DUAL POLARIZED MEANDER LINE ANTENNA AT 3.5 GHZ FOR MOBILE TERMINAL 5G APPLICATION

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DUAL POLARIZED MEANDER LINE ANTENNA AT 3.5 GHZ FOR MOBILE TERMINAL 5G APPLICATION

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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 "Dual Polarized Meander Line Antenna at 3.5 GHz for Mobile Terminal 5G Application" is the result of my own work except for quotes as cited in the references.

Signature :

Author : Nur Syahindah Husna Binti Ramli

Date : 26 Jun 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.Imran bin Mohd Ibrahim

Date : ………26 Jun 2020………

DEDICATION

To my beloved dad and mom, Encik Ramli Jalil and Puan Faridah binti Yunus and my siblings, Muhammad Safwan Asyraf bin Ramli, Muhammad Haziq Izzuddin bin Ramli and Muhammad Hadif Fakhruddin bin Ramli. This thesis is purely of your tremendously support and sacrifice. I dedicate this to all of you. May Allah always bless every each all of you.

ABSTRACT

The fifth wireless generation (5G) is the most recent evolution of mobile technology, intended to significantly improve cellular network capacity and reaction. 5G also helps the amount of data transmitted over wireless networks to increase significantly because of more space and sophisticated antenna technologies available. The 5G application has few frequency bandwidth. The 3.4-GHz to 3.7GHz frequency band. This project will focus on the 3.5GHz 5 G application array design. Dual polarization antenna will be designed with combination of vertical and horizontal polarization for mobile terminal. In this project, Computer Simulation Technology (CST) microwave studio software will be used for simulation results. Besides, FR4 epoxy material with dielectric constant of 4.3 has been chosen for the substrate material. At the end of project, the antenna expected to develop dual polarization for point to point communication with a return loss not less than -10dB and also the illustration of antenna and phone casing. This illustration intended to show how the antenna can perform will ideal and practical condition. For develop dual polarization the antenna need to feed separately meanwhile the combined antenna will develop slanting polarization.

ABSTRAK

Generasi tanpa wayar kelima (5G) adalah evolusi terbaru teknologi mudah alih, yang bertujuan untuk meningkatkan kapasiti dan reaksi rangkaian selular dengan ketara. 5G juga membantu jumlah data yang dihantar melalui rangkaian tanpa wayar meningkat dengan ketara kerana lebih banyak ruang dan teknologi antena yang ada. Aplikasi 5G mempunyai lebar jalur frekuensi yang sedikit. Jalur frekuensi 3.4-GHz hingga 3.7GHz. Projek ini akan memberi tumpuan kepada reka bentuk antena polarisasi ganda pada 3.5 GHz untuk aplikasi 5G terminal mudah alih. Antena polarisasi ganda akan dirancang dengan kombinasi polarisasi menegak dan mendatar untuk terminal bergerak. Dalam projek ini, perisian studio gelombang mikro Teknologi Simulasi Komputer (CST) akan digunakan untuk hasil simulasi. Selain itu, bahan epoksi FR4 dengan pemalar dielektrik 4.3 telah dipilih untuk bahan substrat. Pada akhir projek, antena diharapkan dapat mengembangkan polarisasi ganda untuk komunikasi titik ke titik dengan kehilangan kembali tidak kurang dari -10dB dan juga ilustrasi antena dan selongsong telefon. Ilustrasi ini bertujuan untuk menunjukkan bagaimana antena dapat berfungsi dalam keadaan ideal dan praktikal. Untuk mengembangkan polarisasi ganda, antena perlu memberi makan secara berasingan sementara antena gabungan akan mengembangkan polarisasi miring.

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It would not have been possible to write this thesis without the help and support of kind people around me, to only some of whom it is possible to give particular mention here. Foremost, I am grateful to Allah SWT for establishing me to complete this thesis.

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Special thanks to my collegues, Akmal Bazli Bin Rahmad and Nur Zahirah Binti Khairol Bong for their help and encouragement. I also thank my parents for their unceasing moral support while completing this degree.

