AN ANALYSIS OF BOW-TIE ANTENNA AT 3.75GHZ USING 3D PRINTED TECHNOLOGY FOR 5G COMMUNICATION SYSTEM

MUHAMAD MUSTAQIM BIN MOHD ISHAK

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

AN ANALYSIS OF BOW-TIE ANTENNA AT 3.75GHZ 3D PRINTED TECHNOLOGY FOR 5G COMMUNICATION SYSTEM

MUHAMAD MUSTAQIM BIN MOHD ISHAK

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
Universiti Teknikal Malaysia Melaka

2020

DECLARATION

I declare that this report entitled "An Analysis of Bow-tie Antenna at 3.75GHz 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 : MUHAMAD MUSTAQIM BIN ISHAK

Date : 26 JUNE 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.

Signature	:	....
Supervisor Name	:	DR. ABD SHUKUR JAAFAR
Date	:	26 JUNE 2020

DEDICATION

Special dedication to my beloved parents, Mohd Ishak bin Sulaiman and Rozana binti Rashid, my great supervisors, Dr. Mohd Azlishah bin Othman and Dr. Abd Shukur bin Jaafar, and my fellow friends on helping me with full support to accomplish my final year project report.

ABSTRACT

In this project, an analysis of Bow-Tie Antenna at 3.75GHz using 3D Printed Technology for 5G Communication System is proposed. The concept of manufacturing 3D printed antennas has been used in designing antennas to reduce antenna production costs. The usual fabrication will also not be neglected which is FR4 fabrication method. Bow-tie antenna is a type of dipole antenna UHF fan. It may resemble a periodic antenna, but it is not considered an LP antenna. The proposed antenna will be operating at frequency range of 2.5GHz – 5GHz and simulates using CST Studio Microwaves Suite 17. The performance of the designed antenna will be analyzed in terms of gain, loss, VSWR and radiation pattern at 3.75GHz.

ABSTRAK

Dalam projek ini, dicadangkan analisis Antena Bow-Tie pada 3.75GHz menggunakan Teknologi Bercetak 3D untuk Sistem Komunikasi 5G. Konsep pembuatan antena bercetak 3D telah digunakan dalam merancang antena untuk mengurangkan kos pengeluaran antena. Pembuatan biasa juga tidak akan diabaikan iaitu kaedah fabrikasi FR4. Antena ikatan busur adalah sejenis kipas UHF antena dipol. Ia mungkin menyerupai antena berkala, tetapi tidak dianggap sebagai antena LP. Antena yang dicadangkan akan beroperasi pada julat frekuensi 2.5GHz - 5GHz dan mensimulasikan menggunakan CST Studio Microwaves Suite 17. Prestasi antena yang dirancang akan dianalisis dari segi keuntungan, kehilangan, VSWR dan corak radiasi pada 3.75GHz.

ACKNOWLEDGEMENTS

Prima facea, I am grateful to Allah for the good health and wellbeing that were necessary to complete this book. I wish to express my sincere thanks to my supervisors, Dr. Mohd Azlishah bin Othman and Dr. Abd Shukur Jaafar for the continuous encouragement and guiding me throughput the journey in completing this project. I am indebted to him for his generous motivations during the implementation of the project are highly appreciated. Special gratitude to my family who never fails to support me from the beginning until the end accompanied by prayer and hopeful thoughts for me to go ahead. I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

MIMO	:	Multiple-input and Multiple-output
MPA	:	Microstrip Patch Antenna
RF	:	Radio Frequency
PCB	:	Portable Circuit Board
TV	:	Television
UHF	:	Ultra-High Frequency
VNA	:	Vector Network Analyzer
VSWR	:	Voltage Standing Wave Ration
WLAN	:	Wireless Local Area Network
WPAN	:	Wireless Personal Area Network

CHAPTER 1

INTRODUCTION

1.1 Introduction

Antennas are important components of a wireless network. We are thus the eventual element in the construction of the so-called wireless human network. A transducer is an antenna, and likewise between the amplifier and the waves of free space. In effect they transfer electromagnetic energy from a transmission line to free space. The information is now transmitted over the Internet through an antenna from one physical to another, such as mobile phones and computers, to allow data transfers without physical contact for the telecoms industry and the global positioning system. This increases our life dependency on the antenna network and increases the need for antenna production and productivity.

Bow-tie antenna is a UHF fan type dipole antenna. It can look like a standard log antenna, but it is not an LP antenna. The Ultra Wide Band was initially developed for radar technology and was primarily a solution for burst data in WPAN and WLAN high-speed networks. His reputation rapidly grew because of his many superior characteristics. Largely defined, ultra-wide antenna systems are moving wave structures such as the antenna Vivaldi [1][2], isolated structures frequency such as a biconic antenna or bowtie antenna [3][4], self-complementary antennas with self-complementary metallization, like a logarithmic antenna spiral and fractal antenna. [5][6][7], variations of the above like the log periodic antennas [8][9][10] and the electrically small antennas which includes the modified monopoles [11][12][13]. Additional architectures have also been announced with a frequency ranking in the existing 5-6 GHz WLAN bands. Since the bow-tie has been popular in the telecommunications industry, developers are developing better bow-tie antennas, but more can be expected. Lodge suggested a well-known bow-tie antenna and later re-examined the advantages by Brown and Woodward. [14]

For antenna testing, antenna measurement technique is applied to ensure that the antenna meets or characterizes the requirement. Typical antennas parameters are gain, beam width and radiation pattern. The ratio of real radiated power to antenna terminal power is 3D printed antenna calculation. This paper provides an overview of the 3.75GHz Bow-Tie Antenna using 3D Printed Technologies for the 5G Communication System.

1.2 Problem statement

Antenna architecture limitations include multi-band resonance criteria. When demand is strong and the number of users increases, the frequency bands are now overloaded despite data transmission restrictions. Modern antennas are powerless to meet these requirements and alternatives are therefore required.

The system used in the manufacture of antennas has several faults as they are fragile and sensitive to injury. It remains, however, a tool to be used for this initiative. The growing development of 3D printing technology has opened many new possibilities for plastic production in advance. It can therefore resolve this problem in accordance with rising technological advancement.

This project aims to develop a 3D Printed Bow-Tie Antenna with miniaturisation and low-cost manufacturing. In the manufacture of this antenna, a FR4 process must also take account. Instead the antenna output is investigated so that it can work at frequency 3.75 GHz in line with 5G communication network.

1.3 Objectives

The aim of this project is to study the development of the 5G communication system FR4 and 3D Printed Bow-Tie Antenna. The goal of this project is supported by the following:

1. To design a bow-tie antenna that operating at 3.75GHz for 5G communication system.
2. To analyze the parameters of the designed antenna.
3. To fabricate the designed antenna using FR4 method and 3D print technology.
4. To make comparison between antenna fabricated with FR4 method with antenna fabricated with 3D print technology.

1.4 Scope of project

The project aims to design and stimulate the 3,75 GHz frequency bow-tie antenna for 5 G communications system. The simulation range is set from 2.5GHz to 5GHz and the operating bandwidth is extensive for experimental operation.

This project will be carried out in three parts. The first part focuses mainly on the design and simulation of software. CST Studio Suite 2017 is the software to be used. The program is chosen because the desired antenna can be designed, simulated and analyzed with defined frequency parameters and radiation patter. There will be a few prototypes to distinguish the behavior of each built antenna.

The second component consists of the manufacture of the built antenna by FR4. The type of material that is used during manufacturing is also indicated in the software that is later manufactured physically. The commodity used is primarily copper.

The third part comprises the hardware which is the bow-tie antenna that the Vector Network Analyzer (VNA) computer is computed to print via a 3D printer. Before that, the collation between the simulation, the FR4 antenna and the 3D printer antenna is documented to ensure that all parameters are achieved.

1.5 Thesis outline

Chapter 1 covers roughly the history and antenna architecture of the project. This part comprises problem statement, project goals, project scope and clarifies briefly the methodology for project completion.

Chapter 2 will cover the literature review studies in which both research and technical papers are performed prior to the project. Past work and understanding performance, formulas, and antenna architecture parameters. The next chapter then contains the cover of Chapter 2.

Chapter 3 focuses mainly on the techniques used in project efficiency. The methodology component evaluated the antenna design formulas to meet all necessary requirements.

Chapter 4 presents all details and findings obtained from the program for simulation. In this chapter, the findings and tests are thoroughly analyzed and discussed. The tests will also be taken.

Chapter 5 provides suggestions for future work together with the project that has been completed. This will summarize the completion of this report throughout the procedure.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

This chapter outlines the methodologies of the author to enhance the understanding of field research. The literature review supports the claim made by the developer during this study. In addition, the literature review is carried out in order to make it possible for readers to note this portion of confusion and misunderstanding of some of the words used in this research.

2.2 Overview of 5G communication

5G mobile communication can provide business and society with new experiences, together with higher data rates or higher capabilities, better information measures, increased safety and less latency. These technologies generate new opportunities for the growth of society and business: 5G is a big transition, but we continue to engage in this climate. [15][16].

Under development, the key optional 5G technologies include new multiple access methods, massive MIMOs, fully digital or hybrid beamforming, ultra-dense networking, etc. The introduction of these high-level innovations will lead to new problems for physical infrastructure designers. These challenges certainly include the antenna, however, the associated microwave systems and the characterisation of the radio propagation environment in conjunction. Despite highly successful existing 5G antenna systems research and tutorial and technological activities, a range of problems remain to be solved by themselves or provide higher and more economical solutions.

5G will help the overall potential of Internet of Things considerably higher mobile broadband speeds and wider use of mobile information. [17]. 5G will be at the heart of long-lasting communications, beginning with video games and autonomous cars to commercial networks and good cities. Even like the standard 5G bands, implementations in the metric linear unit area may use higher frequency bands to adjust wider information dimensions and better levels of awareness. Upper frequencies, broader bandwidths, so the designers of antenna need beamforming, beam steering and multiple beams. [18]. Low profile economical antennas and antenna arrays are important to make sure efficient and free communication is needed. Nevertheless, antenna and propagation aspects are complicated by the need for increased power, greater data calculation, higher gains and inability to appeal to the human consumer. This indicates the need for new ideas and groundbreaking antenna design solutions [19][20][21][22].

A special issue includes eight articles on various aspects and implementations of 5 G antennas. Four papers affect the issue of modeling, whereas three papers include multiple input (MIMO) systems which are supposed to be used extensively in 5 G long-term networks. Another paper considers a very important problem in order to provide the necessary coverage reconfiguration by synthesize the relevant radiation pattern of linear and tabular antenna arrays of discretionary pure mathematics. One of the papers deals with the dual-band single-layer array cell that is expected for future 5 G networks. The paper addresses a drawback in the context of finding in a setting of uncertain inhomogeneous noise mistreatment arrays in which a completely new method of finding gridles directions is developed using the low-ranking variance matrix approximation. The following paragraphs include a lot of information on these subjects.

2.2.1 5G Spectrum – 1 GHz to 6 GHz

Spectrum is a reproving part of the wireless network. This awakens the "airwaves" that sustain our daily network services such as mobile telephones, Wi-Fi and TV. The various 5G networks and applications need a diverse range, mixing low and high frequency bands to satisfy specific demands.

The defragmentation and clearing of primary bands in 5G communication systems should be given priority to use a significant number of new and harmonized mobile spectrums. The spectrum is divided into three major frequency ranges to provide broad coverage and support for all applications. There are three different ranges: sub-1 GHz, 1-6 GHz and above 6 GHz. Fig. 2.0 shows common 5G applications in real world.

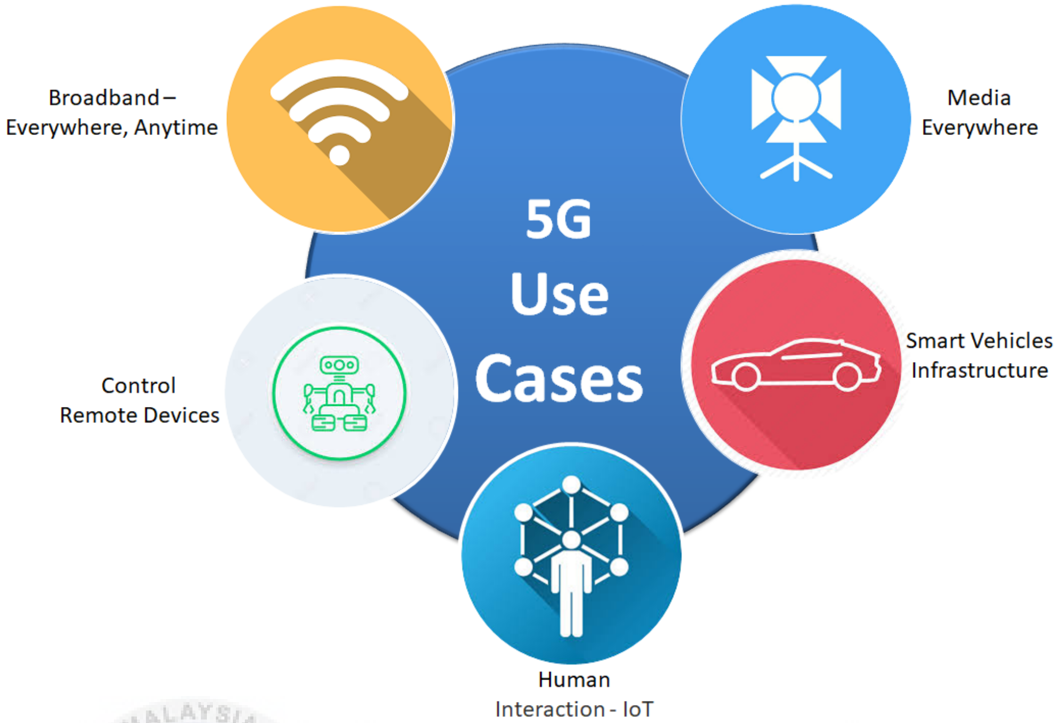


Figure 2.0: 5G applications

The 1GHz and below bands would include Sub-1 GHz, where coverage for IoT networks in urban, suburban, and rural areas is enabled. With the 3.3-3.8 GHz band, which will support several initial networks, band 1-6 GHz is a strong balance of coverage and efficiency benefits. It includes other networks for 5 G including 1800 MHz, 2,3 GHz and 2,6 GHz etc. which can be allocated or reframed by them. More spectrum is needed to maintain 5G service quality for the long term and the spectrum demand between 3 and 24 GHz increases daily. [23].

