (lossy), the entire antenna will be fabricated using copper spray and for the ulti-maker will be used for 3D printing process of the elliptical antenna with the material PLA infused with copper. The dimension of the length with width and so on will be adjusted so that the antenna match-up the specification needed of this project. Lastly, analyze the results in term of simulation result for the antenna.



## 1.7 Thesis outline

Chapter 1 – Clarify antenna history. This contains issue points, priorities, scope of research and approach presentations.

Chapter 2 – In this chapter, the literature review section discusses all the research and technical paper related to this project. Statistics, formulas and antenna-based antenna designs have been included in previous work.

Chapter 3-Antenna architecture approach has been discussed. Section 3 This chapter will discuss the parametric analysis of an antenna parameters, along with the steps to design, simulate and optimize the antenna procedures.

Chapter 4 – Display all the data and results obtained from the CST software simulation. This chapter explores and addresses all the parameters in depth. The result is discussed and observed in more detail.

Chapter 5 – In this completed draft, ideas and future projects will be explored and strengthened. The project's conclusion is summarized in this chapter throughout this thesis.

# CHAPTER 2

# BACKGROUND STUDY



## 2.1 Introduction

This chapter demonstrates the approach of the author to enhance the awareness of field research. The analysis of literature supports the claim formed by the developer during this study. Besides this, the literature review is carried out so that the reader can note some of the words contained in this study that hesitated and misunderstood.

## 2.2 Overview of 5G communication

5G mobile communication can bring new experiences to business and society, together with higher information rates or higher capabilities, higher information measures, increased security and lower latency. This can lead to new opportunities for society and business: 5G makes a big modification, but we tend to take up the world.

Under development, key optional 5G technologies are based on new multiple access methods, huge MIMOs, full digital or hybrid radiation forming, high-density networking, etc. The implementation of these high-level technologies can lead physical infrastructure designers to new challenges. The antenna, but also the associated microwave systems and the characterization of the radio propagation environment, undoubtedly cover these challenges. Along with tutorial and industrial work, several challenges still must be overcome, or they have higher cost-effective solutions despite a terribly active current analysis on 5G antenna systems.

The full potential of the Internet of Things can yet be facultated for 5G to support considerably faster mobile broadband speeds and a more profound use of mobile knowledge. 5G will be in the middle of long-term communications from video games and autonomous automobiles to the trade network and good cities. However, 5G applications can use higher frequency bands within the region of the metric linear unit to alter wider measurement and better rates in the information. High frequency and broader bandwidth are important challenges for antenna designer and therefore they want to beamforming, beam steering and multiple beams. Low profile economical antennas and antenna arrays to ensure reliable and interference-free communication, but the antenna and propagation aspects are additionally complicated by the need for increased power, greater measures of information, greater gain and the inability to present the human user. That means the need for innovative antennas for new concepts and solutions.

Eight documents on various aspects of 5G antennas and their system applications are presented in this special issue. Two documents affect problems of modeling, whilst 3 papers involve multi-input multi-output systems (MIMO) which are expected to be used extensively on 5G systems in the long run. Another paper considers a very important problem with the synthesis of applicable patterns of radiation of linear and table antenna ranges of pure discretionary mathematics to provide the necessary reconfiguration coverage. One paper deals with a dual-band single-layer reflection array cell for future 5G systems. Another paper examines the directional drawback of unknown inhomogeneous noise maltreatment arrays wherever the approximation of the lower-rank variance matrix for an entirely unique methodology of gridless direction search is projected. There is a lot of elaboration on these subjects in the following paragraphs.

### 2.2.1 5G Spectrum – 1 GHz to 6 GHz

Spectrum is a revolutionary wireless network component. It awakens the "airwaves" that are the basis of communication networks, such as mobile phones, Wi-Fi and TV, that we use every day. The numerous sets of 5G networks and implementations include a diverse range of spectrum bands that incorporate both high and low frequencies with different characteristics to satisfy the varying demands.

In the 5G communication system, defragmentation and the clearing of primary strips a significant amount of new harmonized mobile spectrum should be used fully. The spectrum is divided into three main frequency ranges to cover and support all cases. Three ranges are: Sub-1 GHz, 1-6 GHz and more than 6 GHz.

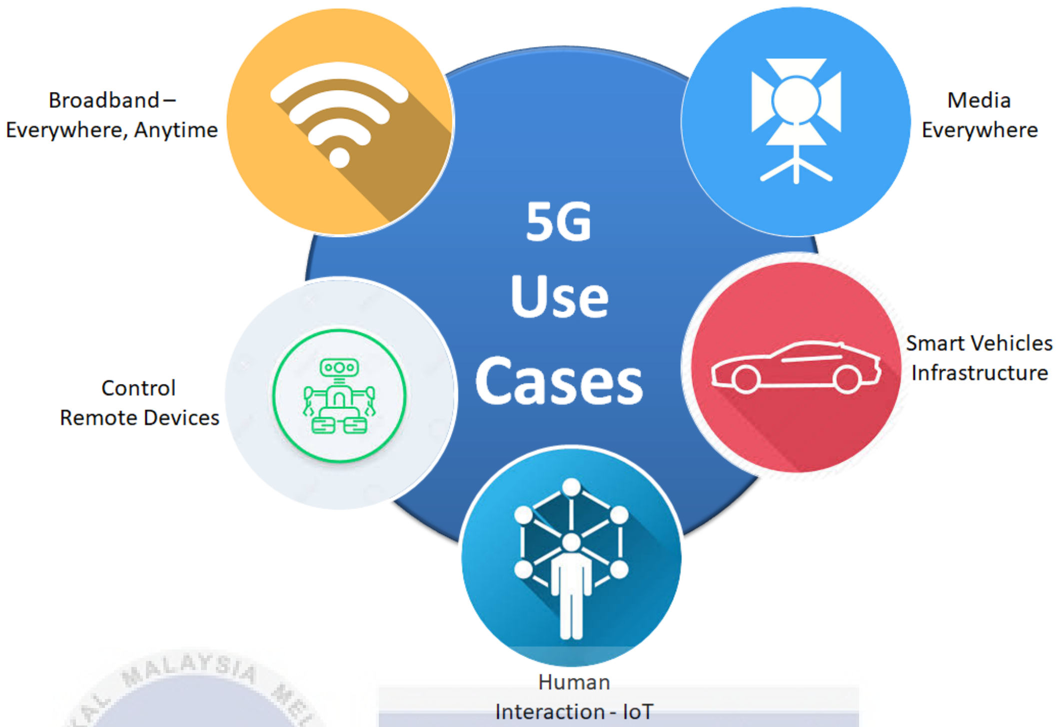



**Figure 2.1: 5G use cases**

The Sub-1 GHz spectrum will cover and will cover the following areas, where it supports Internet of Things services (IoT) coverage throughout urban, suburban and rural areas. For the range from 3.3 to 3.8 GHz, the basis for numerous initial 5G services expected to lie in the range of 1 to 6 GHz, providing a good mix of coverage and capability benefits. It includes others, including 1800 MHz, 2.3 GHz, 2.6 GHz etc., which may also be assigned or reframed by 5G operators. There is a need for greater spectrum to maintain 5G service quality over a long-term basis and demand for spectrum bands from 3 to 24 GHz increases daily[7].

### 2.2.2 Mid-Band (Sub-6)

Mid-band (also called Sub-6) is the commonly used spectrum even for 2G, 3G and 4G communication system for wireless data transmission. Sub-6 operates between the 1 GHz and 6 GHz frequencies (2.5, 3.5, and 3.7-4.2 GHz). This spectrum band has its very own specialty where it can penetrate walls and obstacles, not only that, it has decent speed and covering a lot of space with reasonable Internet speeds.

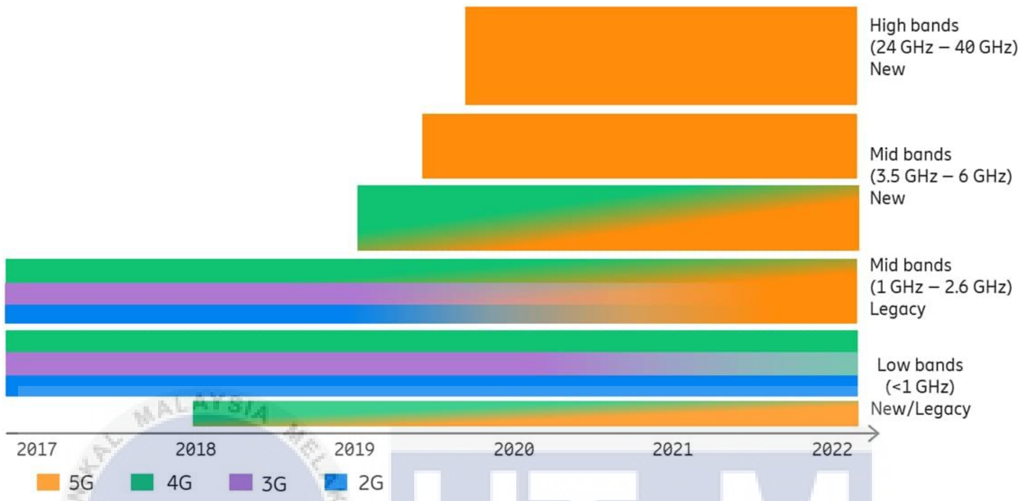



**Figure 2.2: Indicative spectrum allocation over time**

In the spectrum of Sub-6, all frequency ranges are licensed for wireless data transmission and, naturally, 5G will take advantages of those bands. For educational purposes or broadcasts, 2.5 GHz is reserved as an application to be implemented in 5G communication system.

The 2.5 GHz band is at the lower end of the mid-band spectrum, which means it has wider coverage (and slower speeds) than the mid-range bands that currently used for 4G. This band remains chosen by the industry for remote areas so that extremely high-traffic areas don't end up on super-slow, low-band spectrums.

## 2.3 Self-Grounded elliptical Antenna

On 2019, a paper by M. Alibakhshikenari, etv that develop a elliptical antenna for Sub-6 spectrum. A study made by authors from University of Rome and London

Metropolitan University, they made a Wideband Sub-6 GHz Self-Grounded Bow-Tie Antenna with New Feeding Mechanism for 5G Communication System. In this journal, the authors inspired by the shape of eagle wings. On CST Microwave Studio, they optimize the reflection-coefficient less than -12dB and frequency range between 3.35 to 4.4 GHz. As the result shows in Fig. 2.3, the preliminary investigation produce excellent reflection coefficient performance, which is almost below -10 dB over the band of 3.35 GHz to 4.4 GHz that corresponds a fractional bandwidth of 27% [8].

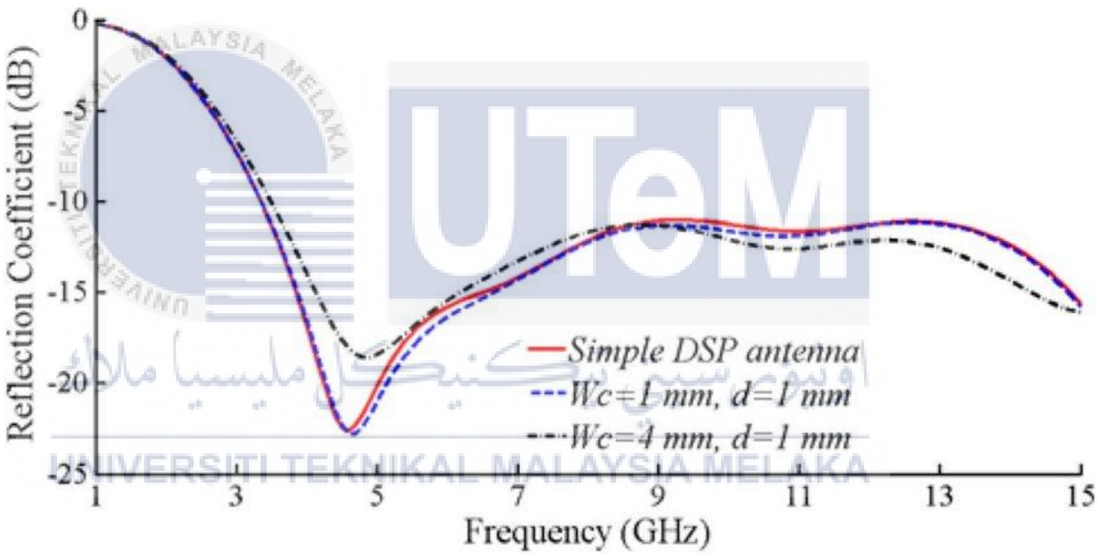



**Figure 2.3: Reflection coefficient (S11<-10) for the proposed elliptical antenna excited using the proposed mechanism**

## 2.4 Characteristics of Antenna

An antenna is a device that converts an RF signal via conductor into an electromagnetic wave in free space. Regardless any kind of antennas, all maintain the same characteristics if it is transmitting and receiving. A MPA consists of a metallic pattern on one side of a dielectric substrate and ground plane on the other side of the substrate. There are different shapes of patch as shown in Fig. 2.4.