Last but not least, my sense gratitude to one and all who, directly and indirectly, had been associated of realization 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
MLA	:	Meander Line Antenna
USB	:	Universal Serial Bus
PCB	:	Printed Circuit Board
fr	:	Resonant Frequency
dB	:	Decibels

CHAPTER 1

INTRODUCTION

1.1 Project Background

In this age of increasing technology, people rely on mobile phones for continuous telecommunications and thus increase demand for higher network with good internet speeds. This illustrates why scientists and engineers around the world have evolved over the past few years into a full-fledged debate that captured their attention and creativity on the early interest and discussion of a potential fifth generation (5G) standard.

5G is the newest mobile technology iteration that significantly improves the wireless network's speed and responsiveness [1]. 5G also allows the transmission of data through wireless systems to increase sharply due to increased bandwidth and antenna technology.

Conception of the propagation channels [3] and measurements on a wide body channel are therefore important to establish and test the five generation communication system. Currently, Mobile 5 G systems expand their range to support high data rates. 5G frequency bands of the candidates below 6 GHz were widely debated at the WRC 2015, and 470-694, 1427-1518, 3300-3800, and 4500-4990 MHz were proposed to follow [3]. In the meantime 3.5 GHz was generally considered acceptable for most countries as shown in Figure 1.1, such as China and Korea.

Figure 1.1: 5G Ecosystem

The benefits of 5G are better mobile broadband (eMBB), ultra-reliable, latency and mass communications of a type of system. Enhanced Broadband (eMBB) for mobile phones is one of 3 collections of 5 G case implementations. The first commercial 5 G services to start, as an addition to existing 4 G broadband services, are to go far beyond allowing for speedier download. Enhanced Broadband (eMBB) is a data-based application which needs high data rates across a wide range of coverage. For example, when using connected cars, an upgrade in vehicle information playback will be involved in the first stage (eMBB), which includes enhanced car information. The second phase involves the creation of mass autonomous vehicles that can connect and communicate with other users in the vicinity.

In addition, highly stable and low latency is also one of the advantages of 5G. Meanwhile, a very great number of devices in the local region, for example the IoT, that are assisted by Massive Machine Type Communication (MMTC), are only able to send sporadically data [4]. With 5 G, consumers can reach speeds of up to 20Gbps faster and improve consumer experience in virtual and increased reality. Furthermore, 5G may also be used in intelligent manufacturing, independent monitoring, e-health and smart agriculture. It has been the 5G element that is probably the most remarkable improvement of what 4G is doing, which enables us to get newer and better interactions and something entirely new. Figure 1.2 shows the fifth generation use cases.