2.2.2 Mid-Band (Sub-6)

Mid Band (also known as Sub-6) is the widely used band for the cellular data transmission in 2G , 3G and 4G communication networks. Sub-6 works between the frequencies of 1 GHz and 6 GHz (2.5, 3.5 and 3.7-4.2 GHz). This spectrum band has its own niche, where walls and barriers can reach, which not only has a good range which wide areas of acceptable Internet speeds.

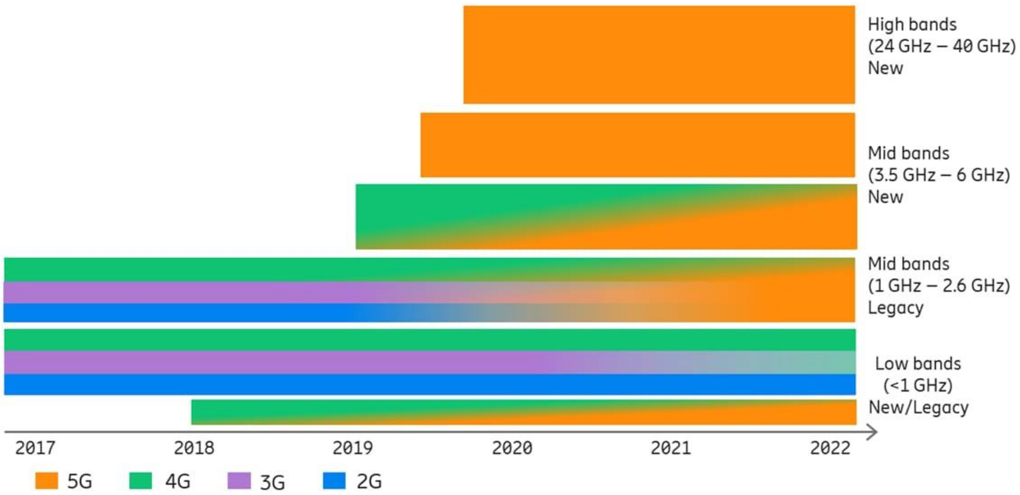


Figure 2.1: Indicative spectrum allocation over time

Fig. 2.1 shows the indicative spectrum allocation over time. Within the Sub-6 spectrum, all frequency ranges are allowed to transmit wireless data and, of course, 5G benefits from these bands. 2.5 GHz is intended for education or broadcasting as an feature to be incorporated in 5G networking networks.

The 2.5 GHz strip is at the edge of the mid-band spectrum, which means that it's wider (and slower) than the mid-range bands commonly used for 4G. This category has been selected by the industry for remote areas so that high-traffic areas do not end up with super-slow, low-band spectrums.

2.3 Self-Grounded Bow-Tie Antenna

A paper by M in 2019. Alibakhshikenari, etv which develops a Sub-6 spectrum bow-tie antenna. A research by authors from the University of Rome and London University of the metropolitan region, they developed a Wideband Sub-6 GHz Auto-grounded 5G Communication Systems Bow-Tie Antenna. The authors in this journal are inspired by the eagle wings shape. With CST Microwave Studio, reflecting coefficient less than -12dB and frequency range from 3.35 to 4.4 GHz are optimised.

The finding appears in Fig. 2.2, the preliminary analysis provides an excellent reflection factor of nearly -10 dB in a band from 3.35 GHz to 4.4 GHz, corresponding to a fractional bandwidth of 27 percent. [24].

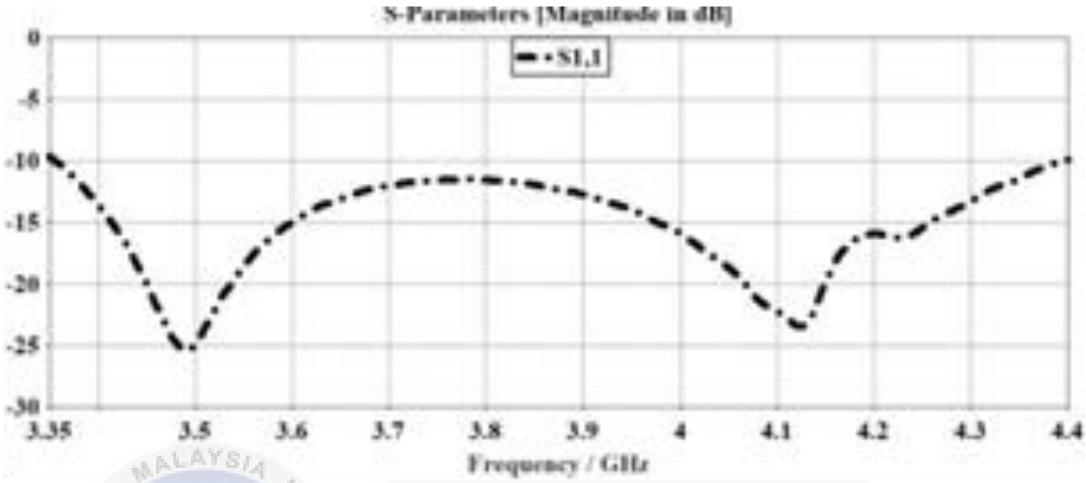


Figure 2.2: Reflection coefficient (S11<-10) for the proposed bow-tie antenna excited using the proposed mechanism

2.4 Characteristics of Antenna

An antenna is a device which transforms an RF signal into an electromagnetic wave in free space via a conductor. Regardless of the type of antennas, they all retain the same features when transmitted and received. A MPA consists of a metallic pattern on the one side of the dielectric substrate and on the other side of the substrate. There are different shapes of patch as shown in Fig. 2.3.

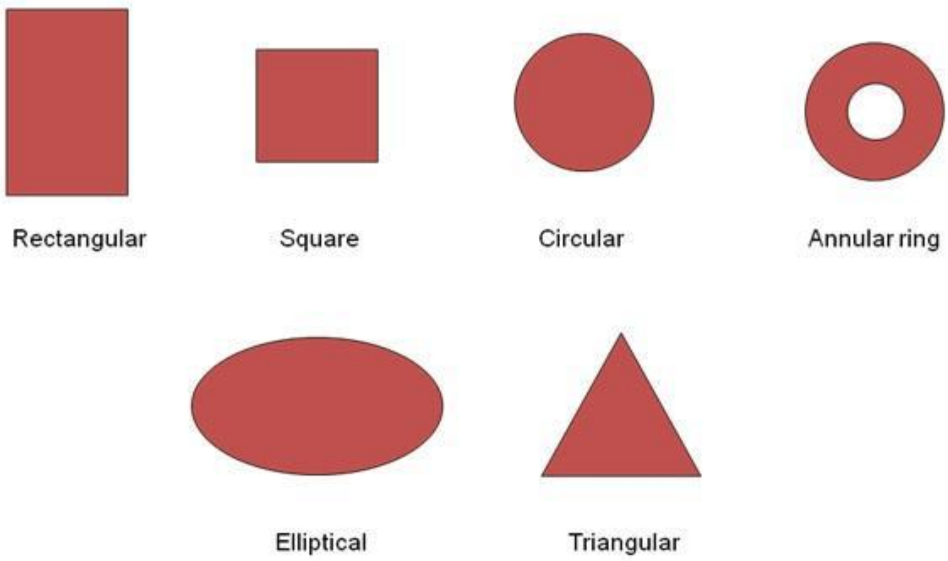


Figure 2.3: Different shapes of patch

Micro strip antennas radiate mainly due to the fringes between the field and the edge of the patch. MPA is recommended for enhanced antenna performance due to excessively improved efficiency, greater bandwidth and better radiation with a thick dielectric substratum, a low dielectric consistent. Due to a higher dielectric designation constant, the compact micro strip antenna has reduced bandwidth and efficiency. The developer must therefore choose between antenna and antenna efficiency.

2.4.1 Bow-Tie Microstrip Patch Antenna

Due to its slight weight and thin configurations of profiles, low production costs, reliability, conforming structure and manufacturing ease, microstrip antennas have been widely used in theoretical and engineering applications in recent years.

The bow-tie patch is the synthesis of an imagined image of two triangular patches made of a single substratum. Fig. 2.4 displays the microstrip antenna bow-tie strip. For today's contact situation, bow-tie microstrip antennas have become appealing candidates because they are lightweight compared to rectangular patches. The the demand for compact wireless communication equipment specifically demands research into compact antenna options which has been the concern of numerous researchers throughout the world in the area of bow-tie microstrip antennas. Yet few attempts have been made in the literature to examine this type of antenna. The bow-tie patch microstrip antenna as a lightweight and proposed an empirical model for the current geodesy's resonant frequency. The past research on bow-ty antenna is visible in.

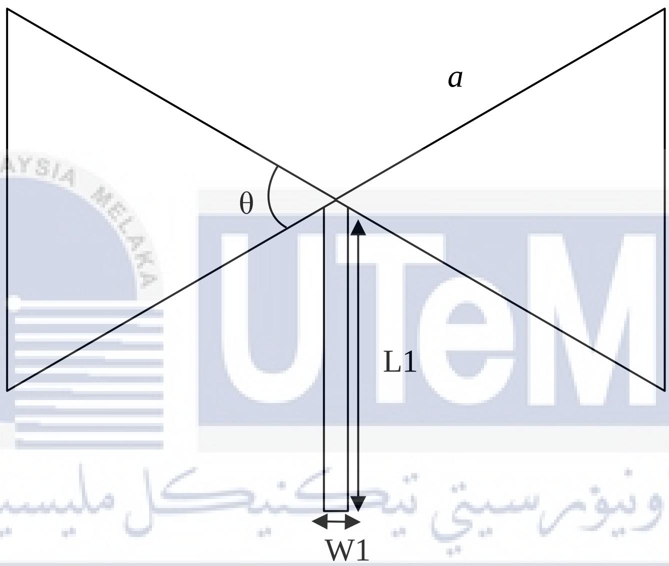


Figure 2.4: Dimensions of Bow Tie Antenna

The dimensions of the bow-tie microstrip antenna are shown in the photograph 5, where an is the bow-tie side length, — an is the equilateral triangular angle; L1 and W1 are the corresponding network dimensions. Resonant frequency according to the different modes defined [25]:

$$f_r = \frac{ck_{mn}}{2\pi\sqrt{\varepsilon_r}} \tag{2.1}$$

$$f_r = \frac{2c\sqrt{m^2 + mn + n^2}}{3a\sqrt{\varepsilon_r}} \tag{2.2}$$

where

- f_r is the resonance frequency
- k_{mn} is the resonating modes
- m and n are number of modes
- c is the velocity of light in free space
- a is the side length of the bow-tie strip

The above expression is valid when a magnetic wall surrounds the triangular resonator. The effect on the resonant frequency of an unperfect magnetic wall can be empirically used for easy measurement.

There have been different suggestions about how to change a specific term for a microstrip patch antenna which is not surrounded by a complete magnetic wall. Most suggestions are to replace the side length with an effective a_{eff} value and to keep the dielectric substrate unchanged. The other kit indicates that both a and ε_r should be replaced with their effective values. An expression for a_{eff} was achieved by a curve that matches the theoretical and experimental findings for the resonating frequency for TM_{10} mode. It's offered by

Resonant frequency dominant mode is:

$$f_{10} = \frac{2c}{2f_r\sqrt{\varepsilon_r}} \tag{2.3}$$

Side length:

$$a = \frac{2c}{2f_r\sqrt{\varepsilon_r}} \tag{2.4}$$

Effective value of side length:

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}} \tag{2.5}$$

Effective dielectric constant:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{4\sqrt{1 + \frac{12h}{a}}} \tag{2.6}$$

Resonant frequency for mn mode:

$$f_{mb} = f_{10}\sqrt{m^2 + mn + n^2} \tag{2.7}$$

Wavelength in free space:

$$\lambda_o = \frac{c}{f} \tag{2.8}$$

Wavelength of the antenna:

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{eff}}} \tag{2.9}$$

$$L1 = \frac{\lambda_g}{4} \tag{2.10}$$

2.4.2 Radiation pattern

The antenna radiation pattern is represented as a diagram of the radiation characteristics of the antenna as a function of space co-ordinates in which the radiation pattern is determined in the far region [26]. For the antenna designer to shape the radiation pattern, selecting the antenna to the end user is easy. Pattern of radiation divided into three groups:

i. Isotropic pattern – The antenna is emitted in all directions or better defined as an imaginary lossless antenna with radiation in every direction. [27].
ii. Omnidirectional pattern – is known as non-directional, where a constant ornament is in the plane [27].
iii. Directional pattern – The antenna only radiated uniformly, whether to the right or to the left [27].