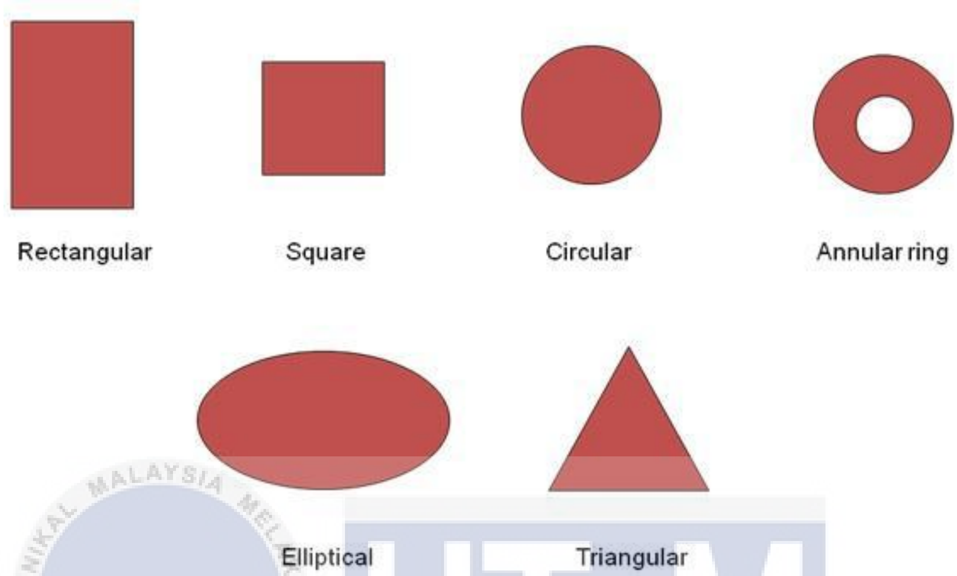



**Figure 2.4 Different shapes of patch**

Micro strip antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. MPA with thick dielectric substrate having low dielectric constant is desirable for better antenna performance due too better efficiency, larger bandwidth and better radiation but this will increase the size of antenna. A compact microstrip antenna resulted to narrow bandwidth and less efficient due to higher dielectric constant in designation. Thus, developer must choose between antenna dimensions and antenna performance. After compromise, elliptical antenna may give better radiation pattern, more bandwidth and good directivity.

### 2.4.1 Elliptical Microstrip Patch Antenna

Technique feeding inset edge was chosen for designing elliptical microstrip patch antenna as shown in Fig. 2.5.

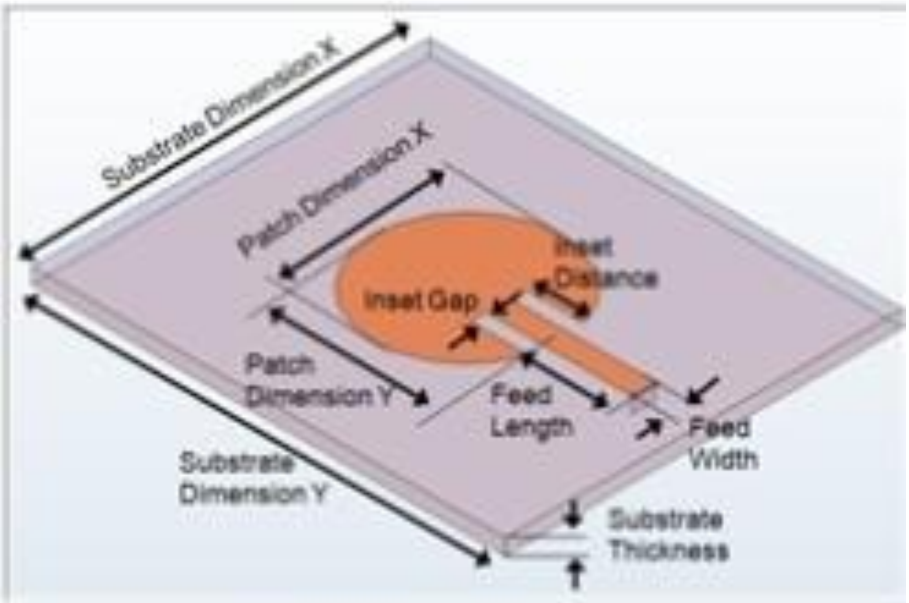



**Figure 2.5 Elliptical Antenna Dimensions with Inset feed technique**

Semi major axis will be "a", semi minor axis will be "b" and "$a_{eff}$" is the effective semi-major axis. The radiated fields cause two modes that are perpendicular to each other and have equal amplitude but are 90° out of phase. An elliptical patch antenna with optimum dimensions acts as a Circular Polarized wave radiator. The patch is excited by an inset edge fed.



Circular polarization may be obtained by using multiple feeds or by altering the shape of a rectangular micro strip antenna. An elliptical patch on a microwave printed circuit board can be made to radiate circularly polarized waves. Such an antenna requires only one feed and its geometrical shape is simple enough to permit theoretical analysis to be carried out in standard coordinate system [9].

### 2.4.2 Radiation pattern

An antenna radiation pattern is defined as a diagrammatic depiction of the antenna's radiation personalities as spatial co-ordinates, in which the radiation pattern is calculated in a remote area.

For the antenna layout, it's easy to choose the antenna for the end user to shape the radiation mode. Divided into three types of radiation patterns:

i. Isotropic architecture pattern-The antenna is transmitted in the same direction as an hypothetical lossless antenna with radiation in all directions.

ii. Omnidirectional pattern — Non-directionally, a constantly ornamented plane is well-known.

iii. Directional pattern – the antenna only radiates consistently to the left or to the right.



Such patterns can also be examined to show the relative field strengths of the antenna radiated field. The antenna radiation pattern is always composed of a 3D graph in three dimensions, as shown in Fig. 2.6 or polar cross-sectional cross-sectional plots. In the diagram, side lobes and back lobes will appear. As shown in Figure, the polar plot can be evaluated as a planer cut from the 3D pattern of radiation.

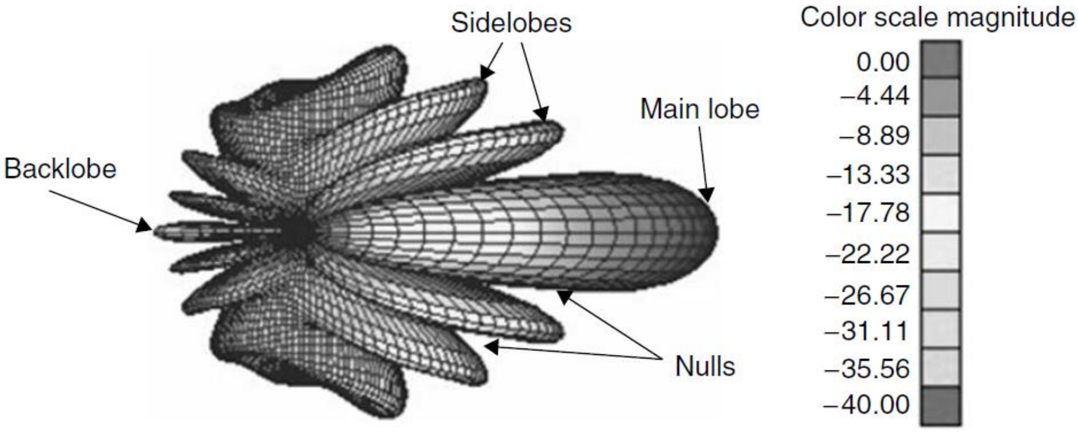



**Figure 2.6 Radiation Pattern with Scale**

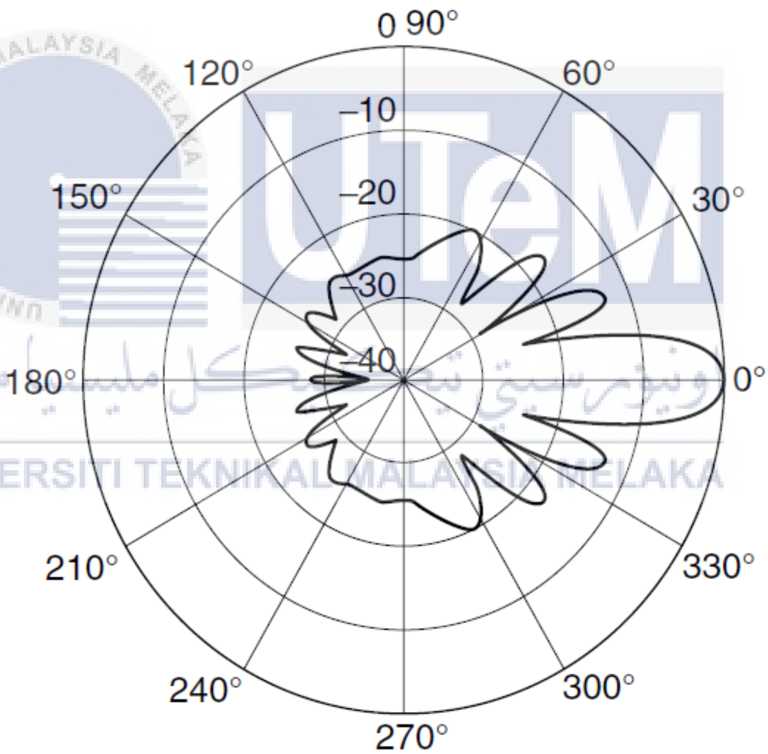



**Figure 2.7 Polar Form radiation**

### 2.4.3 Gain and Directivity

The direction of an antenna is the possibility of directing or centralizing the emission intensity in an unwanted direction. It was defined as "the radiation intensity association in a given direction from the antenna to the radiation intensity in all directions." In other words, the guidance of a nonisotropic source is similar to the ratio of its radiation power to that of an isotropic source in a given direction. By cleaning up the total antenna power of 4π, the average radiation intensity can be intentionally determined. If the direction is not known, the radiation level direction can be shown below:

$$D = \frac{U}{U_i} = \frac{4\pi U}{P_r} \quad (2.1)$$

A low-gain antenna radiates in all directions with equal power, whereas a high-gain antenna radiates in a superior manner in different directions. The intensity ratio (power per unit surface), which is radiated by the Antenna in the given direction at the random distance cut down by the radiation at the same distance through a debatable isotropic, lossless antenna is certainly defined as the gain, directive gain or power gain of an antenna.



$$Gain = 4\pi \frac{U(\theta,\phi)}{P_{in}} \quad (2.2)$$

Which are;

- U is radiation intensity
- $P_{in}$ is total input power

### 2.4.4 Beamwidth

The antenna beamwidth generally is the angular width of the half-power that radiates through a certain cut across the main antenna radiation beam where it radiates most of the energy. The radiation intensity peak, the peak of the main beam, is -3 dB below a peak, where both points on the main beam are located; these points are located on both sides of the peak and separate the angular width of the half power. The angular gain is defined as the beamwidth between the half power points. Half of the power in decibels is -3 dB, so that half the beamwidth is also called beamwidth 3-dB. Horizontal as well as vertical beamwidths are typically taken into account.

# CHAPTER 3

# METHODOLOGY



## 3.1 Introduction

The flows of the project process that were performed step by step to ensure the project is effectively completed are addressed in this chapter. Methodology is the method used in the whole study and is used to collect data and information as well as a guide for working flows in order to start changing the parameter in order to optimize the design of the antenna to achieve the necessary performance.

## 3.2 Literature Review

This research was completed with the methodology. The study on journals and books on elliptical antenna and 3D printed materials began with the project with the literature review. Then begin to compute 5G application calculations at 3.7 GHz for those papers. The antenna is tested in full using the 2017 CST studio set. If the result is unwanted, it will be necessary to optimize the project. If not, move on the stage of manufacturing. The antenna prototype will then be weighed.

i. Research Methodology Flow Chart

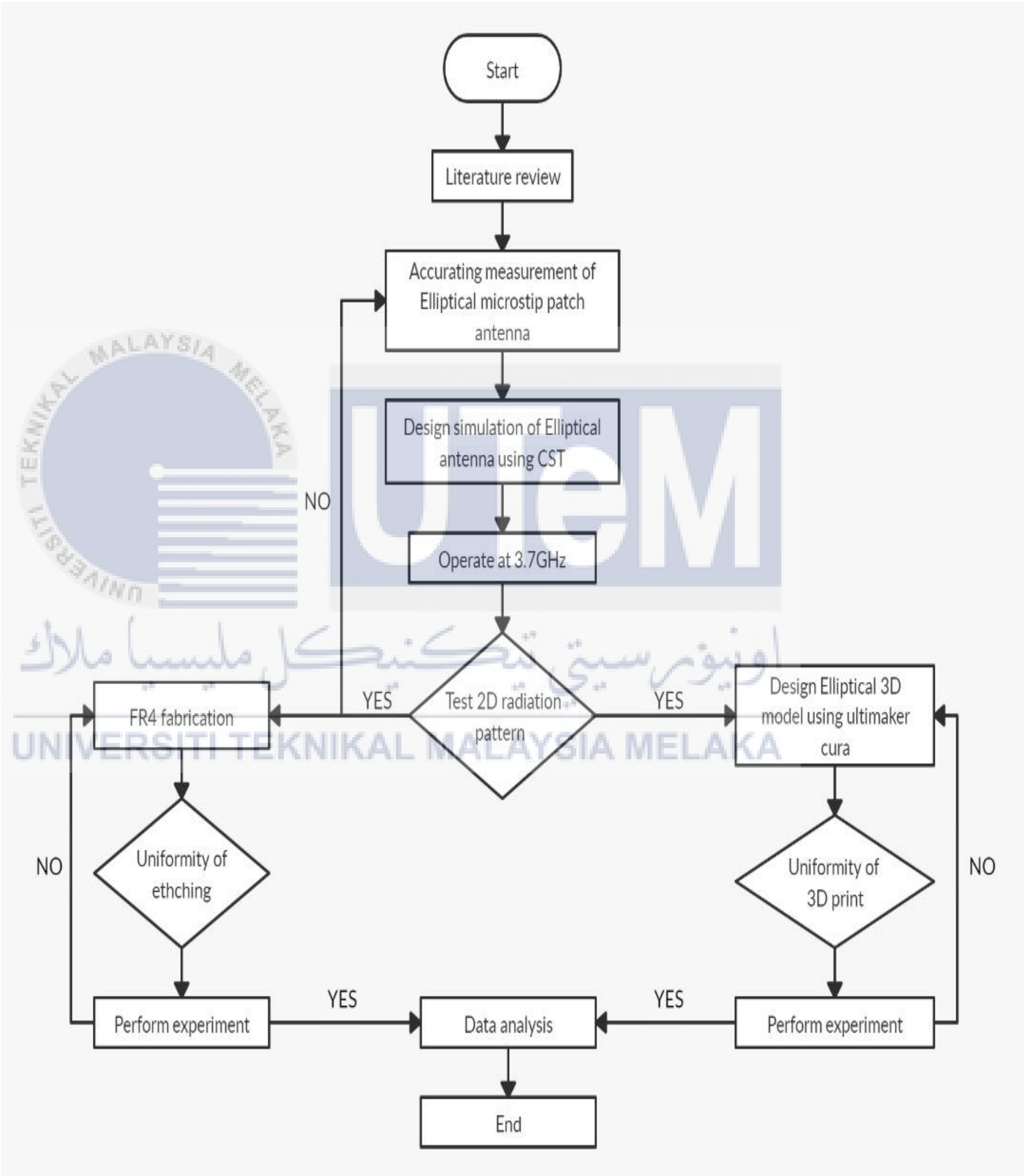



**Figure 3.1: Project development flowchart**

In order to achieve the objectives of my project, several methods are required as shown in the flowchart. The figure shows all the steps needed for this project development. The methods will be explained below.