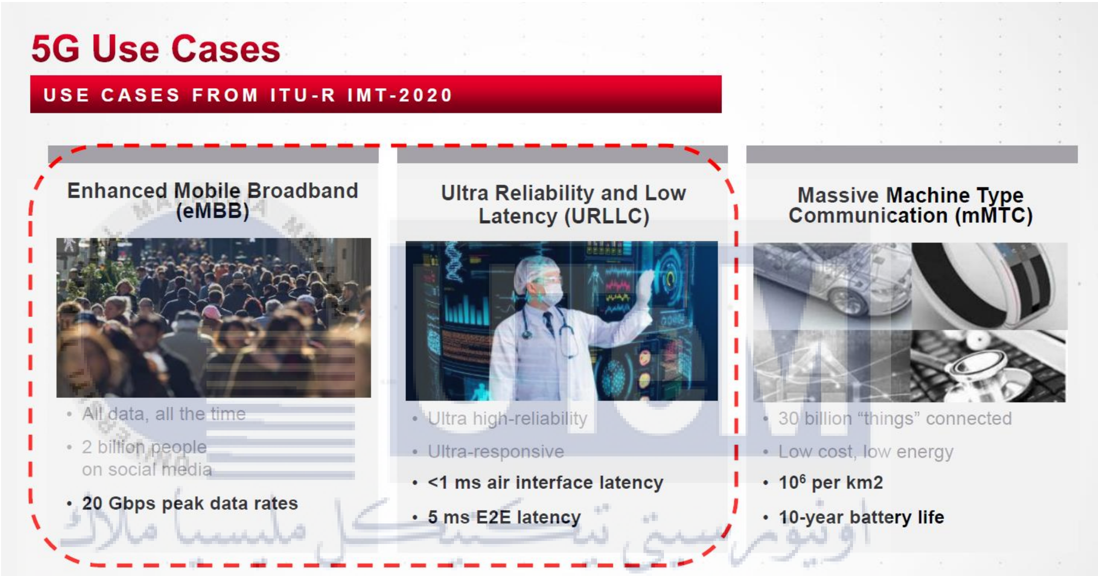


Figure 1.2: 5G Use Cases from ITU-R IMT-2020

In the modern world particularly during the last decade, wireless communication has been widely and rapidly growing. An antenna is a part of wireless communication which is a power plant that converts power into radio waves, and the opposite is true. The radio transmitter or radio receiver is typically used. Figure 1.3 shows wireless communication of antenna.

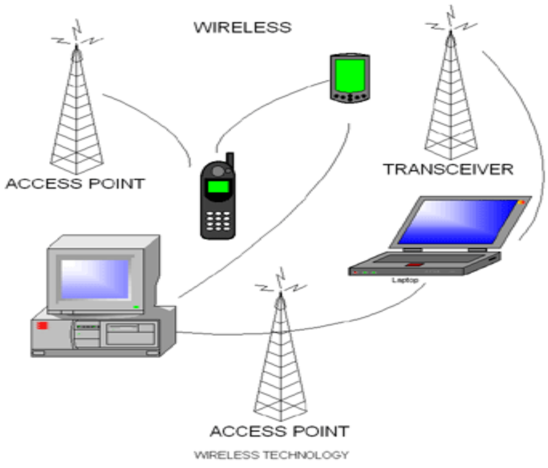


Figure 1.3: Wireless Communication Antenna

1.2 Problem Statement

Today, the rate of data is enormously higher, and smart antennas must be developed for the user due to rapid changes in wireless communication technology. The antenna protected for sub 6GHz consists of the vertical or horizontal line of one part of the meander for mobile terminals [2]. The mobile device's varying movement disrupts the antenna output or disturbs. That is because only the plane surrounds the antenna and contains less radiation.

Dual antenna polarization is therefore designed for achieving most of the radiation by combining horizontal and vertical planes. This antenna also can fit the signal for a different polarization antenna to get the better connectivity and signal coverage.

1.3 Objective

The purpose of this project is to design a dual polarization antenna for mobile terminal 5G application.

1.4 Antenna Design Specification

Referring to the literature review in chapter 2, the specification references Table 1.1 are obtained. The specification will the main references that must be followed to develop the prototype of the antenna.

Table 1: Antenna Parameter

Parameter	Value
Operating frequency	3.5 GHz
Substrate dielectric constant	4.3

1.5 Scope of Project

The research starts with a literature review to validate the clearly-understood outline of this research. It focuses to meet the desired performance on 3.5GHz on 5 G applications with a dual polarization antenna.

The work focuses on the double antenna polarized. The return loss, antenna gain, direction and radiation pattern should be investigated. This shows that before an antenna was built and created, literature review is an important aspect.

For the design and simulation part the CST software will be used. The antenna design is more reliable with the use of CST software because of the variety of devices, forms and etc. This software is available. The frequency or core frequency of 3.5 GHz and the bandwidth spectrum that has to be configured depends on the frequency used, which is between 2 GHz and 5 GHz, when you start the construction of an antenna. The optimization of antenna is to determine the best antenna in different designs. The antenna will design with various design to analyse the best antenna.

1.6 Project Planning

The project starts with a literature review report, which relates to the chosen project title. The investigation concerns a dual polarization meander line antenna. From the previous research the design parameter and specification are obtained. The antenna is then designed and built using CST 2017 software with various designs.

The analyses of different antennas' designs are last but not least compared. The thesis report must include all the simulation tests.

1.7 Organization Report

There are five (5) chapters in this project and the outline as the following:

Chapter 1 provides of the introduction part which acquires the background to the project, the problem statement of project and objective of project and its scope.

Chapter 2 provides background study of the projects discussed about the particular title of the project that was completed by the past researchers which is identified to this title of project.