These patterns can also be examined to indicate the relative field power of the antenna-radiated field. The antenna radiation pattern is often made up of a 3D graph shown in the figure 2.5, or vertical and horizontal cross-section polar plots. The diagram will show side lobes and back lobes. As shown in figure 2.6, the polar plot can be evaluated as a planer cut from the 3D radiation pattern. [28].

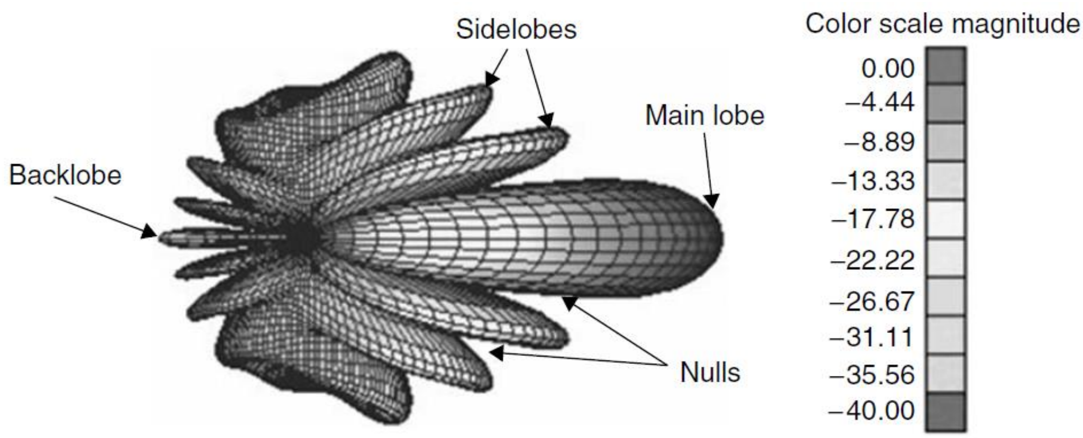


Figure 2.5: 3D Radiation Pattern

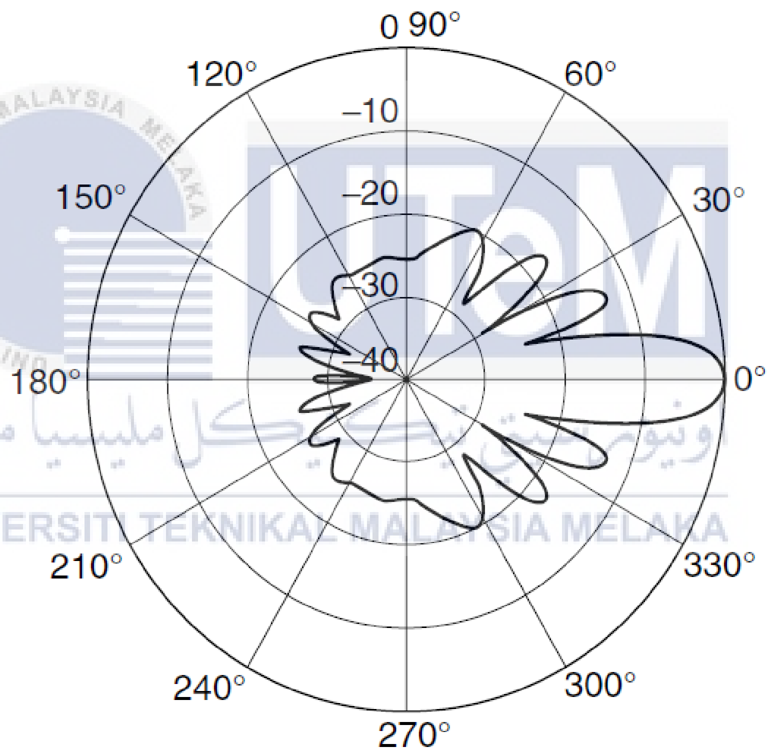


Figure 2.6: Polar plot radiation

2.4.3 Directivity and Gain

The direction of an antenna is its ability to direct or centralize the emitted force in a particular direction and in an undesirable direction. It defined "the correlation of the intensity of the radiation from the antenna with the intensity of the radiation, which is oriented in every direction." In other words, the directivity of a non-isotropic origin is close to that of an isotropic source to that of its radiation potency in a certain way. [28]. The average intensity of the radiation can be deliberate by cleaning the total antenna power by 4π. If the direction is not identified, the direction of intensity of radiation can be shown as [28]:

$$D = \frac{U}{U_i} = \frac{4\pi U}{P_r} \tag{2.1}$$

A low-gain antenna radiates in all directions with the same power while a high-gain antenna radiates superiorly in specific directions [27]. The gain, directive gain or energy gain of an antenna is undoubtedly defined as the ratio of intensity (power per unit surface) radiated from the antenna in a certain direction at a random distance reduced by the intensity radiated from a controversial isotropic lossless antenna at the same distance [28].

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

Where;

- U = radiation intensity
- P_{in} = total input power

2.4.4 Beamwidth

The antenna's beamwidth is generally known to be the angular width of the half power that is radiated in a specific cut into the antenna 's main beam where the bulk is radiated. Depending on the maximum radiation strength of the main-beam pinnacle, the half power level is – 3 dB below the height of the main-beam, where the points are situated at both sides of the pinnacular height, dividing the angular width of the half-power. The angular distance between the half points of power is known as the width of the beam. Half of the power measured in decibels is -3dB, which means that the beamwidth of half power is often called the beamwidth of 3dB. Horizontal and vertical beam widths are typically taken into account [28].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the flow of the project process is discussed step by step in order to make sure that the project is successful. Methodology is the method used for the study and is used to obtain data and information as a way of guiding the flow of the work, in order to start adjusting the parameters to optimize the antenna design to achieve required performance.

3.2 Introduction

The technique for the completion of this mission. The project began with the study of literature by journals and books on elliptical antenna and 3D printed materials. Then continue to measure 5 G application for those journals at 3.75 GHz. The antenna is simulated in its entirety using the 2017 CST studio suite. If the result is not desirable, it will take an optimization step. Otherwise, pass on the stage of manufacturing. The measurement will then be carried out on the antenna prototype. The flowchart shown in Figure 3.0 and Figure 3.1.

i. Research Methodology Flow Chart

- PSM 1

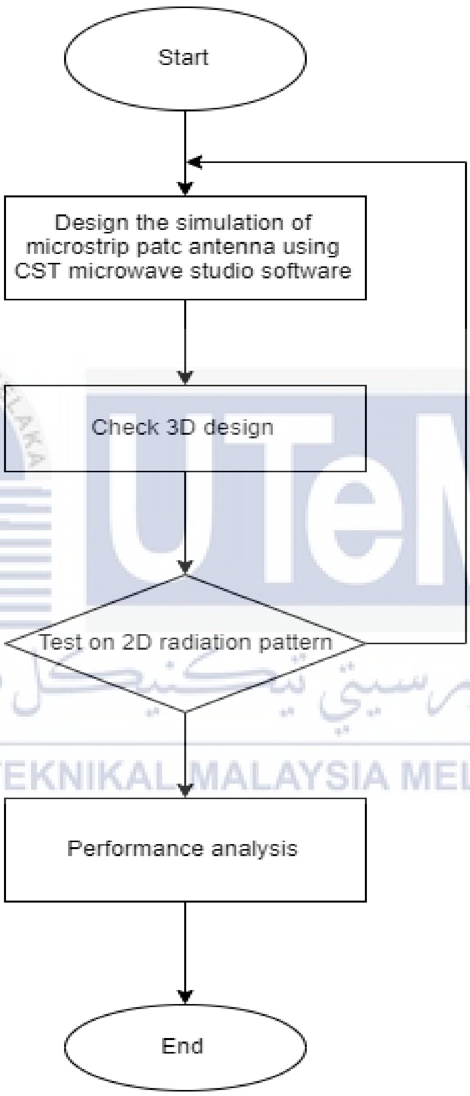


Figure 3.0: Project development flowchart PSM1

ii. Research Methodology Flow Chart

- PSM 2

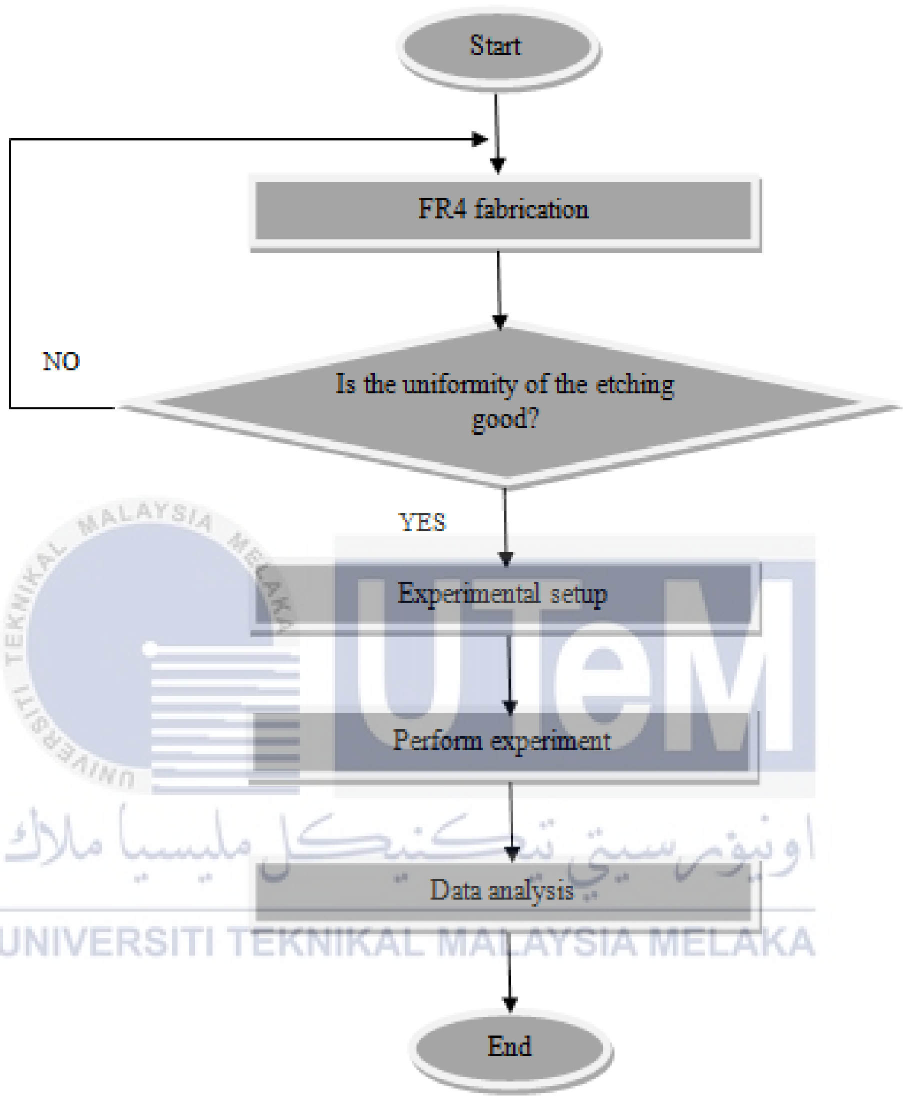


Figure 3.1: Project development flowchart PSM2

To achieve my project objectives, a few methods as shown in the flowchart are required. The figure shows all steps necessary for the development of this project. The methods are discussed below.

3.3 Design Specification

The frequency selected for the operation of the antenna is 3.75 GHz. This is because 3.75 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. The ideal of bow-tie antenna parameters shown in Table 1.

Table 1: Parameter specification of an ideal bowtie antenna

Antenna

Parameters	**Values**
Gain(dB)	-44.859dB
Directivity	5.434dB
Return loss	
Radiated power	1.4502E-12
E-Phi	-95.705
E-theta	84.249
H-Phi	84.488
H-theta	84.248

3.4 Analyzation and optimization of antenna design

With all the setting been done before the simulation of design, the antenna model is ready to be simulate. All the required setting has been shown and set in previous step. The antenna is then simulated and all the parameters such as return loss, gain, and others are furthermore analyzed and discussed.

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.

3.5 Fabrication of Antenna Design

Once the antenna parameter specification is reached, the antenna design is provided for fabrication. There are several steps and steps before fabrication using FR4 and 3D printer technology.

In typical PCBs, the core provides the rigidity and basis for direct impression of PCB traces. Moreover, the FR4 core and lamination form an electrical distribution which separates the copper layer from the plate. The FR4 core separates the top and bottom copper layers for dual flooring, while the FR4 pre-ready layer is clamped between the internal core and the external copper layer on the multiplayer PCB. You can control the requested thickness of the PCB ends by adding or removing single laminates or using different thickness laminates. For example, the 1.6 mm board usually contains 8 glass fiber layers, the board 0.8 mm and the number of sheets is reduced up to 4 sheets.