### 3.3 Design Specification

The frequency selected for the operation of the antenna is 3.7 GHz. This is because 3.7 GHz is the antenna's target frequency to perform well on the 5G application communication system. The return loss must be expected to be below than -20 dB, so that the antenna is functioning well. Hence, antenna efficiency must be over than 70% while the gain is expected to be around 5dB which give far distance coverage as this is the common gain and it is competitive compare with antenna we have today.

**Table 3.1 Parameter specification of an ideal elliptical antenna**

| Parameter | Proposed antenna |
|---|---|
| Gain | 9.1 dbi |
| Bandwidth | 1.674 GHz |
| Main Lobe Direction | 17◦ |
| Radiation Pattern | Conical |
| Polarization | Eliptical |
| Dielectric Media | Air ($\mathcal{E}r$ = 1.00059) |

### 3.4 Design Dimention

A design consisting of a crescent shape and an antenna cut with a uniform space and interconnection was produced from the simulation process using CST software. The feeder's location is at the lower center of the substratum. The simulated antenna is specified in Table 3.2.

**Table 3.2: The Simulated Antenna Specification**

| **Parameter** | **Value** |
|---|---|
| Operating Frequency, $f_o$ | 3.7 GHz |
| Substrate dielectric constant, $\mathcal{E}_r$ | 4.3 |
| Cavity of thickness | 1.6mm |
| No. of turn | 5 |
| Thickness of radiating surface (surface) | 0.035 mm |
| Height of substrate | 30 mm |
| Width of substrate | 28 mm |
| Major axis of ellipse, da | 9.6 mm |
| Minor axis of ellipse, dc | 11.5 mm |
| Major axis of cutting plane, db | 3.0 mm |
| Width of feeder, La | 0.8 mm |

Patch antenna width

$$\text{Wpat} = 1\frac{1}{2\text{f res}\sqrt{\mathcal{E}0\mu0}}\sqrt{\frac{2}{\mathcal{E}re^{+1}}} = \frac{C}{2fres}\sqrt{\frac{2}{\mathcal{E}re^{+1}}} \quad (3.1)$$

Effective dielectric constant

$$\mathcal{E}\text{ref} = \frac{\mathcal{E}re^{+1}}{2} + \frac{\mathcal{E}re^{-1}}{2}\left[1 + \frac{12h}{wpat}\right]^{-1/2} \quad (3.2)$$

The extension length

$$\frac{\Delta L}{hs} = \frac{0.412(\mathcal{E}ref^{+3})(\frac{wpat}{hs}+0.264)}{(\mathcal{E}ref^{-0.258})(\frac{Wpat}{hs}+8)} \tag{3.3}$$

Actual length of patch

$$\text{Leff} = \text{L} + 2\Delta L \tag{3.4}$$

Where hs = thickness of substrate; L = patch length; L eff =effective length.

Based on the above equations, the resonating frequency of chosen length and width of patch is 3.7GHz. Moreover, the antenna structure is design on the CST software with diameters of La is 0.8 mm, da is 9.6 mm, dc is 11.5 mm, db is 3.0 and width of feeder is 0.8 mm from center of substrate to get the best simulation result same as figure 3.2.

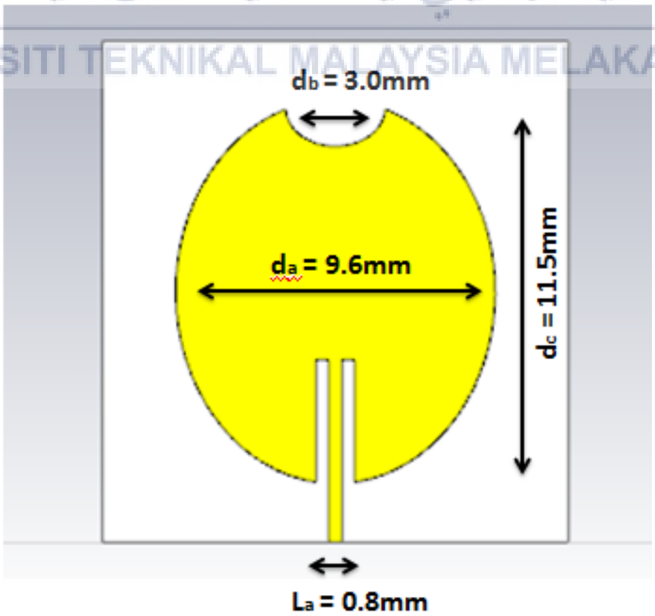



**Figure 3.2: The Crescent Antenna Structure**

### 3.5 Optimization of antenna design

The antenna model is ready to simulate with all the setting done before the simulation of the system. In the previous step, the required setting was displayed and set. The antenna is then simulated, with further study and discussion of all parameters including return loss, gain and others.

Any optimization regarding antenna performance are tabulated and time varying to ensure that the simulated performance of the designed antenna achieve the desired results. To achieve the best performance for antenna design in the simulation test, the process of analyzation of the simulation results are done continuously in either dimension of the antenna, parameter and design of the antenna. Once it achieved the best performance for the antenna, the process of fabrication only can be proceeding.



### 3.6 Fabrication of Antenna Design

The antenna design is provided for manufacture once the antenna parameter specification is reached. Before manufacturing with FR4 and 3D press technology, there are several steps and measures.

The center provides the rigidity and foundation on which the PCB traces can be imposed directly in traditional PCBs. The center and lamination of FR4 are furthermore an electric distribution that separates the copper sheet from the plate. For double platewood, the FR4 core separates copper layers at the top and bottom while the FR4 compression molding layer is clamped between the inner core and external copper layer on a multilayer PCB. PCB ends can be managed by adding or removing laminates or by applying different laminates of thickness. For example the 1.6 mm plank typically has 8 layers of glass fibre, the plank is 0.8 mm, and the number of plates is reduced by up to 4.

The output using 3D printers is regarded as a modern and groundbreaking approach used in antenna production processes, as opposed to conventional methods. This is easily printable, with a smaller form factor, lighter weight, and lower cost and, as a more organic method for producing objects, as an alternative production method for 3D electromagnetic structures, in particular antennas, based on the advantages of this technology, parts manufacturing and different designs.

### 3.7 Preparation of FR4 fabrication

Antennas have evolved to address the problems of this era and upgrade antennas for increasingly sophisticated technologies. Conventional antennas are more difficult to design than microstrip antennas. Conventional antennas are expensive and relatively heavy but microstrip patch antennas have a simple, easy-to-make structure. There are various forms of microstrip patch antennas such as rectangles, circulars, triangles and other types of geometry. To produce antennas for Wireless Network Area Network (WLAN) applications, based on factors, a rectangular microstrip patch antenna will be designed. This project will use Flame Retardant 4 (FR4) and 3D printers as dielectric substrates in antenna fabrication.



FR-4 is a common material for printed circuit boards (PCBs). A thin layer of copper foil is laminated to one or both sides of an FR-4 glass epoxy panel. These are commonly referred to as copperclad laminates. This antenna should be printed on FR-4 substrate with relative permittivity 4.4, loss tangent 0.02, and thickness 1.6 mm to be applicable for UWB systems. Ground Coating the use of low cost FR4 as a substrate introduces some additional complexity to antenna design. This is due to FR4's inaccuracy and high tangent loss (around 0.02). The variation of the FR4 electrical transparency can shift the frequency of operation and the high loss tangent dramatically affects the antenna and axis, resulting in poor radiation efficiency.

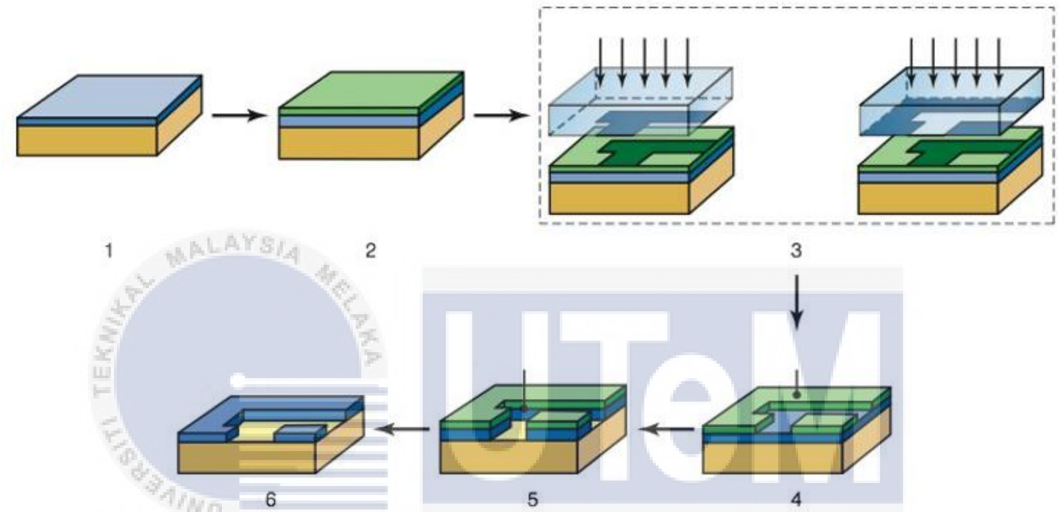



**Figure 3.3 shows Fabrication method**



### 3.7.1 Preparation 3D printer

The process of creating tridimensional solid objects from digital files is 3D printing or additional manufacturing. 3D printed objects are generated by additional processes. An object is created during the additional process by placing a permanent layer of material until the object is created. Growing of these layers can be viewed as a horizontal cross section slipping backward. 3D printing is the opposite of a subtractive processing that uses an example of a milling machine to cut / loose a metal / plastic object. Three-dimensional printing lets you create complex forms with materials less than traditional methods.

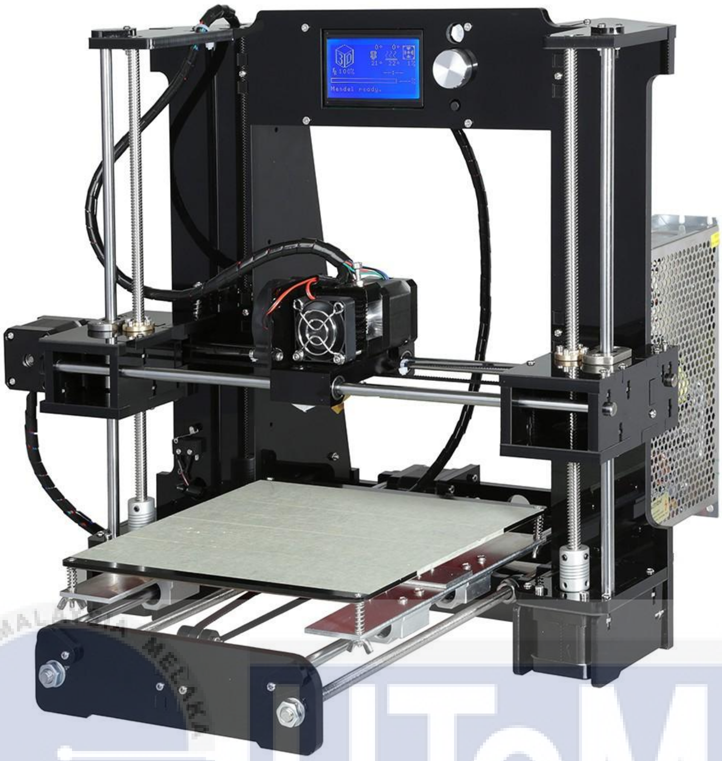


**Figure 3.5 shows 3D printer machine**



### 3.7.2 Material options and selection

In this project, selecting the appropriate material or filament to make the antenna is difficult because the fixed dielectric value of the material can affect the performance of antenna signal transmission. The printed circuit is made of copper, which is coated or engraved on the surface of the substrate to leave the desired pattern. The copper circuit is coated with a tin coating to prevent oxidation. The touch surface is coated with tin, then nickel, and finally gold for excellent conductivity. PCBs made from paper-reinforced phenolic resin with bonded copper foil are cheaper and are often used in home electrical devices.