Chapter 3 provides of methodology part that discusses on how flow of project, the design and simulate the designed antenna that using Computer Simulation Technology Microwave Studio of various design

Chapter 4 provides of the results and discussion that achieved based on the objectives of this project. The simulated results are expressed in parameters gain, directivity, return loss and radiation pattern for proposed antenna.

Chapter 5 provides of explanation regarding to conclusion based on the completed work and also future work recommendation.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

This chapter describes researches related to the project dual polarized for mobile terminal. The project is accomplished by analyzing the literature and linking to other projects. Information are given to the very important researchers.

2.2 Antenna Parameter

It is essential to describe antenna definition with different parameters. The proposed antenna should follow the characteristics of antenna to the certain requirements that might directivity, gain, return loss and radiation pattern.

2.2.1 Directivity and Gain

Directivity definite proportion of the normalized output at main beam strength to average antenna power density when three dimensional models of the antenna are calculated [18].

The directivity of antenna:

$$D = \frac{P_{max}}{P_{av}} \quad (2.1)$$

Antenna gain is maximum radiation intensity ratio at the main stream top with the same direction that can be produced by an isotropic radiator with the same input power. Unity gains are considered for isotropic antennas.

The relation between directivity and gain can be given as:

$$G = \eta D \quad (2.2)$$

η = Antenna efficiency

2.2.2 Radiation Pattern

The radiation pattern defined in three-dimensional antenna radiation as a function of direction as a graphical representation. The radiation intensity of the antenna is produced by a power track radiated from a solid angle unit antenna. If the antenna radiates the total energy is P, then r is the force distributed over a radius sphere and s, the energy density in every direction at that point.

Isotropic antennas can be used to compare the efficiency of functional antennas, but in reality the antennas cannot be implemented. The information provided by the radiation is largely the length of the beam antenna, the side lobes and the antenna resolution.

2.2.3 Return Loss

Return loss means signal power is reflected by inserting a device into an optical or transmitting line. The dB ratio to the signal power can be expressed [5]. The return loss is defined as:

$$RL(db) = 10\log\frac{Pr}{Pi} \quad (2.3)$$

Pi = power supplied by the source

Pr = power reflected

Then, return loss can also be expressed as :

$$Rl = -20log|r| \tag{2.4}$$

The accepted return loss should be less than -10db, so the antenna will radiate effectively.

2.3 Antenna Design

2.3.1 Patch Antenna Design

Nayla Ferdous et al., (2019) designed a low profile patch antenna for 5G application. The frequency for the operating is 3.5 GHz that used substrate of FR4 with dielectric constant 4.3 [6]. The simulation result that has been done by CST software. Figure 2.1 shows the proposed designed.

Figure 2.1: The Proposed Microstrip Patch Antenna [6]

Return loss that achieved is -30dB at 3.5 GHz. This indicates a small return loss of 3.5 GHz in the antenna and will transmit a good amount of the signal. The antenna gain is 5.01 dB and 96.67 percent of efficiency. Figure 2.2 shows the return loss of designed antenna. Figure 2.3 shows the radiation pattern in 3D form.

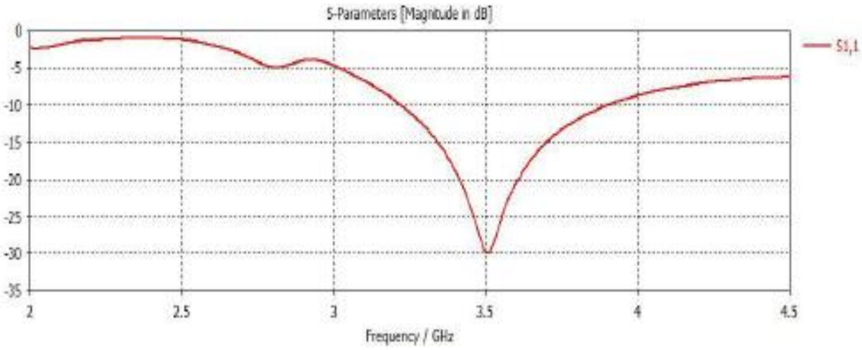


Figure 2.2: The Return Loss of The Designed Antenna [6]