In comparison to conventional methods, the manufacture of 3D printers is known as a modern and groundbreaking process for the development of antennas. On the basis of the advantages of this technology, manufacturing components and versatile designs, a smaller form factor, a lighter weight, lower cost and a more biofriendly method of producing objects is a widely used alternative method for manufacturing electromagnetic 3D structures, in particular antennas.

3.6 Preparation of FR4 fabrication

Antennas have evolved to tackle the problems of this era and update antennas to ever more sophisticated technology. Conventional antennas are harder to build than antennas. The standard antennas are costly and fairly heavy, but the patch antennas are simple and easy to build. Microstrip patch antenna shapes are special, such as rectangles, circulars, triangles and other geometry varieties. A rectangular patch antenna will be designed to create antennas for Wireless Network Area Network (WLAN) applications based on factors. Flame Retardant 4 (FR4) and 3D printers will be used as dielectric substrates in antenna manufacturing.

FR-4 is the standard printed circuit boards (PCBs) material shown in Figure 3.2. One or both parties of an epoxy panel FR-4 are laminated by a thin layer of copper foil. They are commonly referred to as laminates covered with copper. This antenna is supposed to be printed with a relatively primitive 4.4 substrate, a loss tangent 0.02 and a thickness of 1.6 mm applicable to UWB systems. The use of low-cost FR4 as a substratum brings a certain additional complexity to the antenna design. This is because of the inaccuracy of FR4 and the high tangent loss (around 0.02). The change in FR4 electric transparency can change the frequency of operation and the high loss tangent has a severe effect on the antenna and axis which causes poor radiation efficiency.

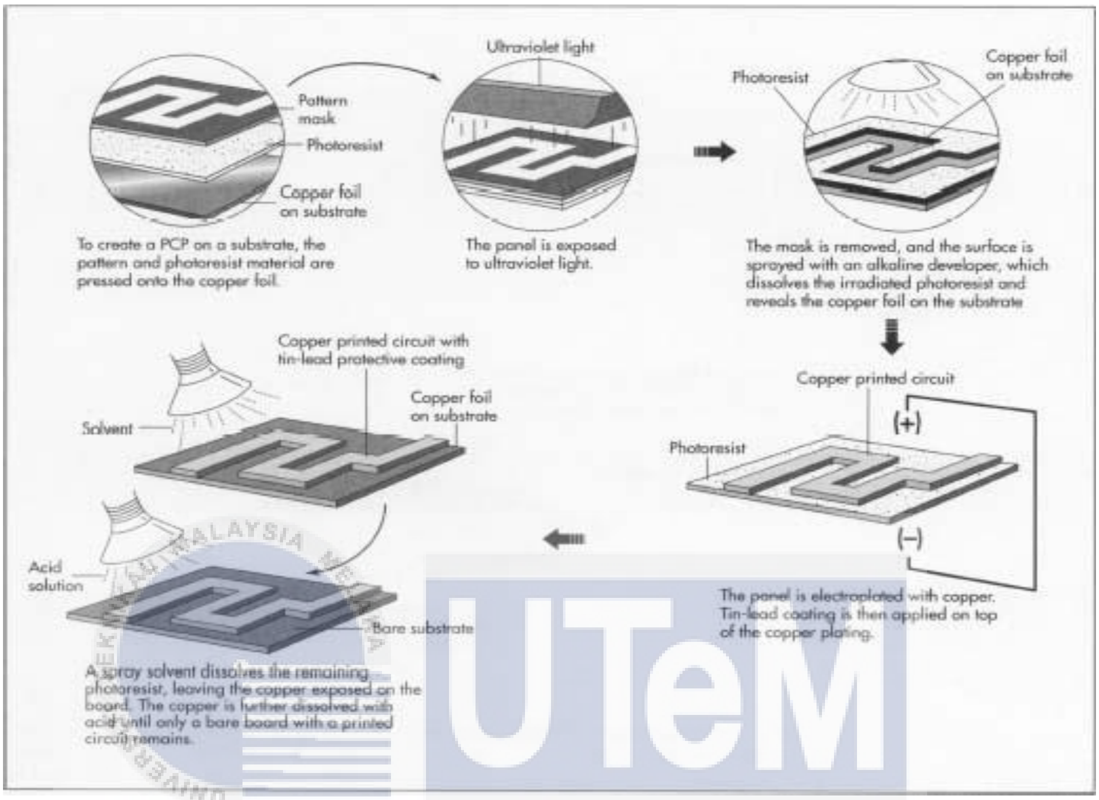


Figure 3.2: Fabrication using FR4 method

3.6.1 Preparation 3D printer

The method of creation of three-dimensional solid objects from digital files is 3D printing or additional output. 3D printed objects are produced using additional processes. The object is created in the additional phase by adding a layer of material continuously before the object is formed. Each layer is perceived as a horizontal cross section, sliding away from the end point. 3D printing is the opposite of a manufacture which cuts / loosens a piece of metal or plastic with an example of a milling machine. 3D printing helps you to create complex shapes using less than conventional materials. Example of 3D printer shown in Figure 3.3.

Figure 3.3: 3D printer machine

3.6.2 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 and is painted or graved to create the desired pattern on the substratum surface. The copper circuit is covered from oxidation by a tin coating. The contact surface is filled in silver, nickel and eventually gold for great conductivity. PCBs from paper-strengthened copper foil phenolic resin are cheaper to use in electric appliances at home.

Copper is the best material for FR4 manufacturing patch antennas. The metal, although soft and muddy, is very rigid. The tensile strength of stainless steel is higher so that thinner wire can be used. For mobile whip antennas, steel is therefore an excellent choice where flexibility is a must. The copper on a top of the antenna as flexibility is not a problem because of its high electrical conductivity. The layers is shown in Figure 3.4.

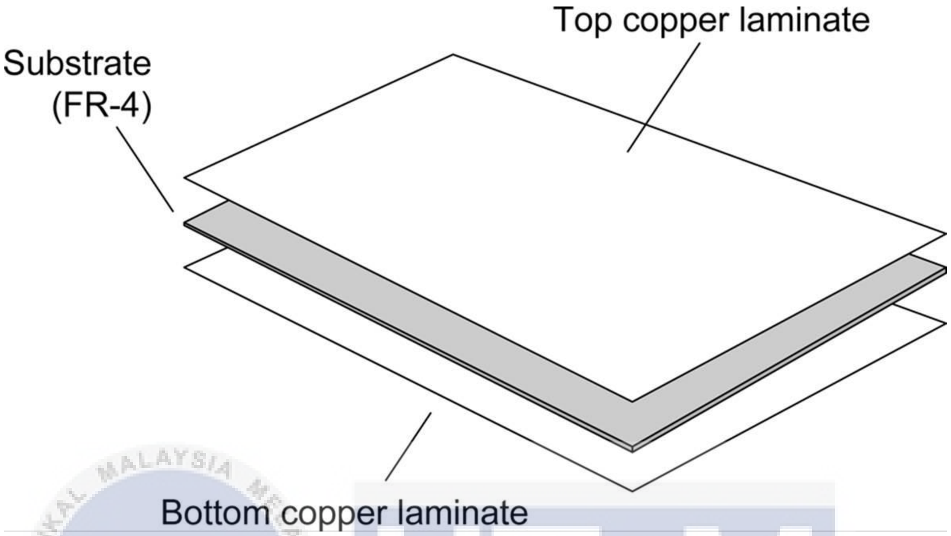


Figure 3.4: Copper on top of the FR4 board

For the 3D material, we use PLA (polylatic acid) material that is easy to print by producing antennas as shown in Figure 3.5. It has a lower printing temperature than ABS, and does not warp easily, so a heated bed is not necessary. Another advantage of PLA is that there is no bad odor when it is printed. They are usually considered odorless filaments, but many have reported sweet odors according to the PLA type.

PLA is available in nearly unlimited styles and colours. As you will see in the exotic section, PLA is a base material for most of these specialized filaments like conductivity or luminosity, or wood or metal.

Eventually, PLA is more environmental friendly than other forms of 3D printer filaments, made from sustainable sources every year including maize starch or sugar cane.

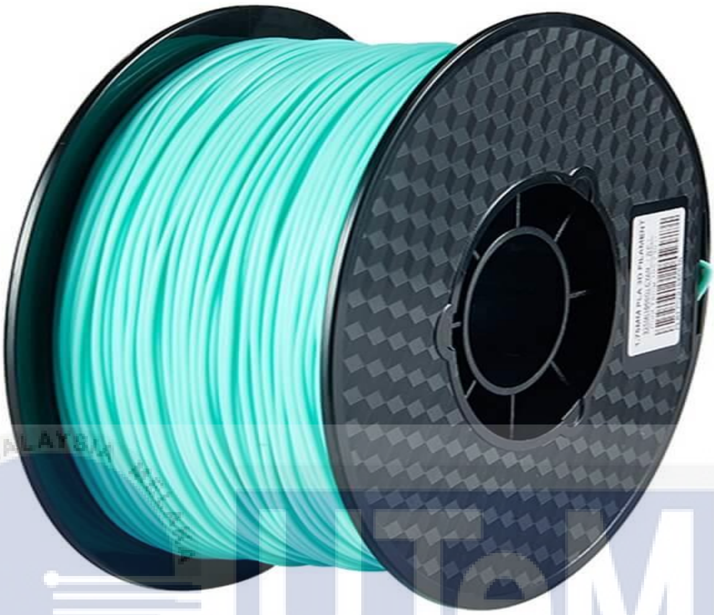


Figure 3.5: PLA filament for 3D printing

Antenna part cutting from 3D printers is a process whereby the horizontal layer is distributed using software. The software used for the pross is Ulti-Maker Cura as shown in Figure 3.6. This software file is then uploaded layer by layer with the settings provided. From figure 3.7, shows 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.

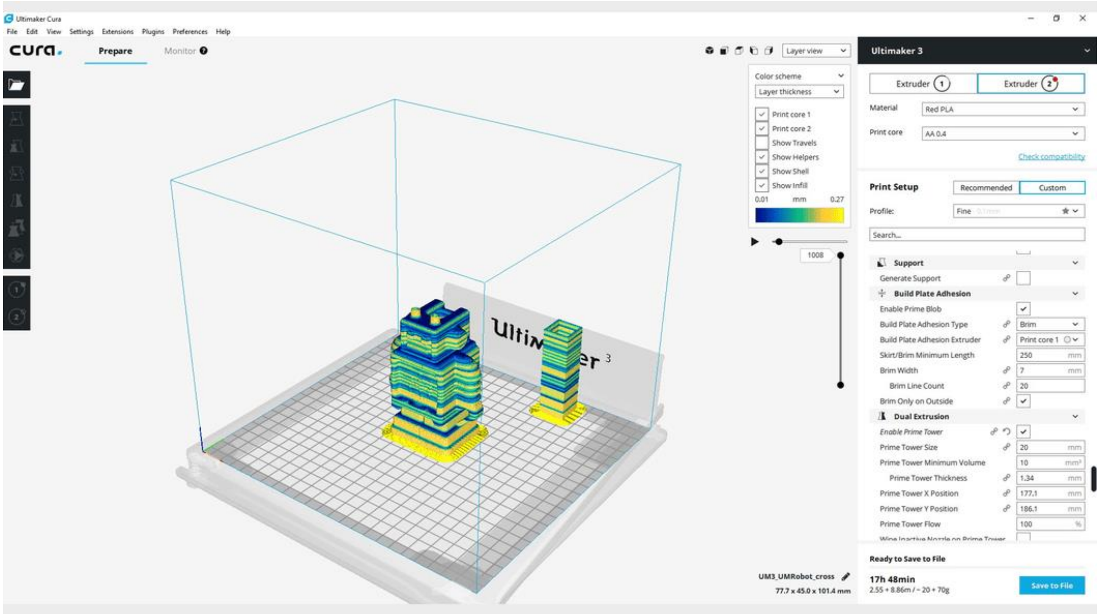


Figure 3.6: Model slice in Ultimaker Cura

3.6.3 Design a bowtie antenna

The bowtie shape of the antenna was created using CST Studio 2017 as shown in Figure 3.7. 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.