Copper is a best suited material for patch antennas for FR4 fabrication. The metal, while soft and malleable, is quite rigid. Stainless steel has a higher tensile strength, so thinner wire can be used. This makes steel an excellent choice for mobile whip antennas where flexibility is a must.  The copper on a top board antenna as flexibility isn't an issue and its high electrical conductivity greatly and also increase its efficiency.

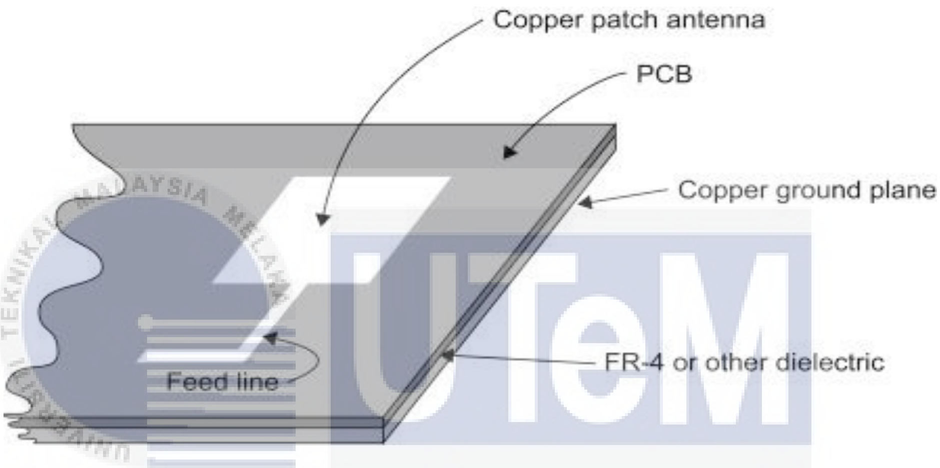



**Figure 3.5 copper on top of the FR4**



The material of PLA (polylatic acid) is easy to print through the processing of antennas for the 3D impression material. It does not sleep easily and it does not require a heated bed. Therefore it has a lower pressure temperature than ABS. Another advantage of PLA is that when you print it does not produce bad odours. They are commonly known as smellless filaments but, depending on the PLA, many have registered sweet odors.

In nearly unlimited colors and styles is also available PLA. As you see in the exotic section, PLA is a simple material, such as conductive or luminous properties or grown in wood or metal, for much of this advanced filament.

Lastly, PLA is more polluting than many other types of 3D printer filaments from annual renewable sources such as maize starch or cane as a modern thermoplastic.

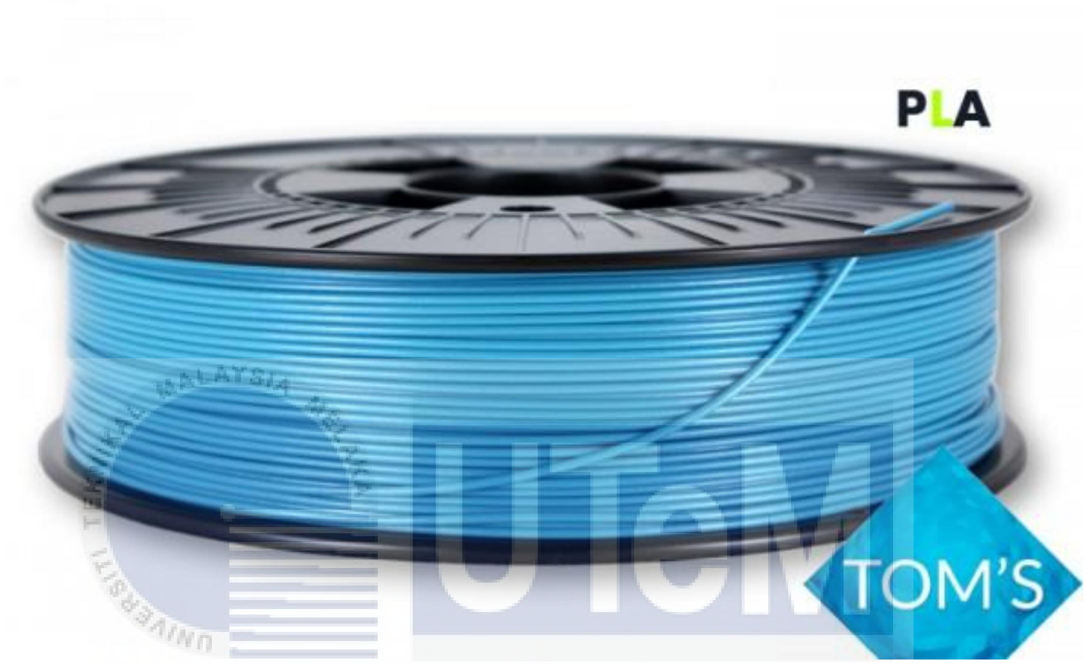



**Figure 3.6 shows PLA filament**



Antenna part cutting from 3D printers is a process whereby the horizontal layer is distributed using software. The software used for the process is Autodesk 3Ds max. This software file is then uploaded layer by layer with the settings provided. From figure 3.7 shows the antenna 3D models exported into STL formats identified through software. The uploaded file is then opened for changes to the 3D printer settings such as the material thickness of each section and other settings.

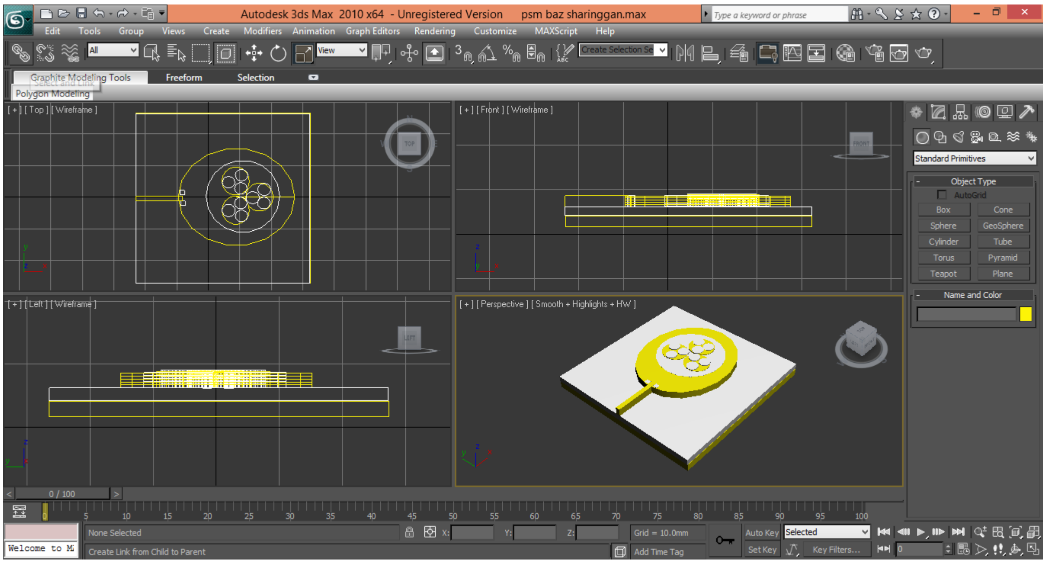



**Figure 3.7 shows 3D model slice in Autodesk 3Ds max**

### 3.7.3 Design an elliptical antenna

The elliptical shape of the antenna was created using CST Studio 2017. The CST software can shape the space or size of the antenna in the various shapes we want until we obtain the output frequency set based on the 5G application device.



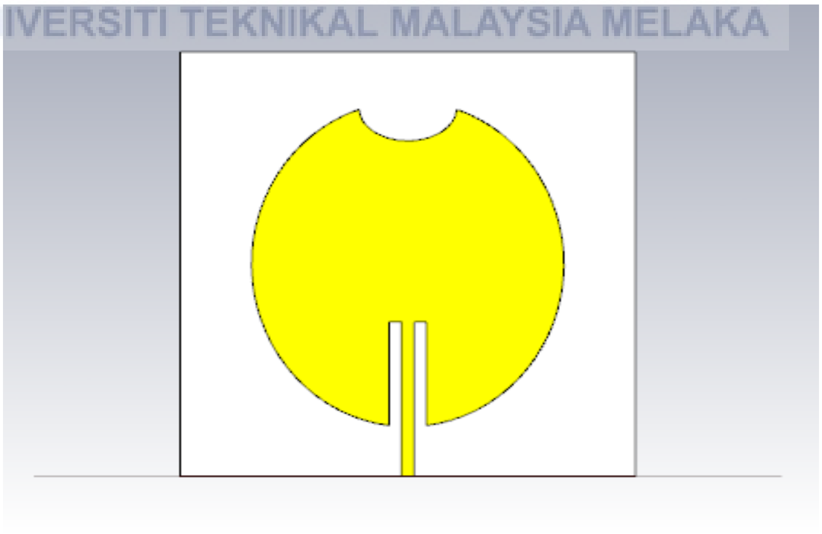


**Figure 3.8 shows the front view of an elliptical antenna**

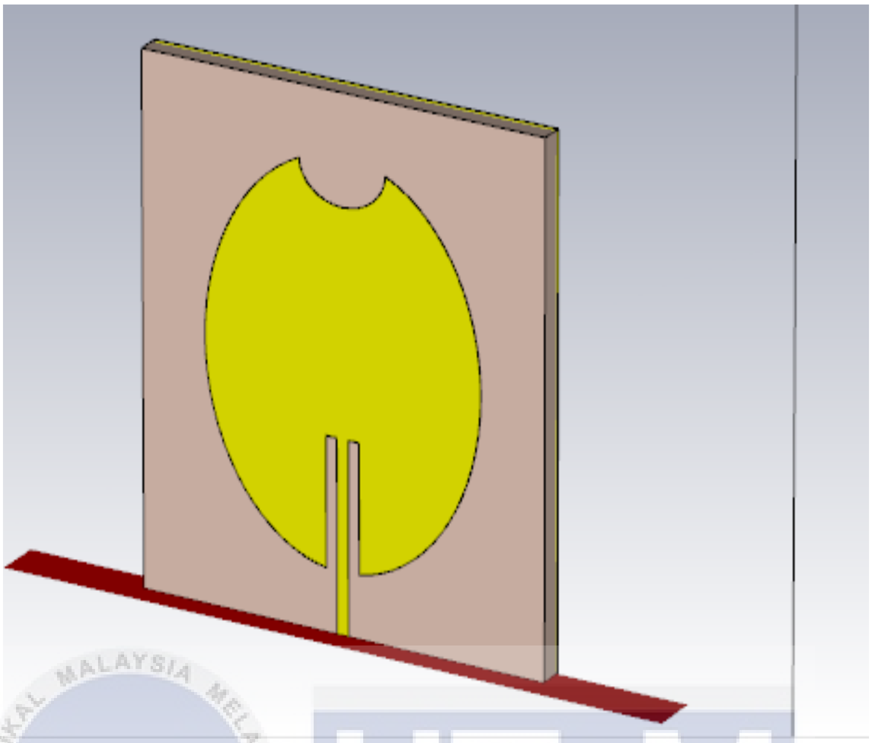


**Figure 3.9 shows the perspective view of 3D design**



**Figure 3.10 shows the back view of the antenna (ground antenna)**

### 3.7.4 Port antenna

Each antenna designed has a different port to support the parameter. Even different ports may have different functions. Since this project has been designed for the 3.7 GHz parameter then the port's suitability should be tested with the appropriate port for the elliptical antenna as well as the PCB thickness. Figure 3.11 shows a RS port of the RS Surface Mount MCX Jack RS port, 50Ω Impedance, 0 → 3 GHz, 0 → 6 GHz and table 3.3 shows the specifications of the port.



**Figure 3.11 shows port RS Pro surface mount MCX jack, 50 Ω impedance, 0 → 3 GHz, 0 →6 GHz**

**Table 3.3 shows the specification of the port**

| Attribute | Value |
| --- | --- |
| Gender | Female |
| Body Orientation | Straight |
| Mounting type | Surface Mount |
| Body Plating | Gold |
| Impedance | 50Ω |
| Operating Frequency | 0 – 3 GHz , 0 – 6 GHz |
| Contact Platting | Gold |
| Contact Material | Brass |



### 3.7.5 Antenna measurement process

Measurements are taken after the fabrication process has been successful. Return loss of the fabricated antenna is tested by a network analyzer like the figure below. S-parameter process measurement started with the calibration process. a calibration tool was connected to a port of the network analyzer at the place of the antenna. During process calibration, the frequency range must be set in the network analyzer calibration wizard. The frequency range must be the same as that done in the simulation at 2.5 GHz up to 4.9 GHz. Finally, the calibration tools were replaced back to the antenna under test management result will show once the antenna is connected to the network analyzer. All data will be displayed and recorded.