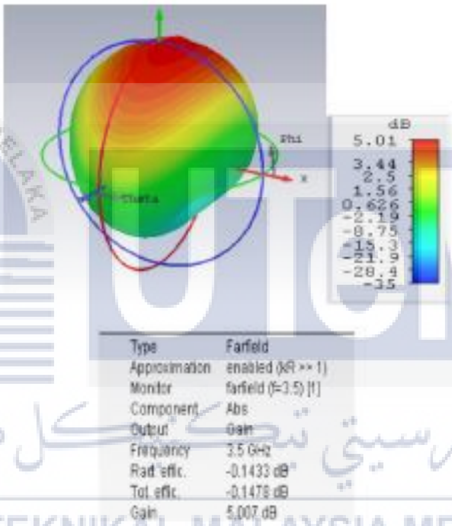


Figure 2.3: Radiation Pattern in 3D Form [6]

2.3.2 Microstrip Patch Antenna

Ashish Kumar et al., (2018) were proposed microstrip antenna design on with frequency of 3.55 GHz. The simulation designed by using ADS software that is WiMax suitable. This design is used FR4 with permittivity of 4.6 mm [7]. Figure 2.4 shows the layout with inset feed.

Figure 2.4: The Layout with Inset Feed [7]

The return loss achieved is -19dB. Meanwhile, the gain of antenna is 5 dB and directivity is 7dB. Antenna gain is also known as power gain. The designed is matched in efficiency and directionality. It shows that the antenna can spread the energy effectively in a specific direction to the space of transmission antenna.

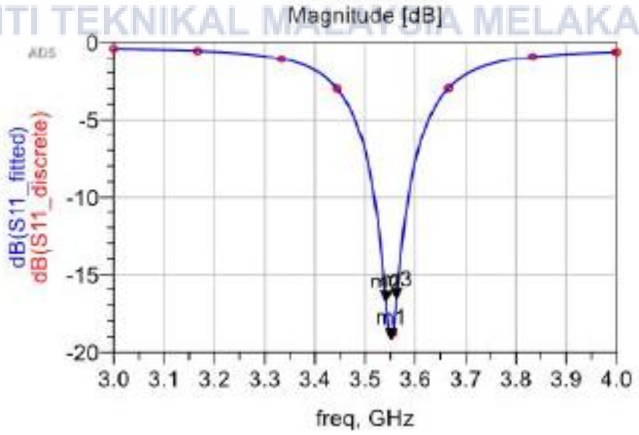


Figure 2.5: The Return Loss of the Designed Antenna [7]

2.4 Meander Line Antenna (MLA)

Microstrip antennas are now popular because they are low profile, cheap and easy to make by photolithographing. Antenna is a metallic radiation or radio wave reception device. While the design of an antenna with a microstrip can be traced few years back [8], MLA is type of microstrip which an electrically low antenna. The antenna on a meander line is a slow wave circuit consisting of a uniform space and interconnection, vertical and horizontal lines. In applications with less space or compact size, MLA is widely used.

V.B. Ambhore et al., (2012) were proposed single element meander line antenna to operate on 2.44 to 2.68 GHz with 240 MHz for USB and wireless application. For meander line and ground the substrate used is FR4. The antenna is eight times over shown in Figure 2.6.

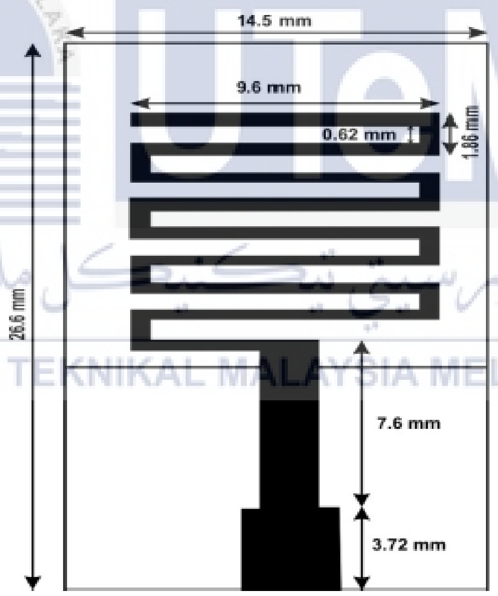


Figure 2.6: The Proposed MLA Antenna Structure [8]

The parameters are configured to reach gain and unidirectional radiation pattern shown in Figure 2.7. Return loss achieved is -39.1dB at 2.5 GHz. The impedance bandwidth measured for this band at a level of -10 dB is 240 MHz.