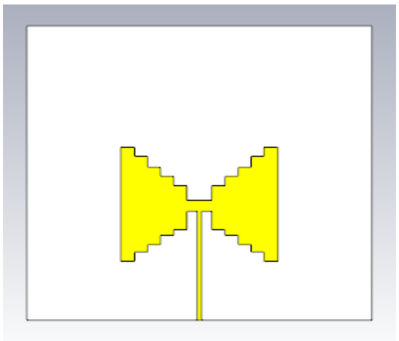


Figure 3.7: Front view of bow-tie antenna

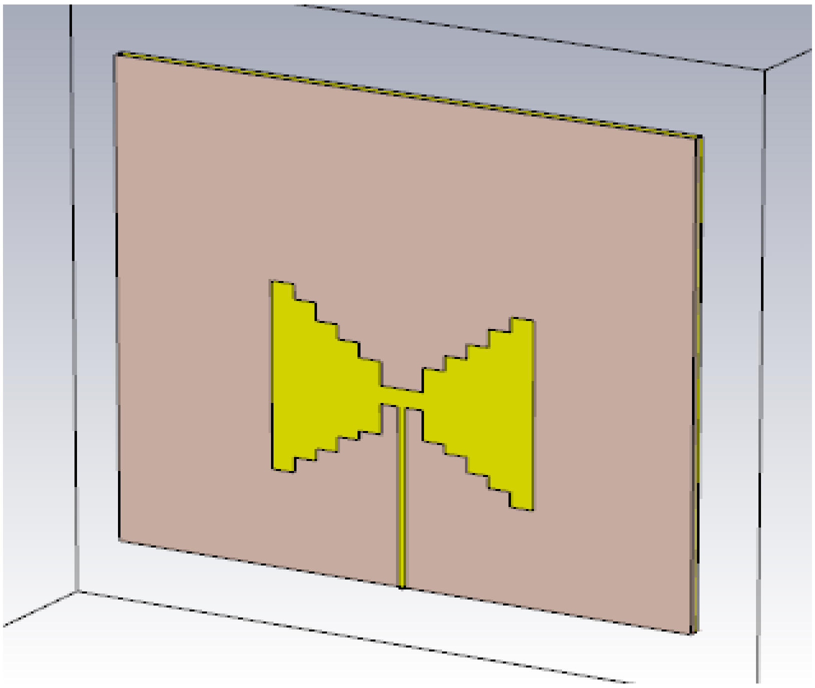


Figure 3.8: The perspective view of 3D design

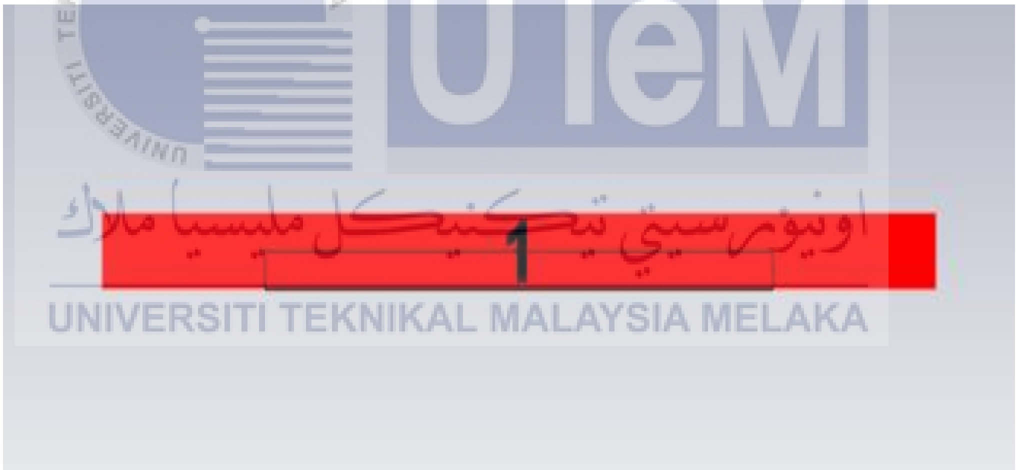


Figure 3.9: Bottom vie and port placement

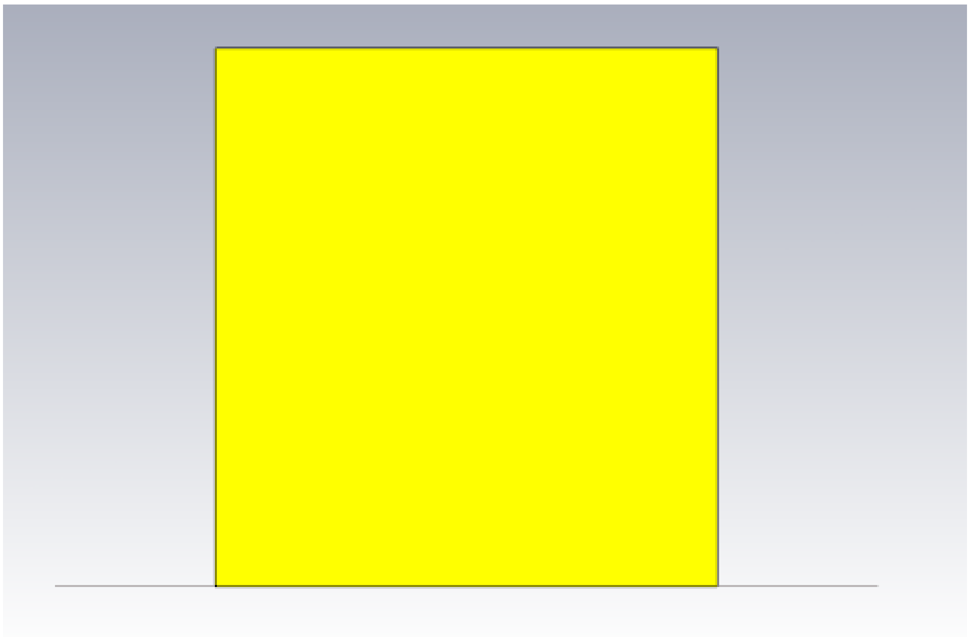


Figure 3.10: View of the ground antenna (back view)

3.6.4 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 3.75 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 2 shows the specifications of the port.

Figure 3.11: Port RS Pro surface mount MCX jack

Table 2 Specification of the RS Pro port

Specification

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 Plating	Gold
Contact Material	Brass

3.6.5 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 5 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 through the analyzer shown in Figure 3.12.

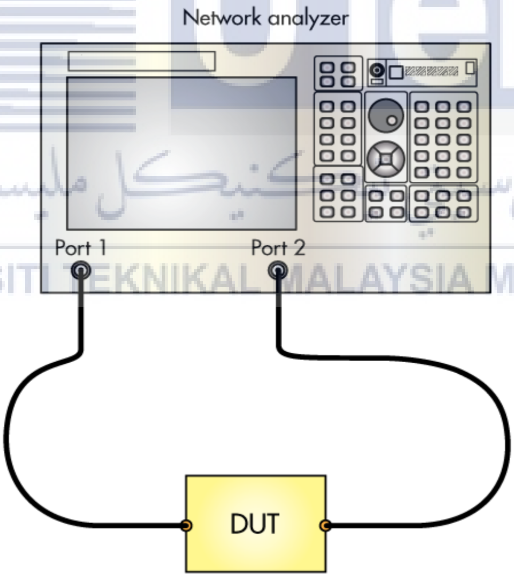


Figure 3.12: S-parameter (S_{11}) analyze using network analyzer

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Each section analyzes the effects of the calculation and the effects of the simulation. Parameters such as loss of return, gain and radiation will be discussed. The result graph of the bow-tie antenna was drawn and analyzed. Some of the statistics in Chapter 3 are repeated for the ease of data analysis.

Once the antenna has been constructed, it is imitated through the CST studio software. The results of the simulation parameters are frequency, return loss, gain, voltage standing wave ration (VSWR), directivity, and radiation pattern. The results shown are the most significant data obtained from the simulation, which regulates the strength of the signal transmitted through the bow-tie antenna.

S_{11} parameter return loss of the bow-tie antenna. The aggregate of the return loss from 1GHZ to 5GHz frequency range is below-10db and shows that the strength of the signal received during data transmission is well established in order to obtain a coherent data diagram.

In fact, at least 95% of the signal received through the antenna should be sustained at a minimal loss rate. This is demonstrated by the fact that the VSWR was intentionally created during the simulation. The antenna gain that is exposed is a main function of the antenna.

The antenna data matching must be in agreement with the current characteristics, so if it did not radiate, it would be pointless. The antenna gain is an indicator of the efficiency of the radiation antenna on the basis of capacity. The antenna data match must be consistent with the current features, so it would be useless if it did not irradiate. The antenna gain depends on how efficiently the radiation antenna depends on the transmitting power. The influence of an antenna power gain is one of the possible effects to the human body.

The antenna guidance refers to the area in which the signal emission force has been radiated and the maximum gain is achieved. The defined course would offset the gain by rising the course as the gain declines. The highest position of the antenna depends on the frequency of the signal.

Therefore, the bow-tie antenna radiation configuration has three kinds of lobes, including the middle, lateral and back lobes. The right lobe is broader than the sides and the lobe 's back. It means there is a lot of power radiating in the other direction around the main lobe. The great radiation intensity is determined by the small main lobe of the pattern.

4.2 Bow-Tie Antenna Design

To improve the shape, the differences have been made based on which one is better to choose. Table 3 and table 4 show that there is a significant difference between the simulation of bow-tie antenna and fractal bow-tie antenna. The resonant frequency was set at 3.75GHZ in simulation CST software for both designs.

For the two resulting designs show single band of S_{11} parameter graph based on frequency range 2.5 to 5 GHZ. The simulation has been processed after some detailed studies have been done.

Table 3 Design 1

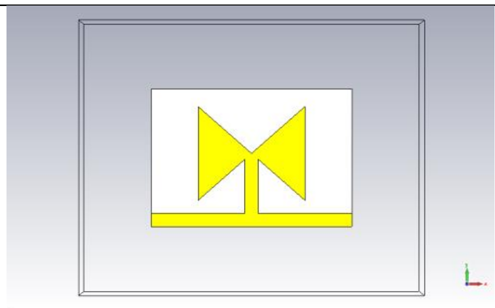
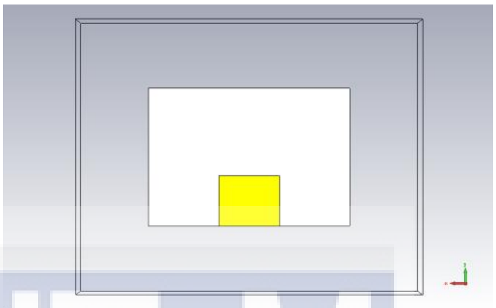
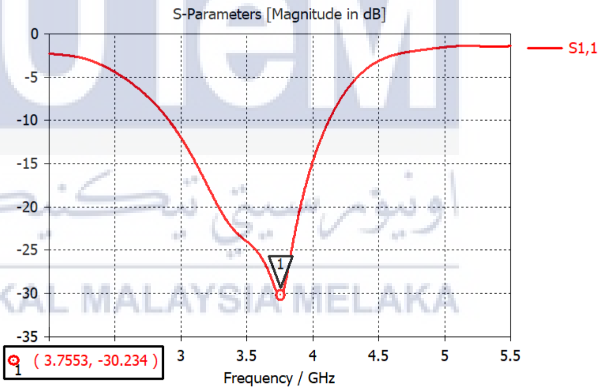
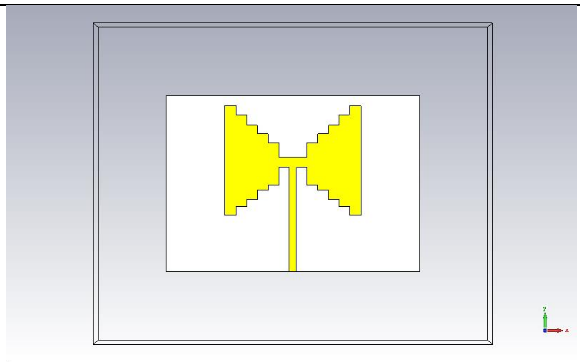
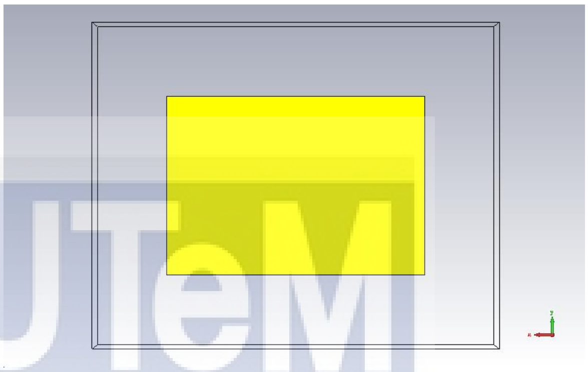
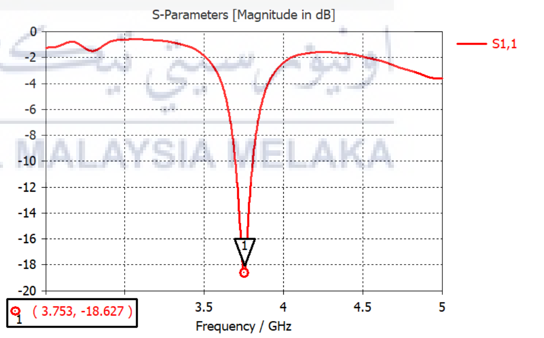
<table>
<tr><th>Parameter</th><th>Simulation</th></tr>
<tr><td>Design 1, bow-tie antenna</td><td>
</td></tr>
<tr><td>Return loss, dB</td><td>
</td></tr>
<tr><td>Gain, dB</td><td>2.484</td></tr>
<tr><td>Directivity, dBi</td><td>3.395</td></tr>
</table>

Table 4 Design 2

Parameters	**Simulation**
Design 2, fractal bow-tie antenna	 
Return loss, dB	
Gain, dB	1.997
Directivity, dBi	6.333

4.3 Fabrication of Antenna

The fabrication for this antenna design could not be proceed due to the pandemic strike since March 2020. Universities and buildings are closed during this pandemic and people were ordered to self-quarantine. From this cause, fabrication using FR4 method could not achieved and full simulations took place.

4.4 Simulation Results

This section covers the simulation result for return loss, radiation pattern, directivity, gain and VSWR. The chosen result simulation fully recorded from the CST Studio Suite software.

4.4.1 Return Loss

Parameter S_{11} determines the bow-tie antenna return loss. Figure 4.0 shows that the aggregate return loss from 2.5GHz to 5GHz is below -10dB and shows that the signal intensity obtained during transmission is sufficiently stable to obtain a reliable data graph.