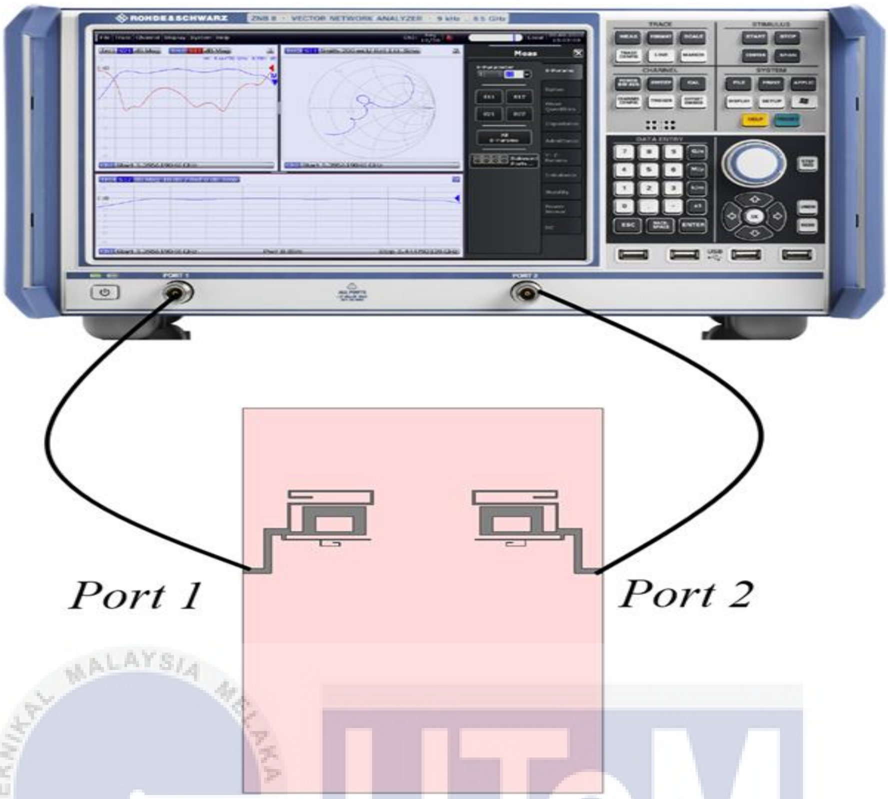





**Figure 3.12 shows S-parameter ($S_{11}$) analyze using network analyzer**

# CHAPTER 4

# RESULTS AND DISCUSSION



## 4.1 Introduction

This chapter describes an analysis and simulation and hardware output of measured results. The antenna parameter comprises a return loss, gain and radiation pattern. The result of the slotted elliptical antenna patch was traced and analyzed. Details on basic data analysis to provide a picture of the antenna can be found in the previous chapter.

The antennas are continuously transmitted to CST studio software once the design is complete. The simulation results include the frequency, the loss of return, the gain, the voltage standing wave ratio (VSWR), bandwidth, guidance and the radiation pattern. The resulting simulation is very exact and popular for the signal force transmitted through the elliptical antenna.

S1, 1 indicates an elliptical antenna return loss. The total loss rate between 1GHZ and 5GHz is less than -10db and shows that the signal strength received during data transmission has been well established for a consistent data diagram.

Moreover, it is possible to maintain minimum loss levels at least 95 percent of the signal transmitted through the antenna. The fact that the VSWR was created intentionally during the simulation demonstrates that. The key feature of an antenna is the exposed antenna gain.

An antenna data match will comply with the present feature, but if it does not radiate it will be useless. The gain from the antenna is one of the measurements of the radiation antenna performance. The antenna data match must correspond to the current feature, but if it doesn't radiate it will be useless. The antenna gain is a measure of the efficiency of the radiation antenna. The effect of the power gain antenna is one of the potential effects that the human body can get through.

The antenna directivity refers to the region in which the signal emission strength radiated and the maximum increase was made. The indicated guidance has to match the gain as the gain also increases the guidance. The highest guidance is dependent on the strength of a signal radiated by the elliptical antenna opening.

In addition, three different types of lobes, the principal, side and back lobes are present in the pattern formed from the elliptical antenna. The lobe is larger than the lobes on both sides and back. It means that the main lobe is highly powered compared with the other direction. The intensity of the broad radiation is determined by the pattern's small main lobe.

### 4.2 3D Printed Elliptical Slotted Patch Antenna Design and Analysis

The elliptical antenna is one of the most well-known microstrip antennas and is widely used due to the tendency of antennas that are closely related to the microwave and the implementation of it can be managing clearly. Therefore, microstrip antenna is much less expensive than other traditional transmission lines such as waveguide technology [2].

There are many forms of elliptical antennas produced and one of them is the elliptical fractal for the linear polarization. The resulting open-ended waveguide creates a straightforward directivity and broad beamwidth.

The elliptical antenna however was developed from the open waveguide and is flared from both E and H planes, meaning that the study found that there are two principal planes of small beam widths. Theoretically, the phase of the field across the top of the ellipse should continue until the side lobes are small and the lobes are large. However, for the 3.7GHz frequency, the elliptical size must be a smaller size where the frequency increases while the antenna size should be smaller.

### 4.3 Elliptical and Fractal antenna design

In order to improve the shape, the differences have been made based on which one is better to choose. Figure 4.1 and figure 4.2 show that there is a significant difference between the simulation of crescent antenna and fractal antenna in perspective view. The resonant frequency was set at 3.7GHZ in simulation CST software for both designs.

For the two designs show the different style of antenna was created in great detail through sharp cuts and measurements. The simulation has being processed after some detailed studies have been done.

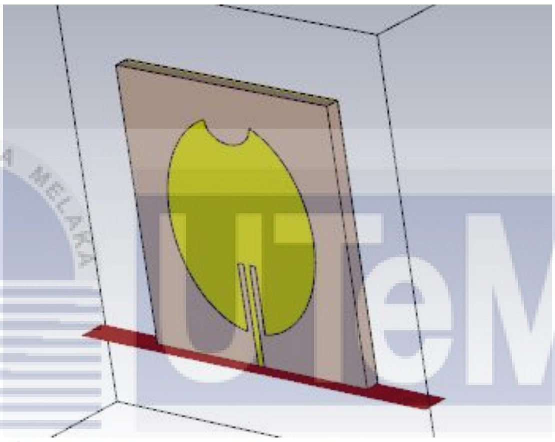


**Figure 4.1 Perspective view of crescent antenna**



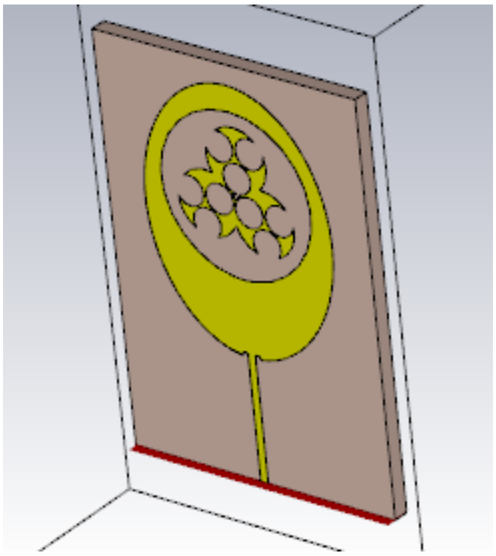


**Figure 4.2 Perspective view of fractal antenna**

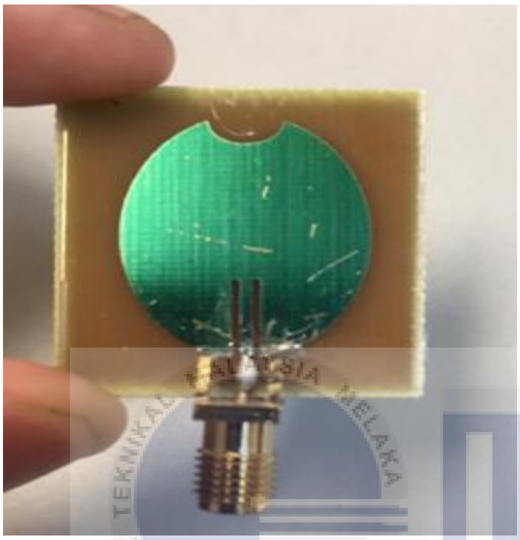
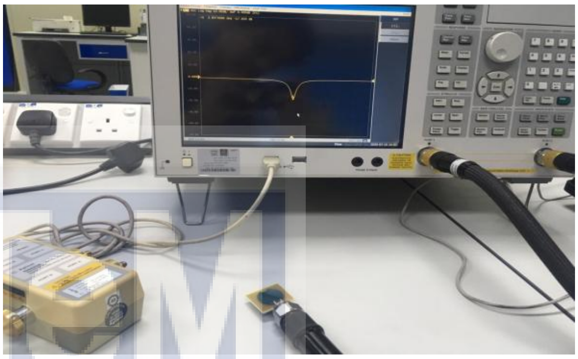
## 4.4 Fabrication of the antenna design using FR4

It shows that the elliptical fractal antenna has been favoured over the antenna with higher fractal antenna characteristics in terms of the loss and gain. The simulation of half the crescent antenna configuration using a Corel drawing program is shown in Figure 4.0. The black is the copper and the white is the substrate. Table 4.3 displays the antenna from fr4 manufacturing, as well as the output of the network analyzer's fractal antenna hardware. Figure 4.1 also displays the real graphs of antennas taken from fr4 manufacturing equipment.



**Figure 4.3 Design of Crescent Antenna using software Corel draw**

**Table 4.1 Fabrication hardware and result**

| **Fabrication** | **result** |
|---|---|
| <br>Single antenna with the front view<br><br>Antenna with coaxial cable | <br>Setup antenna with network analyzer |

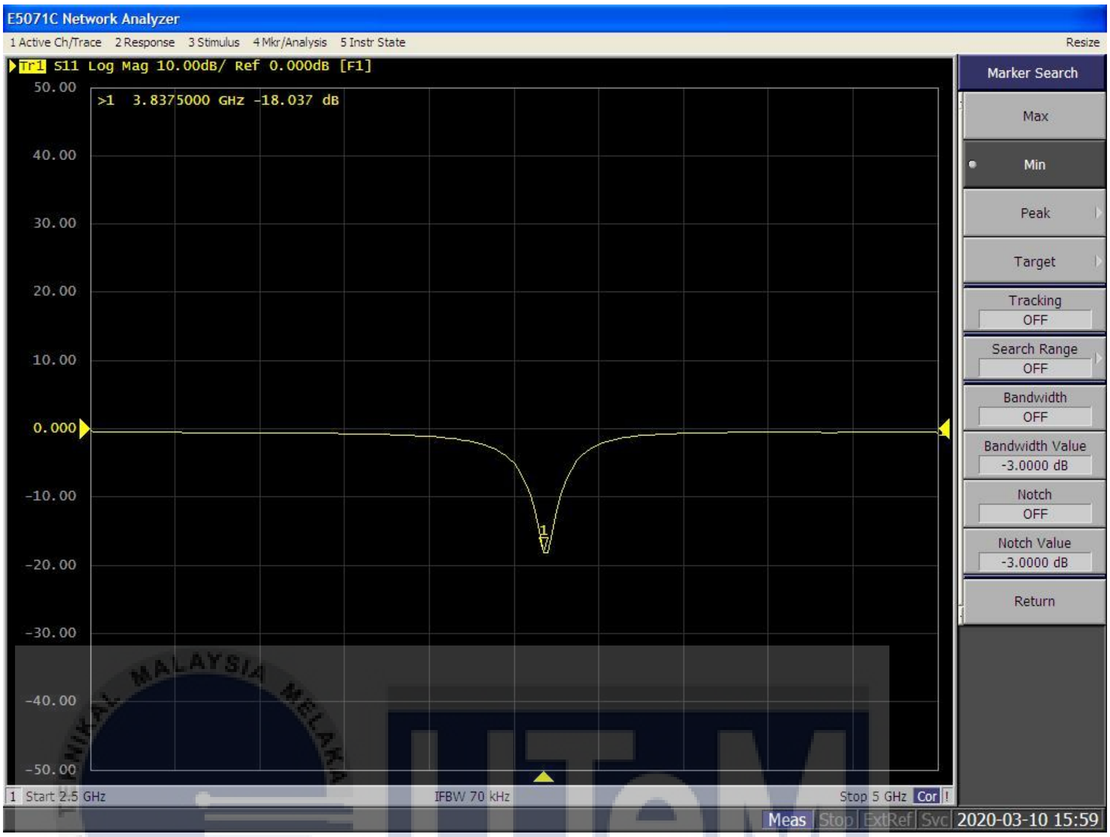



**Figure 4.4: Graph measurement result of antenna fabrication**



### 4.4.1 Simulation of 3D Antenna Design

Only the second type of two Autodesk 3Ds Max antennas with the same color substrate and copper is defined in this simulation. A 3D crescent antenna model shows in Figure 4.5 while a 3D fractal antenna is in Figure 4.6.