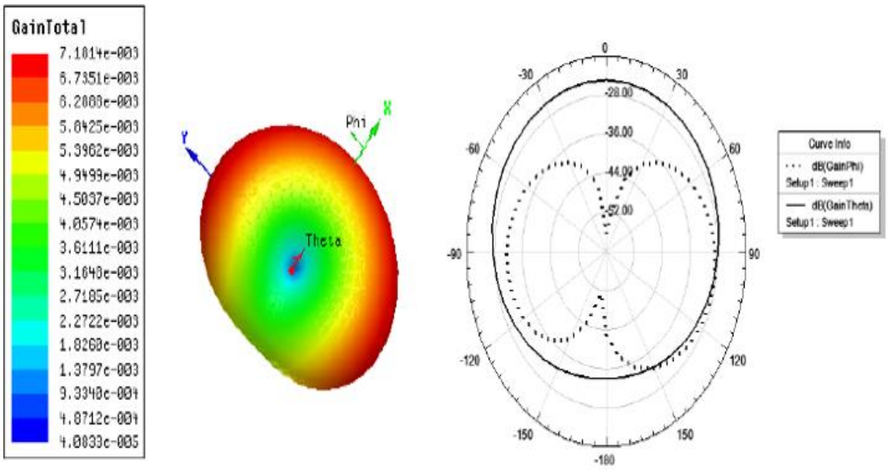


Figure 2.7: Radiation Pattern of Proposed Antenna [8]

Prakash S. Andhare and Abbhilasha Mishra were designed an electrically small antenna (ESA). They used the same concept of V.B. Ambhore et al., (2012). The proposed antenna is built for USB application which work at 2.4 to 2.7 GHz. The single antenna had measured the centre frequency which is 2.52 GHz and return loss -39.17 dB is gained. The Figure 2.8 below shown the designed antenna that has been fabricated.

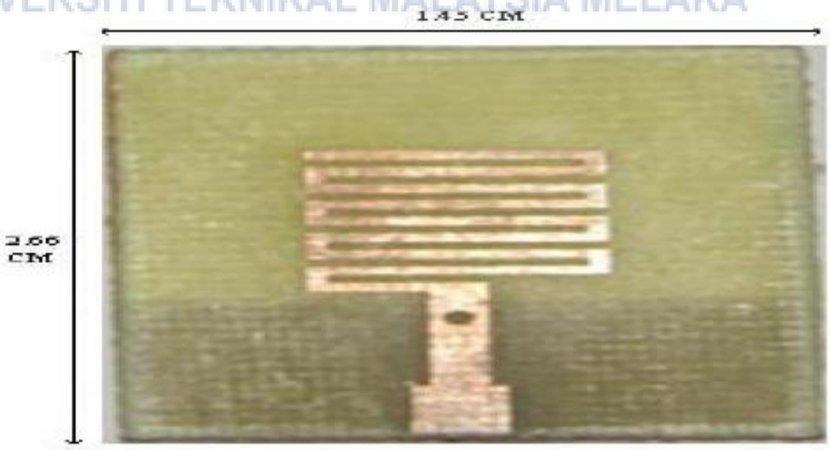


Figure 2.8: Fabricated Antenna on FR-4 Substrate [9]

Bedir Yousif et al., (2015) were proposed meander line antenna for a wireless local area network application using defected ground structure. The proposed antenna from front and back view presented in Figure 2.9. The enactment of the proposed design obtained efficiency that reached to 82% and bandwidth of 57MHz. Misman, D et al., (2008) designed planar meander line antenna to operate at 2.4 GHz for WLAN application. The antenna is simulated using computer simulation technology software and using an etching technique for fabricating process of FR-4 as shown in Figure 2.10. The number of turns for this design is N=5. The return loss obtained is -19.66dB and gain of 4dB.