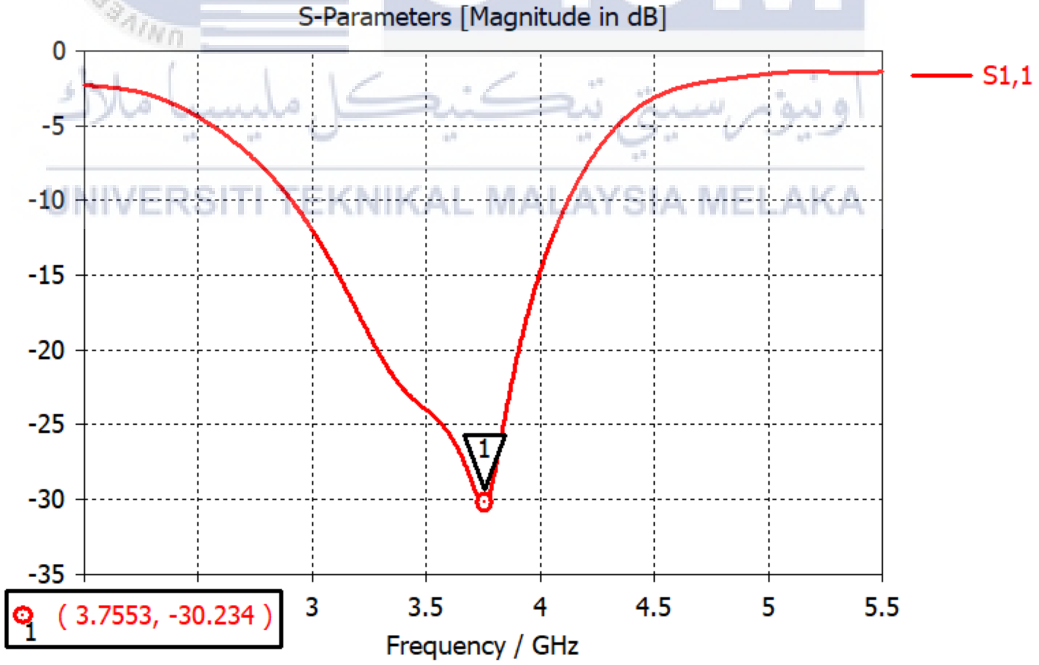


Figure 4.0: Return Loss for bow-tie antenna

However, for the fractal antenna the resultant S_{11} parameter is −33.371dB. this return loss is much greater than fractal design while it is at the same frequency. So between the normal and the fractal antenna result, the fractal design looks more efficient and good for transmitting signals. Besides that, this comparison is only to see how well an antenna works from the single band of an elliptical antenna. Figure 4.1 shows the S_{11} result of fractal bow-tie antenna.

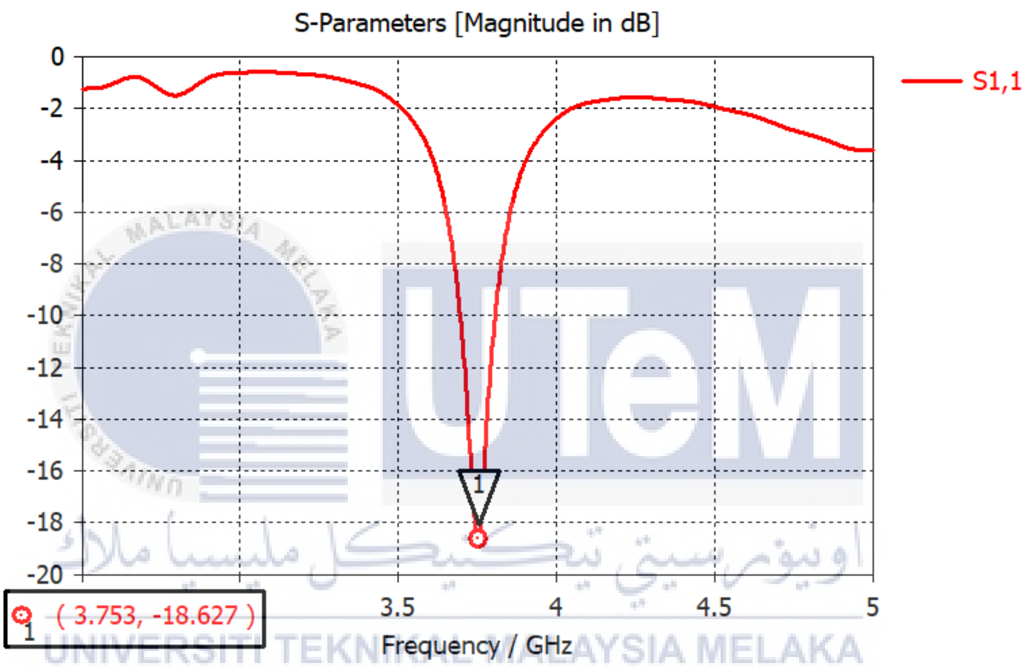


Figure 4.1 Return Loss for fractal bow-tie antenna

4.4.2 Directivity

The directivity indicates the region in which the signal radiated the strongest emission and the maximum gain was obtained. The direction always matches the gain. As the gain increases, so does the direction. High guidance reveals the stronger signal radiated by the bow-tie antenna. The simulated bowtie antenna and fractal bow-tie antenna radiate directivity of 3.395dBi and 6.333dBi from Figure 4.3 and Figure 4.4.

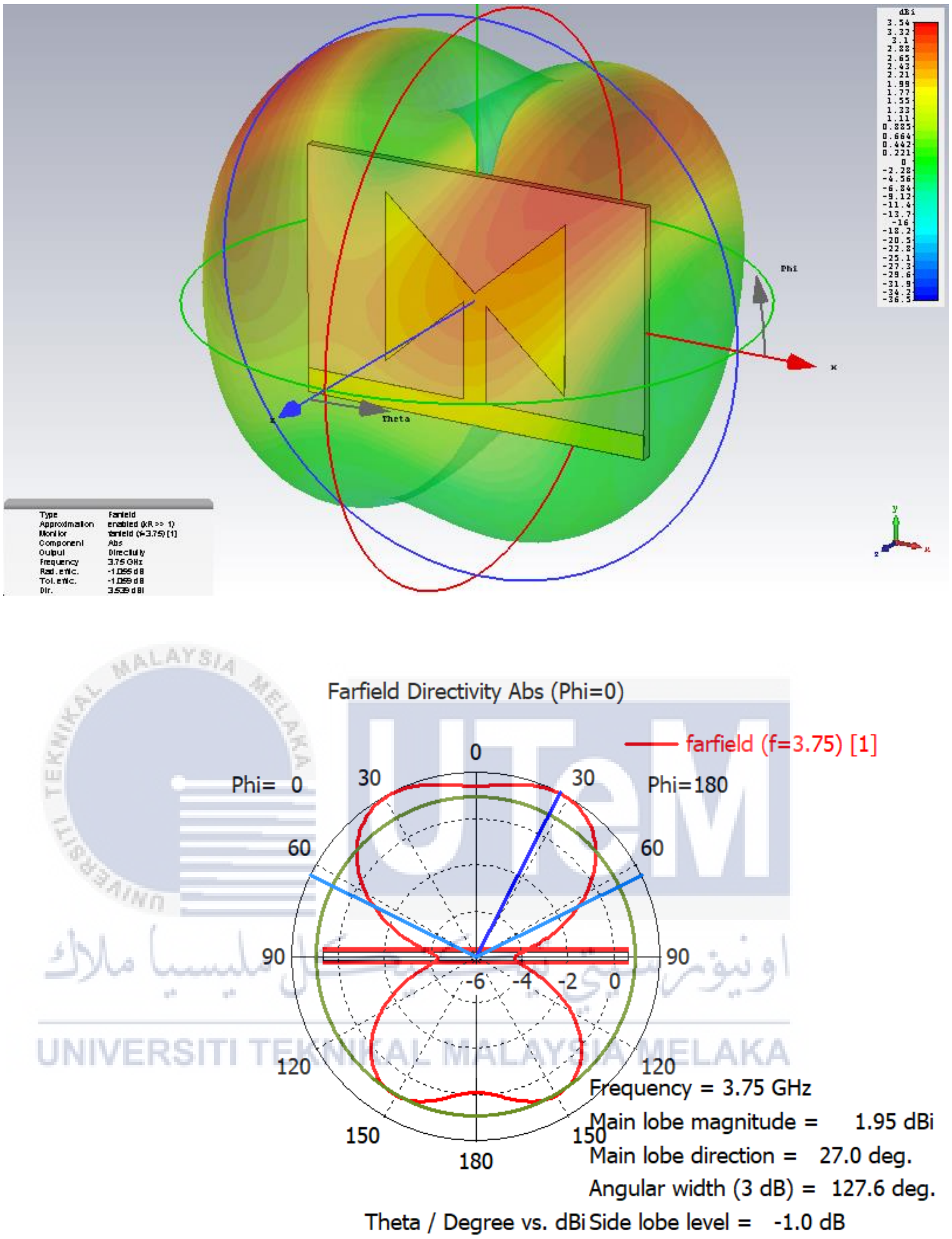


Figure 4.3: The Directivity of bow-tie antenna

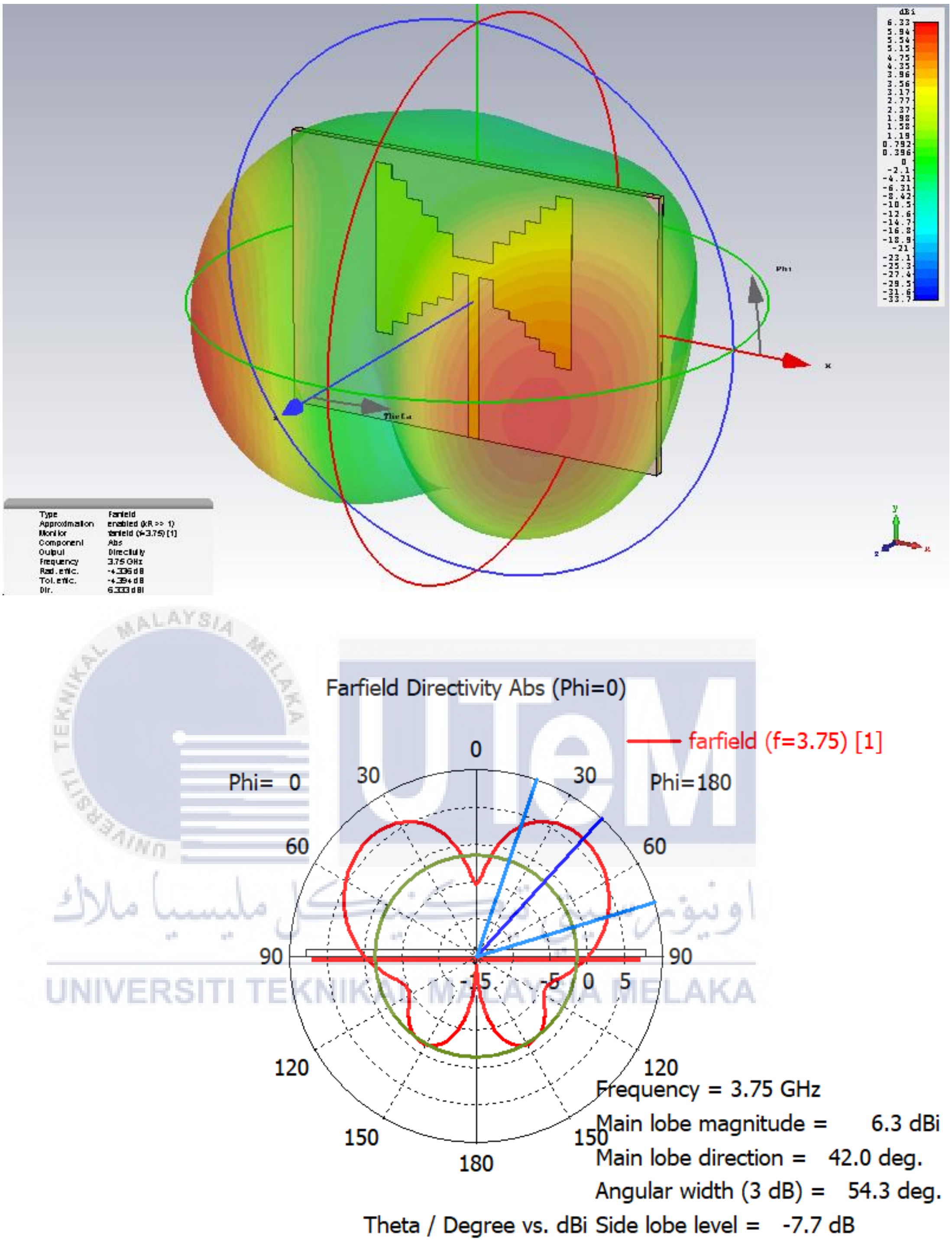
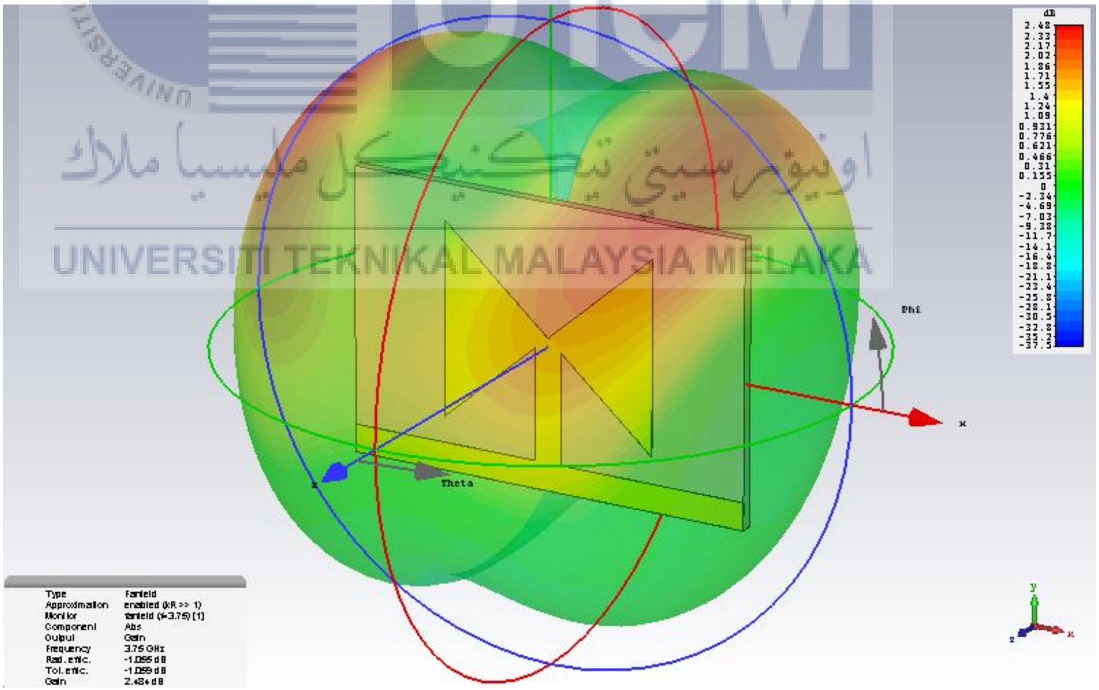