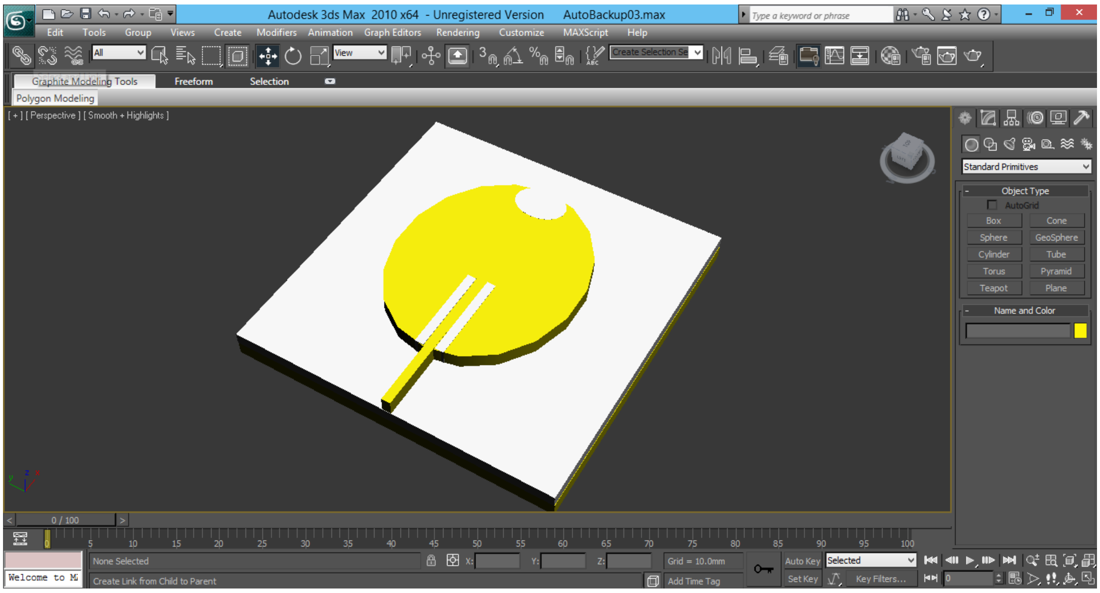



**Figure 4.5 shows 3D model slice in Autodesk 3Ds Max for Crescent Antenna**




**Figure 4.6 shows 3D model slice in Autodesk 3Ds Max for Fractal antenna**

### 4.4.2 Simulation of Return Loss, $S_{11}$ Parameter

The following figure shows the s11 wave value that corresponds to the frequency and the elliptical antenna return loss. From 2.5GHz up to 4.9GHz, the sum of the total return loss is less than -10db. The simulation value resulting from the return loss indicates the thickness selected to reflect the energy from input to output in compliance with the strength of an antenna. Figures 4.7 and 4.8 show that 3 graphs of the copper crescent differential are present and the highest thickness of TC = 0.035 is taken, as its value is higher than its other return loss. However the fractal antenna of return loss also indicates that the value is the same. This adjustment shows that the antenna can be better transmitted by the copper thickness.

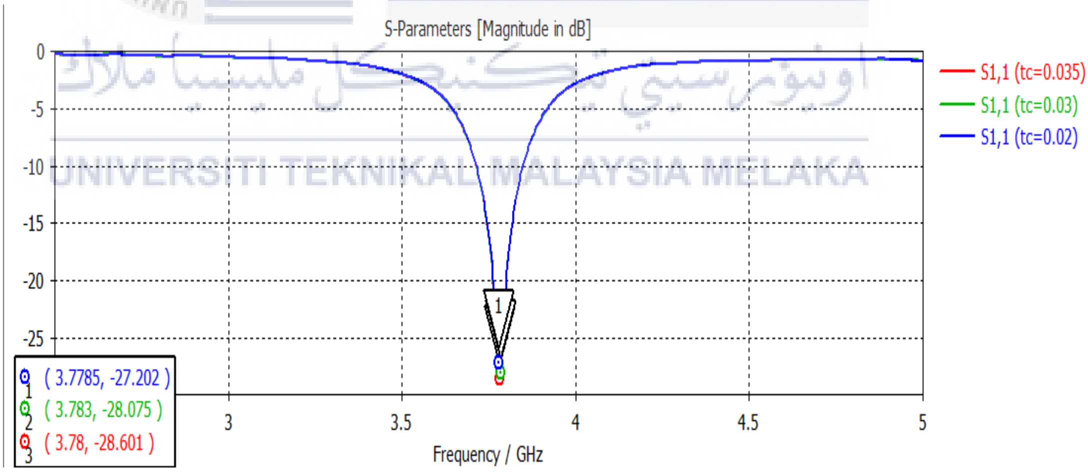



**Figure 4.7: The $S_{11}$ parameter of crescent antenna when thickness of copper changed**

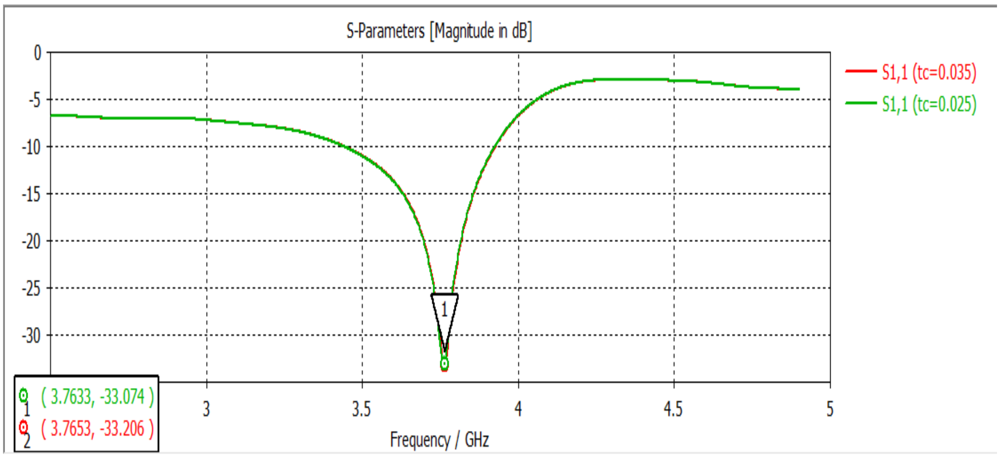



**Figure 4.8: The $S_{11}$ parameter of fractal antenna when thickness of copper changed**



Therefore, the evaluated antennas should be used for the best results of the s11 parameter. The result shows in Figure 4.9 below at the frequency of 3.7 GHz is less than -10 dB and is -28.388. The objective project was achieved by supplementing the 5G spectrum of the base station and mobile antennas. As an antenna which is very low-profile, it is also ideal for potential portable implementations of 5G Internet of Things ( IoT).

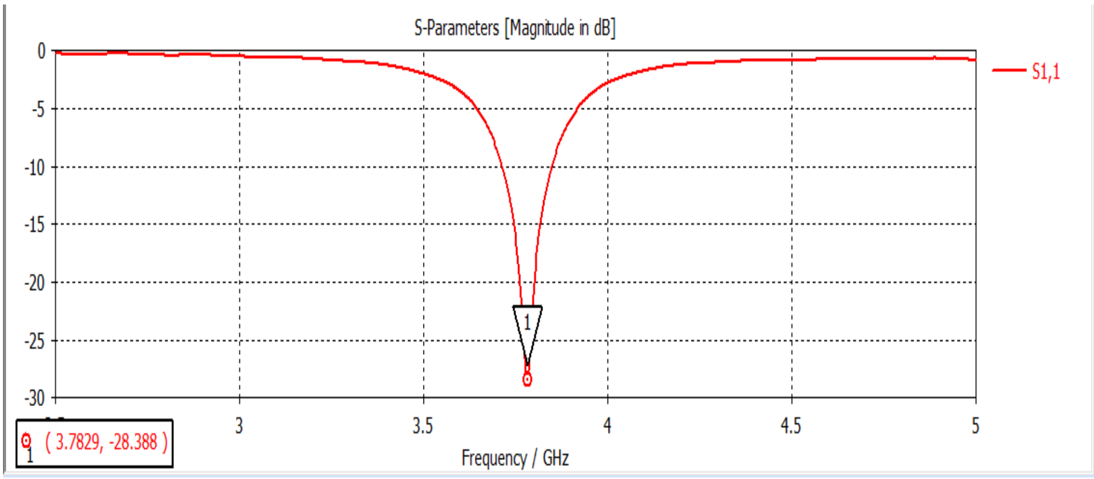



**Figure 4.9: Frequency and return loss of simulation crescent antenna design**

Furthermore, for the fractal antenna the resultant s11 parameter is −33.371 dB. This return loss is much greater than fractal design while it is at the same frequency. So between the crescent and the fractal antenna result, the fractal design looks more efficient and good for transmitting signals. However, this comparison is only to see how well an antenna works from the single band of an elliptical antenna. Figure 4.10 shows the s11 result of fractal elliptical antenna.



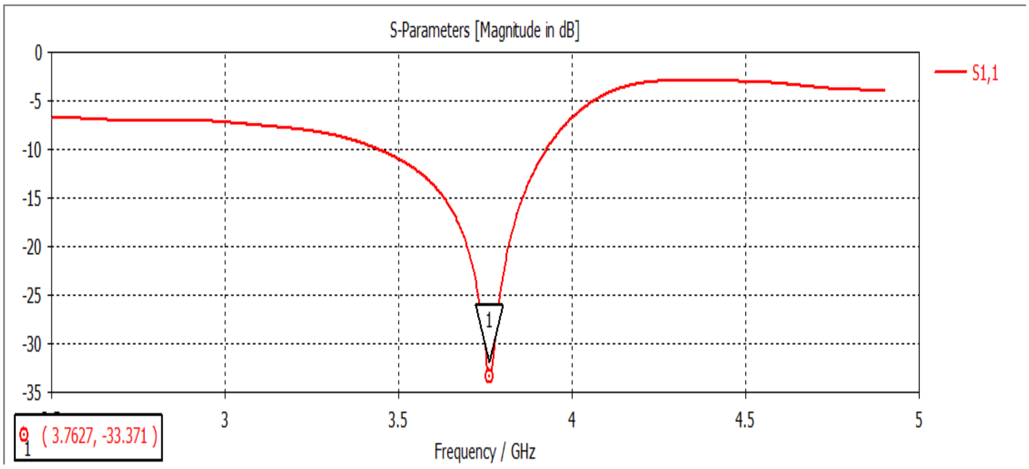



**Figure 4.10: Frequency and return loss of simulation fractal antenna design**

### 4.4.3 Simulation of Directivity, s11 parameter

Directivity is the area in which the highest absorption of the signal is emitted and the maximum profit is processed. The direction of the simulation of the crescent antenna is 5.68dBi. The antenna simulation of the fractal Design is 3,58dBi in the meantime. The guidance always matches the gain. As the income is higher, the guidance is high. The greater the distance, the stronger the signal radiated by both antennas. The antenna direction for the crescent antenna design and fractal antenna design is illustrated in Figures 4.11 and 4.12 below.

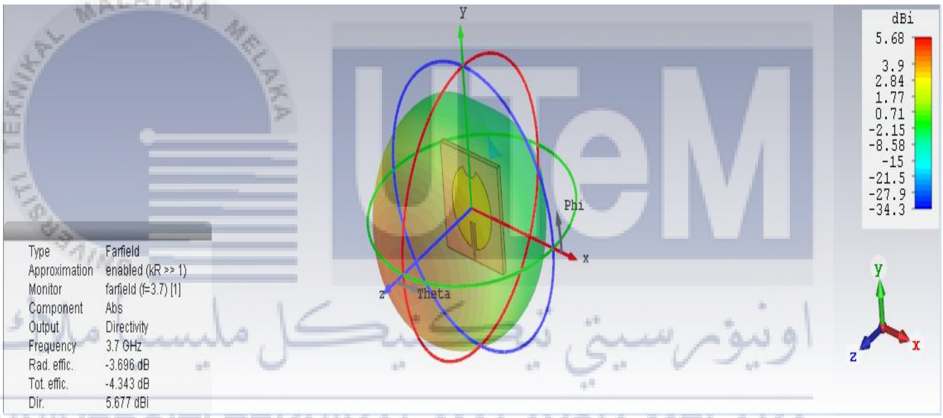




**Figure 4.11: The Directivity of crescent antenna Design**

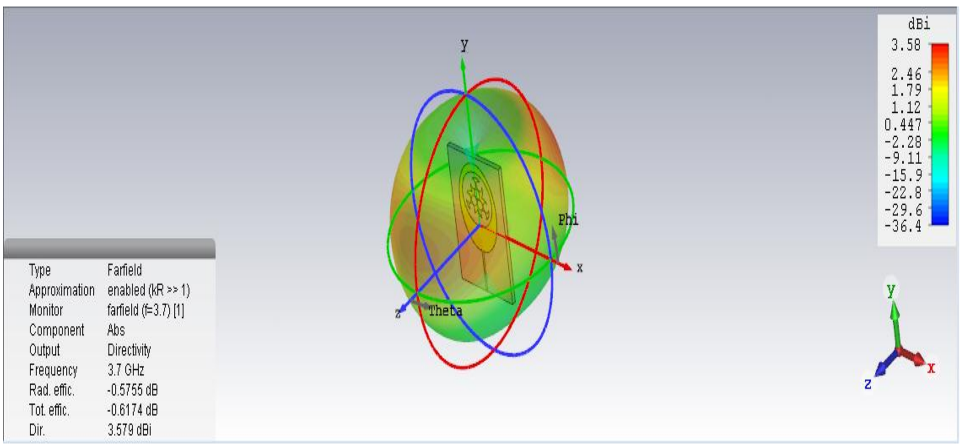



**Figure 4.12: The Directivity of fractal antenna Design**

### 4.4.4 Simulation of Gain

Antenna gain determines the efficiency of the antenna to close the radio wave in the direction specified. An antenna gain may also mean the antenna's efficiency or the antenna power reception.

The antenna gain on the crescent antenna is 1.98 dB at the operating frequency at 3.7 GHz, and the fractal antenna provides an aerial gain of 3dB greater than crescent. In order for the antennas to pass signal through the well-performing and suitable applications of 5G, a gain of 2dB or more must be obtained or positive from the microstrip antenna reference. The antenna gains in crescent antenna design and fractal design are shown in Figure 4.13 and Figure 4.14 below.