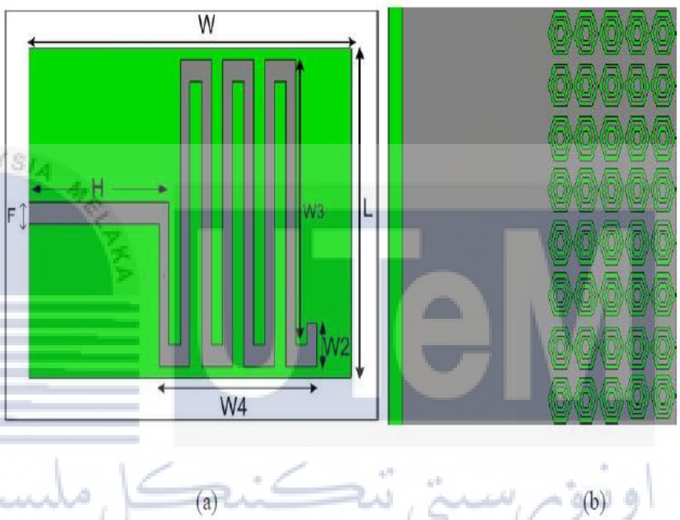


Figure 2.9: The Proposed Antenna. (a) Front. (b) Back [10]

From this proposed design, the frequency is at 2.4GHz and produced return losses -38 dB at <-10dB and good gain enhancement of 3.38 dB. The antenna formed the omnidirectional radiation pattern. Figure 2.10 shows the 3D radiation pattern.

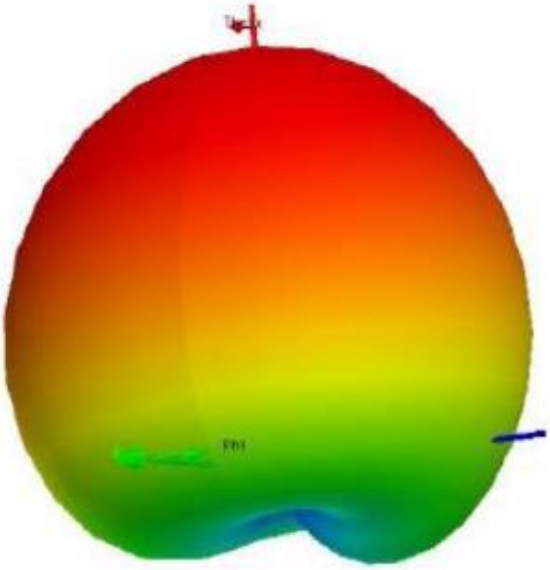


Figure 2.10: 3D Radiation Pattern [10]

Figure 2.11: The Proposed of Meander Line Antenna Structure [11]

Elaiyabharathi. N et al., (2019) were designed the Meander line antenna (MLA) that operates on 3.4 GHz. FR4 substrate was used in designing of this project. Figure 2.11 the designed MLA antenna structure.

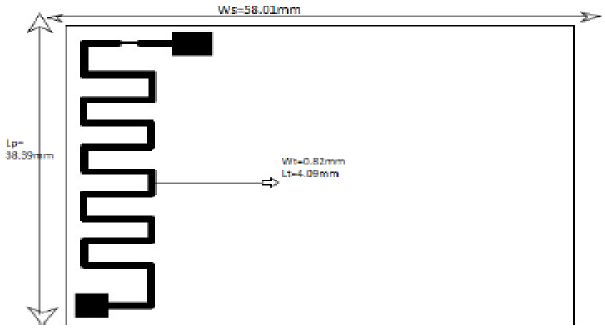


Figure 2.12: The Proposed MLA Antenna Structure [12]

From simulated results, return loss obtained is -18dB, gain of 2.5 dB, and VSWR is 2.13823 at 2.4 GHz. Figure 2.12 shows radiation pattern in 3D forms.