Figure 4.4: The Directivity of fractal bow-tie antenna

4.4.3 Gain

Antenna gain is the main fundamental characteristic of an antenna. An antenna has an excellent match, but if it does not radiate it will be pointless. The antenna gain is a result of how well an antenna radiates or receives power. The gain of the fractal antenna is shown in Figure 25.

At the operating frequency of 3.75GHz, the antenna gain on the bow-tie antenna is 2.484dB while the fractal bow-tie antenna produces an antenna gain of 1.997dB. From the microstrip antenna's reference, a gain must be obtained 2dB and above or positive for the antenna to transmit signals well through output and suitable for 5G applications. Figure 4.5 and Figure 4.6 below shows result for the gain of both antennas.



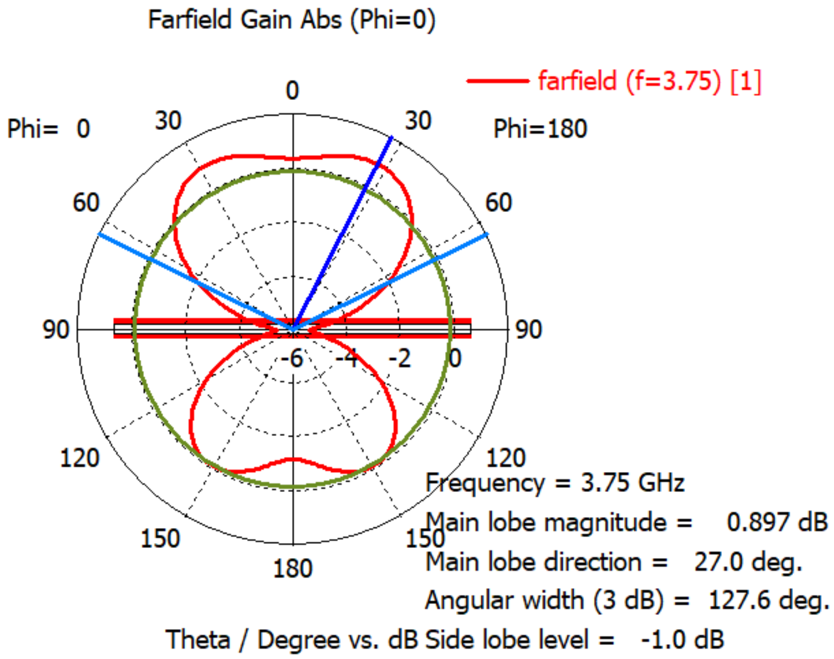
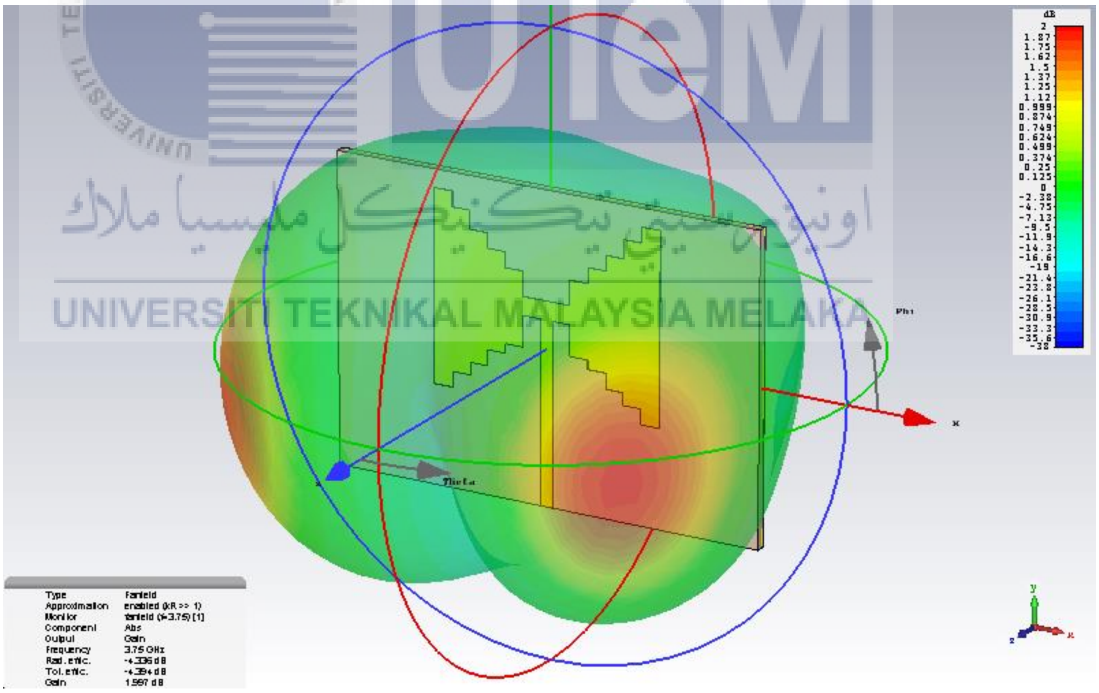


Figure 4.5: Gain for bow-tie antenna



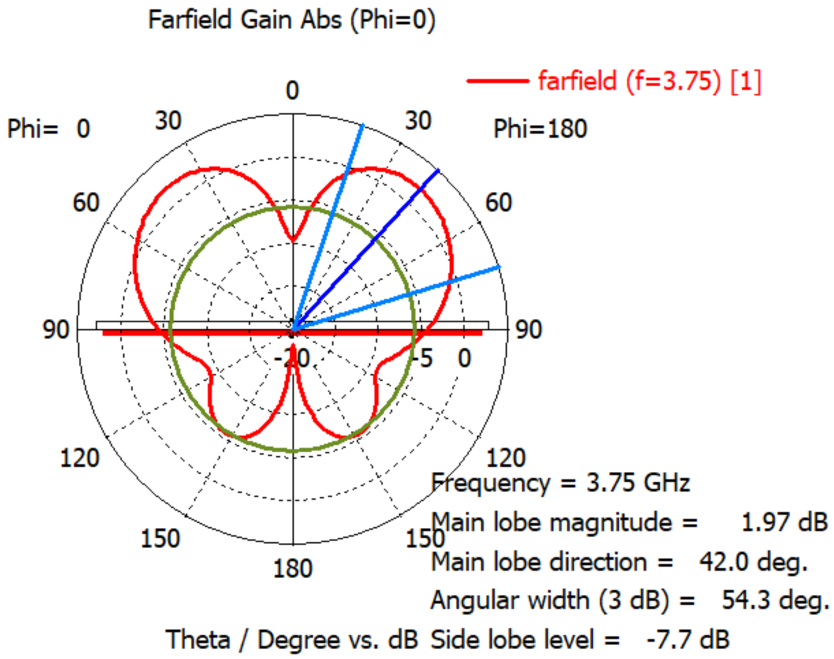


Figure 4.6: Gain for fractal bow-tie antenna

4.4.4 Radiation Pattern

Radiation pattern is a diagrammatic characterization of the distribution of electromagnetic power in free space. This pattern can also be thought to indicate the relative field strengths of the antenna-emitted field. Table 5 and table 6 show the bow-ti antenna and fractal bow-tie antenna, E-field and H-field.

Table 5 Bow-tie antenna

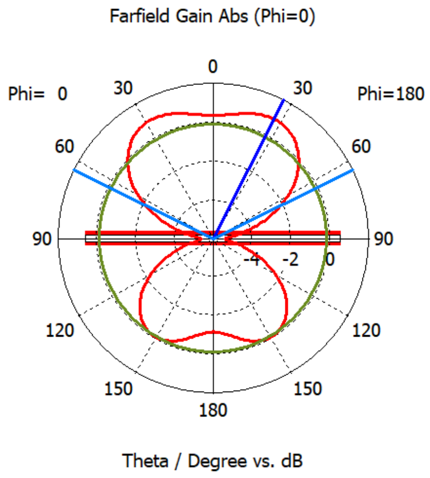
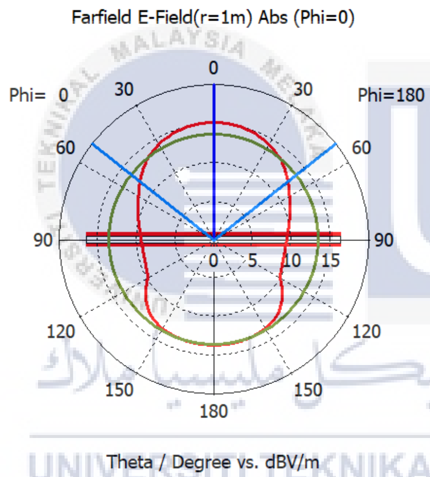
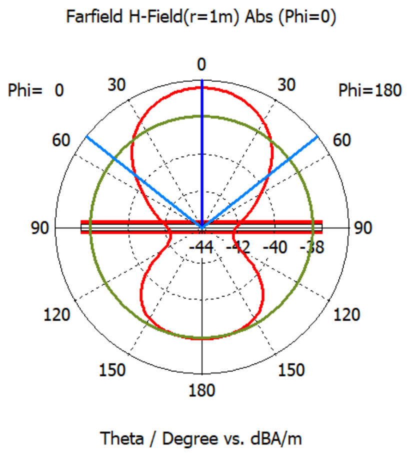
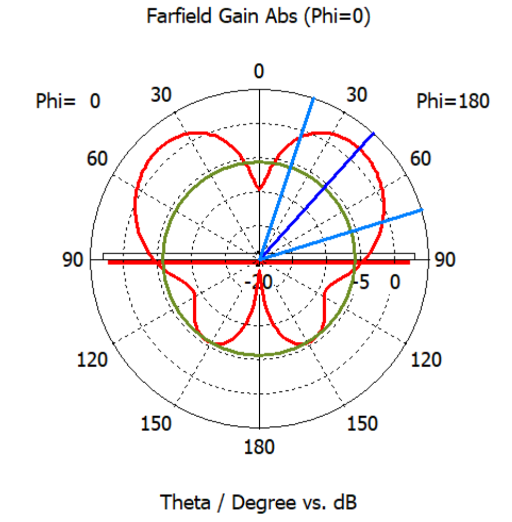
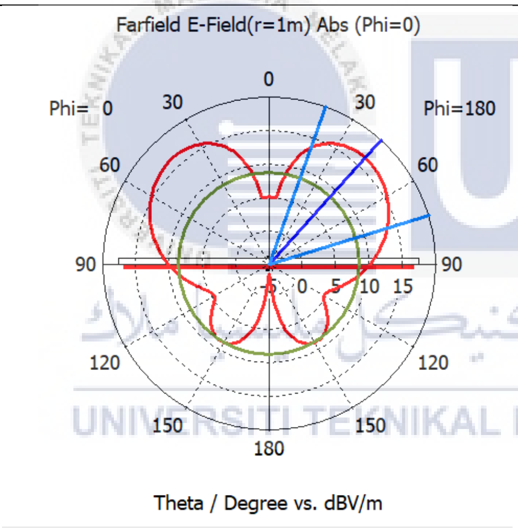
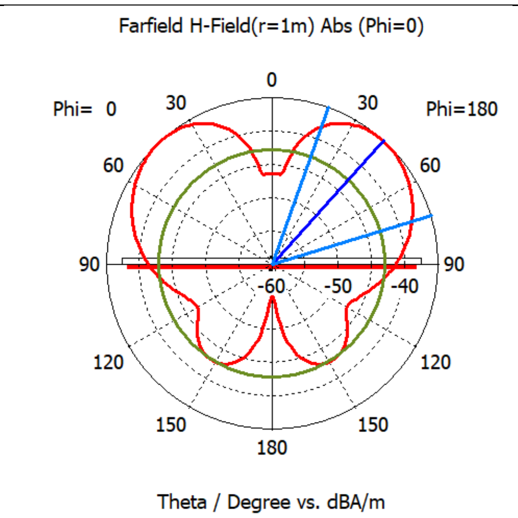
<table>
<tr><th>Pattern</th><th>Measurement</th></tr>
<tr><td>
</td><td>Frequency = 3.75GHz
Main lobe magnitude = 0.897dB
Main lobe direction = 27.0deg
Angular width (3dB) = 127.6deg
Side lobe level = -1.0dB</td></tr>
<tr><td>
</td><td>Frequency = 3.75GHz
Main lobe magnitude = 15.1dBV/m
Main lobe direction = 0.0deg
Angular width = 103.7deg
Side lobe level = -1.5dB</td></tr>
<tr><td>
</td><td>Frequency = 3.75GHz
Main lobe magnitude = -36.4dBA/m
Main lobe direction = 0.0deg
Angular width = 103.7deg
Side lobe level = -1.5dB</td></tr>
</table>