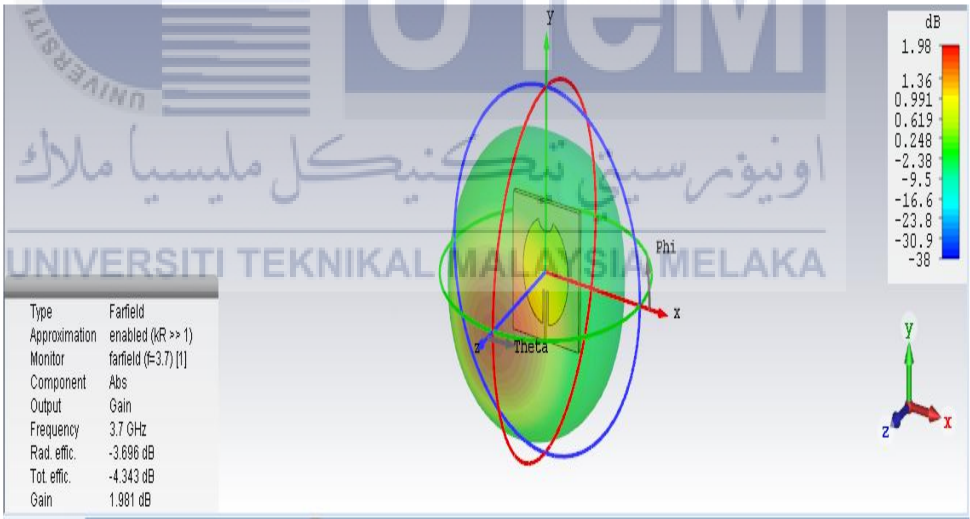



**Figure 4.13: Antenna gain for the design of Crescent Antenna**

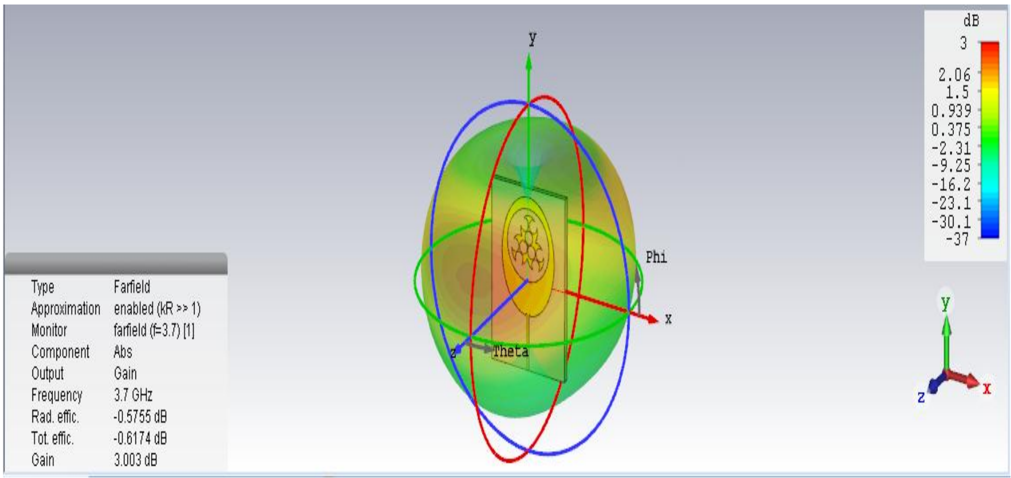



**Figure 4.14: Antenna gain for the design of fractal antenna**

### 4.4.5 Simulation of Radiation Pattern of Antenna

The pattern of the antenna can be described as a graph of the 3D radiation of the antenna in terms of direction. The radiation intensity of the antenna is measured by mapping the antenna power by a fixed angle array.

It indicates that the main lobe is much bigger than the side lobes and the lobes of the back. This means that the main lobe has more energy than other directions. The smaller the main lobe, the higher the level of radiation.

Guidance is one of the main antenna parameters. It defines the radiation dose in a specific way. Once the antenna is designed for radiation in a specific direction, leadership plays a critical role. The radiation pattern parameters of Crescent design radiation and fractal design are shown in Table 4.2 and Table 4.3 below.

**Table 4.2: The parameter value for radiation pattern of Crescent Antenna Design**

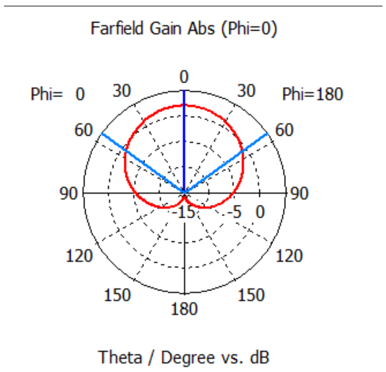
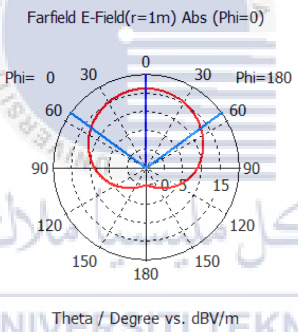
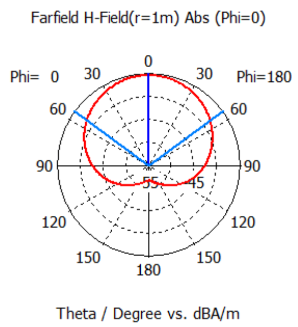
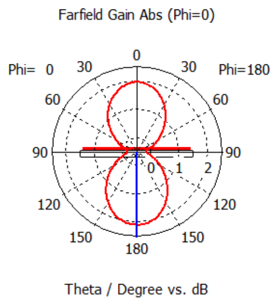
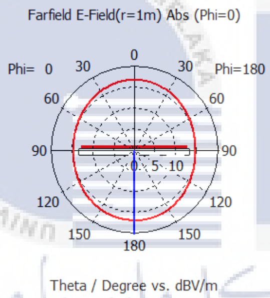
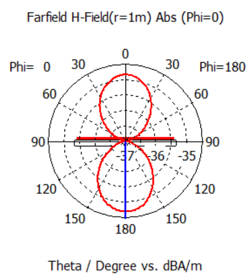
| | |
|---|---|
| Gain (IEEE)<br> | • Frequency : 3.7 GHz<br>• Main lobe magnitude : 1.98dB<br>• Main lobe direction : 0.0 deg<br>• Angular width (3dB) : 108.8 deg |
| E-Field<br> | • Frequency : 3.7 GHz<br>• Main lobe magnitude : 16.1dBV/m<br>• Main lobe direction : 0.0 deg<br>• Angular width (3dB) : 107.9 deg |
| E-Field<br> | • Frequency : 3.7 GHz<br>• Main lobe magnitude : -35.4dBA/m<br>• Main lobe direction : 0.0 deg<br>i.<br>• Angular width (3dB) : 107.9 deg |

**Table 4.3: The parameter value for radiation pattern of Fractal Antenna Design**

| | |
|---|---|
| Gain (IEEE)<br> | • Frequency : 3.7 GHz<br>• Main lobe magnitude : 2.08dB<br>• Angular width (3dB) : 180.0 deg |
| E-Field<br> | • Frequency : 3.7 GHz<br>• Main lobe magnitude : 16.8dBV/m<br>• Angular width (3dB) : 180.0 deg |
| H-Field<br> | • Frequency : 3.7 GHz<br>• Main lobe magnitude : -34.7dBA/m<br>• Angular width (3dB) : 180.0 deg |

### 4.4.6 Simulation of Antenna Surface Current

This explanation shows how both the crescent and the fractal antenna radiate within the single polarization. The results demonstrate how the wave transmitted to the antenna from the waveguide terminal. The simulation of the Antenna Surface Current is illustrated in Figures 4.15 and 4.16.

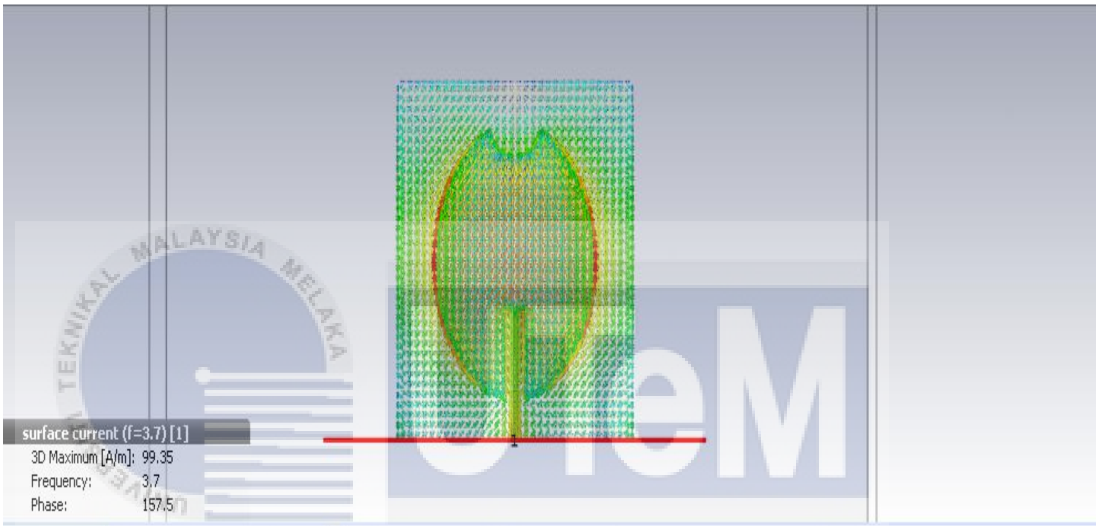



Figure 4.15: Simulation of Antenna Surface Current for Crescent Design



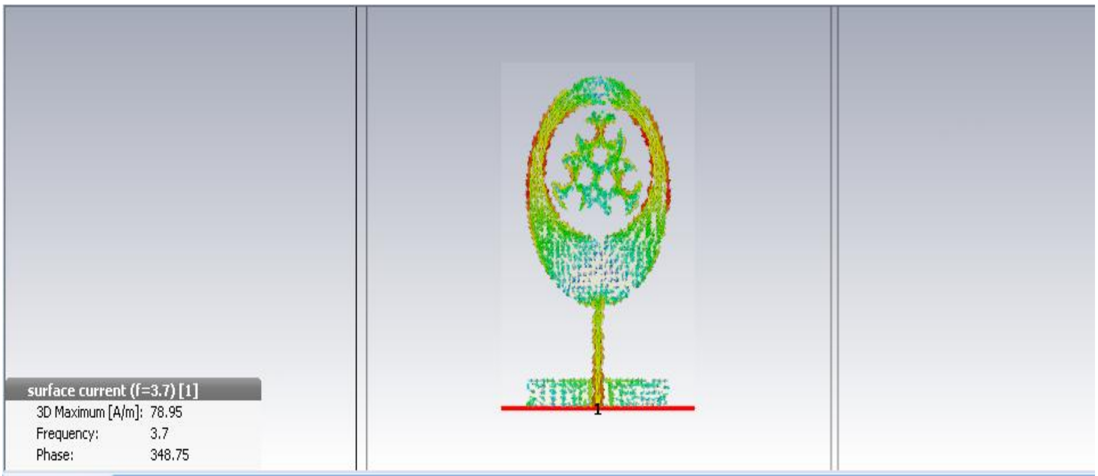



Figure 4.16: Simulation of Antenna Surface Current for Fractal Design

### 4.4.7 Efficiency of antenna

The efficiency of the antenna is defined as the ratio of the total radiated power to the total input power. The input power to the antenna is the total power, including the radiated power, and the overall loss of power. So, the gain can be represented as the formula below:

$$n = \frac{Prad(radiated\ power\ of\ the\ antenna)}{Ptotal(total\ input\ power\ of\ the\ antenna)} \tag{4.1}$$

Total input power includes lost power due to conduction, dielectric and surface wave losses and antenna radiated power.

The efficiency contained in the db must be converted to radiated power and total power for easy integration into formulas and calculations. Figure 4.17 and Figure 4.18 below show the efficiency values generated by the crescent and fractal design together with the total efficiency values.