Table 6 Fractal bow-tie antenna

<table>
<tr><th>Pattern</th><th>Measurement</th></tr>
<tr><td>
</td><td>Frequency = 3.75GHz
Main lobe magnitude = 1.97dB
Main lobe direction = 42.0deg
Angular width = 54.3deg
Side lobe level = -7.7dB</td></tr>
<tr><td>
</td><td>Frequency = 3.75GHz
Main lobe magnitude = 16.5dBV/m
Main lobe direction = 42.0deg
Angular width = 53.5deg
Side lobe level = -7.8dB</td></tr>
<tr><td>
</td><td>Frequency = 3.75GHz
Main lobe magnitude = -35.1dBA/m
Main lobe direction = 42.0deg
Angular width = 54.3deg
Side lobe level = -7.7dB</td></tr>
</table>

4.4.5 VSWR

The voltage standing wave ratio provides the benefit that complements our antenna with the impedance or resistance of the transmission line. The simulated values for the standing voltage wave ratio are less than two and thus, when low attenuation is present, can be appropriate to the signal transmission. The VSWR graph is shown in figure 4.7 and figure 4.8.

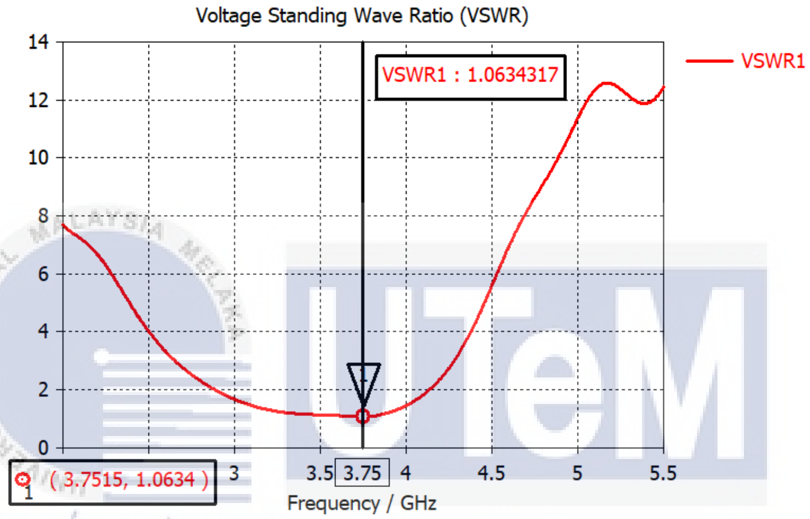


Figure 4.7: VSWR for bow-tie antenna

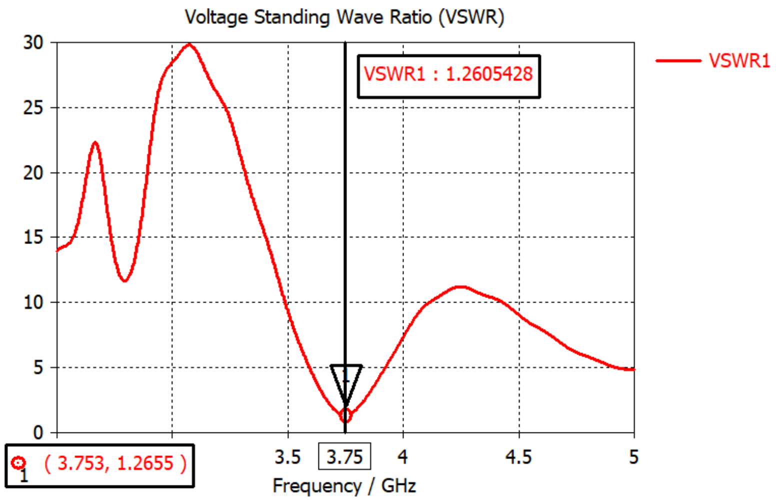


Figure 4.8: VSWR for fractal bow-tie antenna

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

This chapter summarizes and summarizes all the potential work that has been done. Potential research and proposals to further develop this initiative will also be discussed.

The parameters of the antenna such as gain, return loss, radiation pattern and VSWR are investigated in the phase. Evidence indicates that the radio waves arriving at the input of the antenna, which are ignored as a percentage of the accepted signals, are below -10dB and above 2dB, are the antenna configuration for the systems used to have strong gains and return losses. The pattern of radiation is often directed at a high gain. These characteristics of the antenna will do well in the future to make the antenna a common feature of 5G network systems.

5.2 Completed Works

For the research carried out in this thesis, two antennas designed which are bow-tie design and fractal design. This implies that the polarization of the antenna radiation is produced when the antenna is placed from the bottom of the input until the output is directed upwards. In the meantime, both antennas need to be modified and refined in order to improve the simulation value and the antenna parameters, in order to achieve this research objective, the production of 3D elliptical design antennas and the production using FR4 board at 3.75 GHz for 5G applications.

All antenna designs are designed using the CST Microwave Studio Program and can be differentiated by the output of both antennas. Numerical and parametric methods have been used in the antenna design to achieve effective optimization of the antennas by changing the dimensions of the antennas. Changes in antenna parameters can also produce the optimal configuration of single polarization bow-tie antennas.

The fractal design was preferred over the normal bow-tie design when operating at a frequency of 3.75 GHz based on better simulation performance. The tests show a high return loss and a perpendicular wave voltage ratio in the selected antenna. This is because it ensures that the transmitted signal is in an almost balanced state. This also ensures that the signals sent and received at lower frequencies are close to optimal.

This concept also achieves strong returns and direction. As a result, the fractal antenna is good when the antenna produces or receives a given or applied force, radiation emissions and maximum processed amplitude.

If the emission is higher and weaker, the identification and reflection of the antenna should be easier to conform to the 5G device setting. It seems that fractal antennas are more suitable for science. CST is therefore very simple to build and run with fractal antennas. The object of the simulation is to show that the antenna is functioning correctly and efficiently.

5.3 Recommendation for Future Works

The design of the 3D antenna can be implemented for future work using 3D printing technology as well as the design concept of the bow-tie can also be improved by means of a triangular structure in a leaf shape.

The predefined fit of the project concept simulation was achieved by all the outcome parameters. However, the design of the fractal antenna project along with two types of 3D hardware antenna design could not be completed. This is because the problem of the Covid-19 is widespread all over the world.

In addition, the study centered primarily on the goal of testing both antennas and process models using the CST software studio and implemented 3D antenna design using 3D printing and metallization technologies. Further studies should be performed to increase average antenna gain along with the antenna return loss. In addition, a shift in the material and also in the diameter of the antenna can also be seen to boost the efficiency of the antenna to suit into the application 5G network.

REFERENCES

[1] A. Z. Hood, T. Karacolak, and E. Topsakal, "A small antipodal vivaldi antenna for ultrawide-band applications," *IEEE Antennas Wirel. Propag. Lett.*, 2008.

[2] L. Ying and C. Ai-Xin, "Design and application of Vivaldi antenna array," in *ISAPE 2008 - The 8th International Symposium on Antennas, Propagation and EM Theory Proceedings*, 2008.

[3] K. Kiminami, A. Hirata, and T. Shiozawa, "Double-sided printed bow-tie antenna for UWB communications," *IEEE Antennas Wirel. Propag. Lett.*, 2004.

[4] Y. Ito, M. Ameya, M. Yamamoto, and T. Nojima, "Unidirectional UWB array antenna using leaf-shaped bowtie elements and flat reflector," *Electron. Lett.*, 2008.

[5] M. Naghshvarian-Jahromi, "Novel wideband planar fractal monopole antenna," *IEEE Trans. Antennas Propag.*, 2008.

[6] M. Karlsson and S. Gong, "An integrated spiral antenna system for UWB," in *EURAD 2005 Conference Proceedings - 2nd European Radar Conference*,

2005.

[7] J. D. Dyson, "The Equiangular Spiral Antenna," *IRE Trans. Antennas Propag.*, 1959.

[8] S. Y. Chen, P. H. Wang, and P. Hsu, "Uniplanar log-periodic slot antenna fed by a CPW for UWB applications," *IEEE Antennas Wirel. Propag. Lett.*, 2006.

[9] R. R. Pantoja, A. R. Sapienza, and F. C. Medeiros Filho, "A Microwave Printed Planar Log-Periodic Dipole Array Antenna," *IEEE Trans. Antennas Propag.*, 1987.

[10] A. Calmon, G. Pacheco, and M. Terada, "A novel reconfigurable UWB log-periodic antenna," in *IEEE Antennas and Propagation Society, AP-S International Symposium (Digest)*, 2006.

[11] N. Behdad and K. Sarabandi, "A compact antenna for ultrawide-band applications," *IEEE Trans. Antennas Propag.*, 2005.

[12] C. C. Lin, Y. C. Kan, L. C. Kuo, and H. R. Chuang, "A planar triangular monopole antenna for UWB communication," *IEEE Microw. Wirel. Components Lett.*, 2005.

[13] W. Wiesbeck, G. Adamiuk, and C. Sturm, "Basic properties and design principles of UWB antennas," *Proc. IEEE*, 2009.

[14] H. G. Schantz, "A brief history of UWB antennas," in *2003 IEEE Conference on Ultra Wideband Systems and Technologies, UWBST 2003 - Conference Proceedings*, 2003.

[15] W. H. Chin, Z. Fan, and R. Haines, "Emerging technologies and research challenges for 5G wireless networks," *IEEE Wirel. Commun.*, 2014.

[16] M. Shafi *et al.*, "5G: A tutorial overview of standards, trials, challenges, deployment, and practice," *IEEE J. Sel. Areas Commun.*, 2017.

[17] C. H. See, R. A. Abd-Alhameed, A. A. Atojoko, N. J. McEwan, and P. S. Excell, "Link Budget Maximization for a Mobile-Band Subsurface Wireless Sensor in Challenging Water Utility Environments," *IEEE Trans. Ind. Electron.*, 2018.

[18] W. Hong *et al.*, "Multibeam Antenna Technologies for 5G Wireless Communications," *IEEE Trans. Antennas Propag.*, 2017.

[19] N. O. Parchin *et al.*, "Eight-Element Dual-Polarized MIMO Slot Antenna System for 5G Smartphone Applications," *IEEE Access*, 2019.

[20] W. Hong, K. H. Baek, and S. Ko, "Millimeter-Wave 5G Antennas for Smartphones: Overview and Experimental Demonstration," *IEEE Trans. Antennas Propag.*, 2017.

[21] M. Alibakhshikenari, M. Khalily, B. S. Virdee, C. H. See, R. A. Abd-Alhameed, and E. Limiti, "Mutual coupling suppression between two closely placed microstrip patches using EM-bandgap metamaterial fractal loading," *IEEE Access*, 2019.

[22] K. H. Sayidmarie and M. E. Bialkowski, "Fractal unit cells of increased phasing range and low slopes for single-layer microstrip reflectarrays," *IET Microwaves, Antennas Propag.*, 2011.

[23] GSMA, “5G Spectrum,” *Public Policy Position*, 2016.

[24] M. Alibakhshikenari, S. M. Moghaddam, A. Uz Zaman, J. Yang, B. S. Virdee, and E. Limiti, “Wideband Sub-6 GHz Self-Grounded Bow-Tie Antenna with New Feeding Mechanism for 5G Communication Systems,” in *13th European Conference on Antennas and Propagation, EuCAP 2019*, 2019.

[25] M. K. A. Rahim, M. Z. A. Abdul Aziz, and C. S. Goh, “Bow-tie microstrip antenna design,” in *2005 13th IEEE International Conference on Networks jointly held with the 2005 7th IEEE Malaysia International Conference on Communications, Proceedings*, 2005.

[26] C. A. Balanis, *Antennas Third Edition*. 2005.

[27] C. G. Christodoulou, P. F. Wahid, C. Christodoulou, and P. Wahid, “Fundamental Parameters of Antennas,” in *Fundamentals of Antennas*, 2009.

[28] A. Kishk, “Fundamentals of Antennas,” *Antennas Base Station. Wirel. Commun.*, p. 1, 2009.