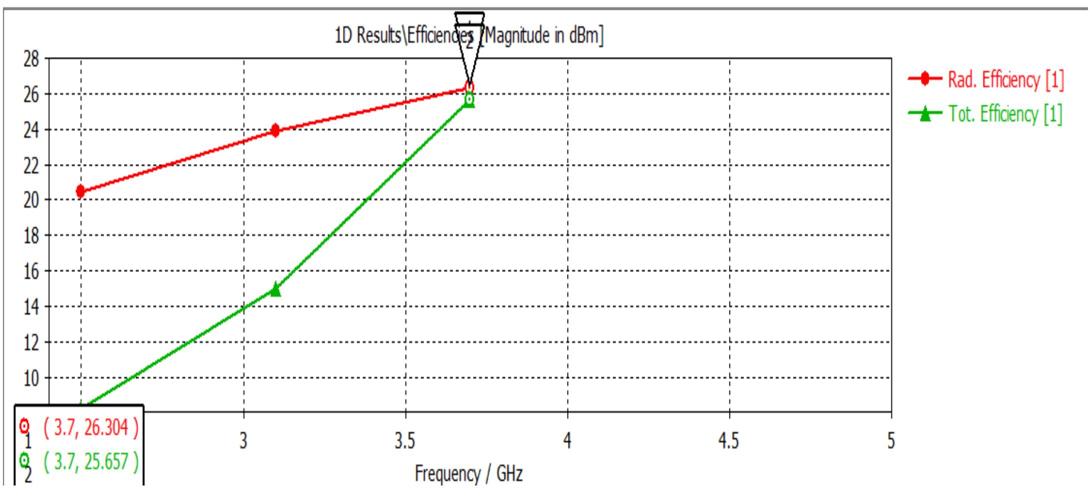



**Figure 4.17: The efficiency of Crescent Antenna in magnitude (dBm)**

Prad = 26.304dBm = 0.4269 Watt

Ptotal = 25.657dBm = 0.3678 Watt

$$n = \frac{0.4269 \text{ Watt}}{0.3678 \text{ Watt}} \text{ x } 100\%$$

n = 116.8 % efficiency

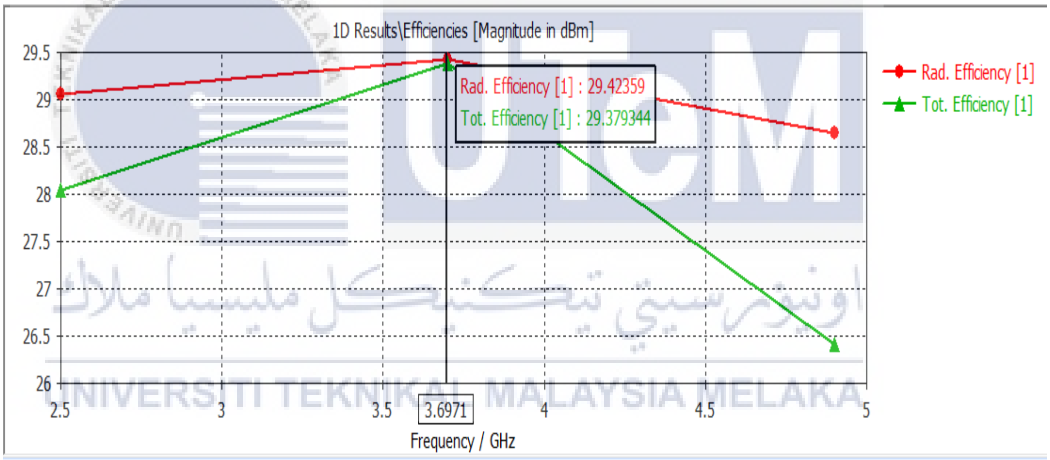



**Figure 4.18: The efficiency of Crescent Antenna in magnitude (dBm)**

Prad = 29.423dBm = 0.8758 Watt

Ptotal = 29.373dBm = 0.8675 Watt

$$n = \frac{0.8758 \text{ Watt}}{0.8675 \text{ Watt}} \text{ x } 100\%$$

n = 101.2 % efficiency

### 4.4.8 Simulation of Voltage Sending Wave Ratio (VSWR)

The standing wave voltage ratio gives the value of how the transmission line impedance or resistance is complemented with our antenna. The voltage-standing wave relationship simulated value is less than 2 and thus it has ceased that the constructed antenna complements the operating frequency if low attention is paid to signal transmission.

The VSWR values of crescent antennas and of fractal antennas are determined by figures 4.19 and 4.20.

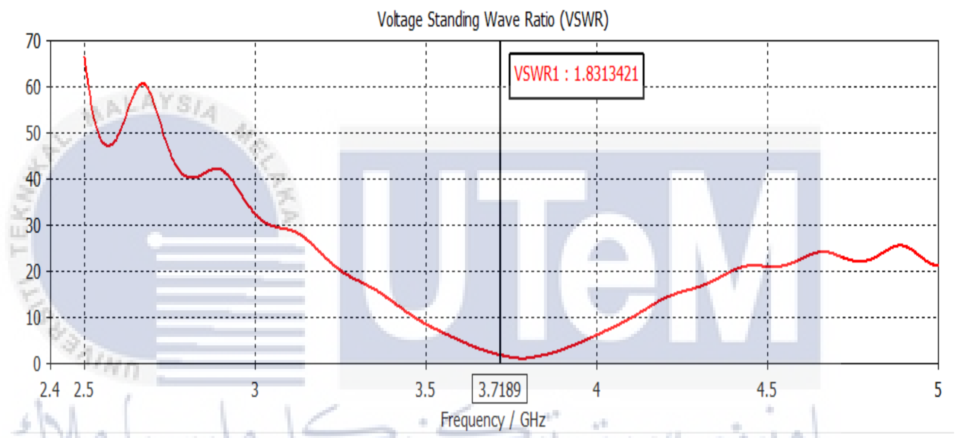



**Figure 4.19: Simulation of Voltage Standing Wave Ratio (VSWR) Crescent Antenna**



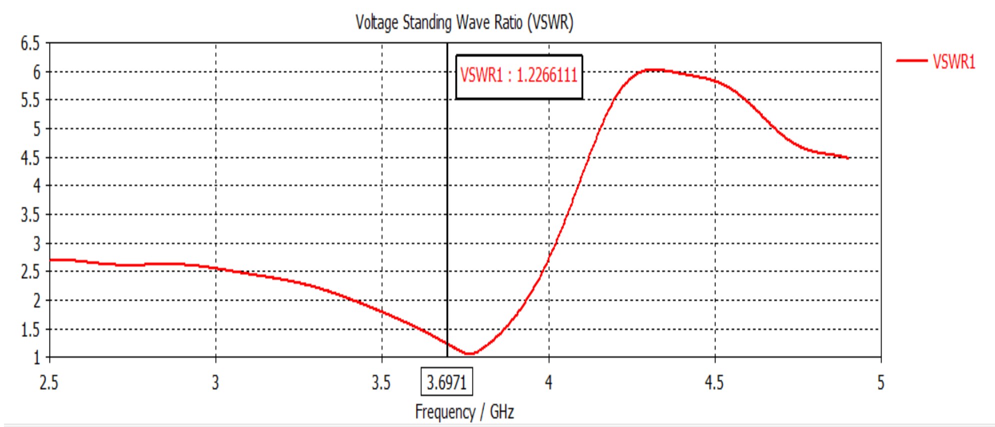



**Figure 4.20: Simulation of Voltage Standing Wave Ratio (VSWR) Fractal Antenna**

### 4.4.8 Antenna bandwidth

The antenna bandwidth is dependent on the frequency range in which the antenna complies with a certain parameter. Gain, radiation pattern, VSWR, etc. are typically defined parameters. The VSWR is typically chosen as a bandwidth parameter, and is referred to as bandwidth impedance. The lower and top frequencies of the desired VSWR set the frequency band in which the antenna complies with the VSWR. The widely accepted bandwidth standard is 2:1 ratio of VSWR. The formulas of bandwidth are shown below:

$$Bw = [\mathrm{FH} - \mathrm{FL}] \times 1000 \quad (4.2)$$

Figure 4.21 shows the bandwidth value of the crescent antenna taken at 3.7 GHz equal to (-10dB) with 128 bps while Figure 4.22 shows the fractal value with 455.3 bps.



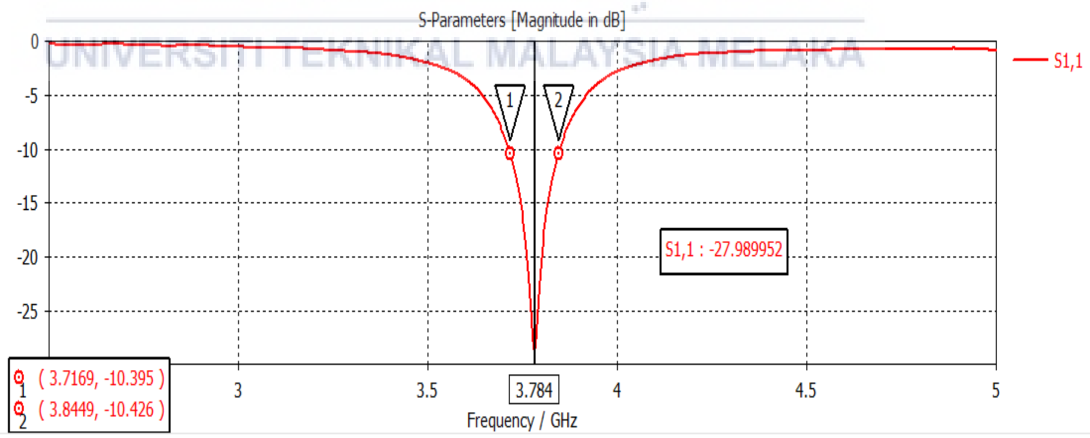



**Figure 4.21: The bandwidth of Crescent Antenna**

$$Bw = [3.8449\mathrm{GHz} - 3.7169\mathrm{GHz}] \times 1000$$

Bw = 128 bps

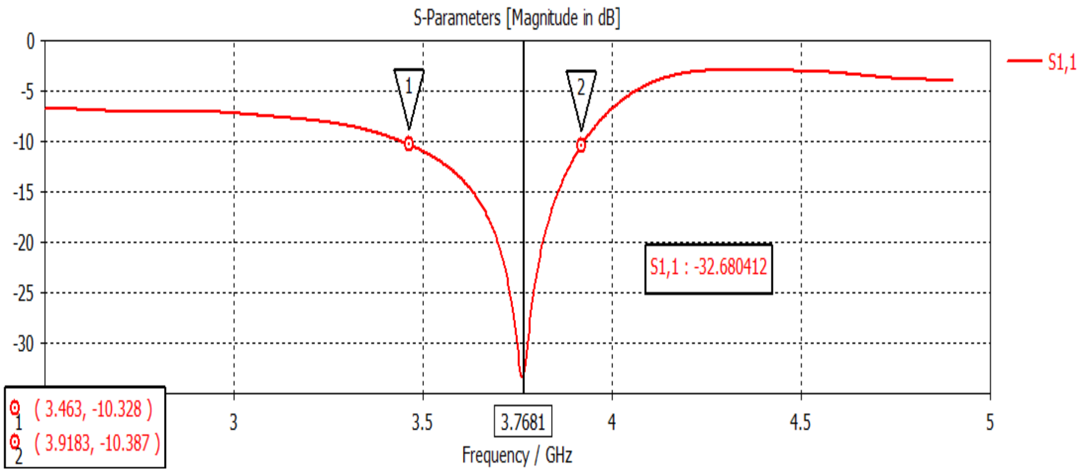



**Figure 4.22: The bandwidth of Fractal Antenna**

$$Bw = [3.9183\text{GHz} - 3.463\text{GHz}] \text{ x } 1000$$

Bw = 455.3 bps

# CHAPTER 5

# CONCLUSION AND FUTURE WORKS

## 5.1 Conclusion

This chapter summarizes and summarizes all possible activities. Future work and recommendations to improve this project further will also be discussed.

The single-polarization elliptical antenna has been built for operating frequency of 3.7 GHz. Based on the Microwave Studio platform and Autodesk 3Ds max platform, this antenna is computer simulation technology (CST).

The project will investigate antenna parameters such as gain, loss of return, radiation, VSWR and bandwidth. Investigations show that an antenna system with a good gain and loss of return are designed for radio waves that come into the input of an Antenna which is rejected in a ratio of accepted ones below -10dB and above

2dB. The pattern of radiation is often highly advanced. Such antenna features will make the antenna popular in 5G network systems in the future.

## 5.2 Completed Work

Two antenna designs changed from ellipse to crescent and fractal design were used for the research done by this thesis. Consequently, this means that the antenna radiation polarization is generated when the antenna is set from the bottom of the input before the output is directed upward. In the meantime, both antennas need to be modified and refined to improve the simulation value and the antenna parameters in order to achieve this research objective of making 3D elliptical design antennas as well as fr4 manufacturing at 3.7 GHz for 5 G application. All antenna designs are designed using the CST Microwave Studio Software and can be distinguished by the performance of all antennas. In antenna design, numerical and parametric methods were used to achieve effective optimized antennas by changing the dimensions of the antennas. Changes in antenna parameters can also generate the best configuration of elliptical antennas with single polarization.



The fractal design antenna was chosen over the crown-antenna while the simulation results were improved at a frequency of 3.7 GHz. The tests show a strong return loss and a wave voltage ratio perpendicular to the selected antenna. This is because it ensures that the signal is transmitted in nearly balanced condition. The signals sent and received at lower frequencies are therefore always considered to be nearly perfect.

Furthermore, this concept achieves strong returns and direction. The fractal antenna is therefore good when the antenna produces or receives a given or applied force, emissions of radiation and maximum amplitude processed.

When the radiation is stronger and smaller it will be easier for antenna detection and reflection to suit the 5G application environment. For research it seems that fractal antennas are more acceptable. Thus, CST is very easy to build and operate with fractal antennas. The simulation aims to prove that the antenna works correctly and effectively. The resulting fractal design was created using Corel software and 3D max for manufacturing and 3D software and finished with a full antenna in the real world.

## 5.3 Recommendation on Future Work

3D antenna design can be implemented for future work using 3D print technology as well as the concept of ellipse design can also be improved by means of a circular structure into a coveted shape.

From project design simulation, the predefined fit has been achieved by all the result parameters. However, project manufacturing for fractal antenna design along with two types of 3D hardware antenna design could not be completed. This is because the covid-19 problem is widespread all over the world. However, one of the design antennas, the crescent antenna, has been prepared and the result value read on the Vector Network Analyzer (VNA) to be tested elsewhere for the frequency return band loss signal.



Moreover, the aim of the project was to only analyze antennas and process simulations using the CST software studio and to use the 3D printing technology and the metallization process as an antenna shape. Further testing can be done with the return loss antenna to increase the overall antenna gain. Currently, modifications of the material and even the diameter of the antenna may also be considered to boost the antenna's efficiency in order to be added to the 5G network.

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