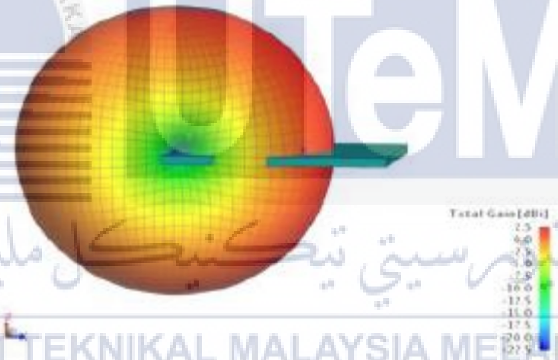


Figure 2.13: Radiation Pattern in 3D of the Antenna [12]

D. Misman et al., (2011) had designed dual beam meander line antenna. Figure 2.13 proposed designed structure for dual beam planar meander line antenna. FR-4 was used for the fabricating. This antenna can operated for WLAN application at 2.4GHz and range of frequencies of 2.47GHz to 2.52GHz. The bandwidth of the simulation results is 50MHz. The antenna is resonated at 2.395 GHz with -36.43dB of the return loss. Figure 2.14 shows structure of dual beam planar MLA and Figure 2.15 shows result of parameters that has been simulated.

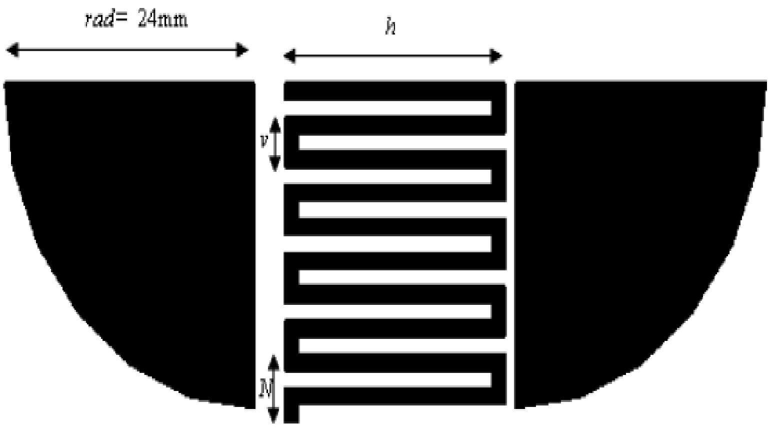


Figure 2.14: Structure for Dual Beam Planar Meander Line Antenna [13]

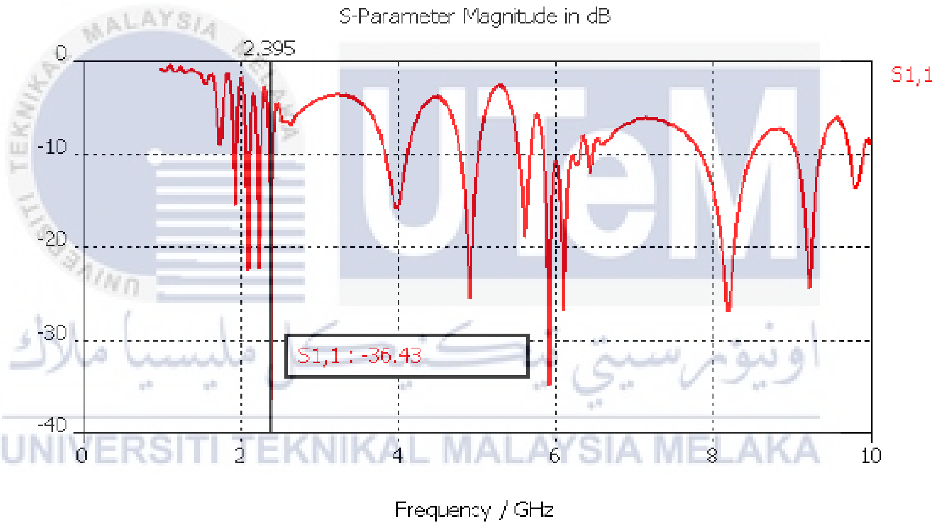


Figure 2.15: Simulation Results for Dual Beam Planar Antenna [13]

Gupta, A. K et al., (2015) proposed dual meander slot antenna for frequencies of 2.4 GHz and 3.5 GHz. This simulation of antenna shown in Figure 2.15. The return loss produced of frequency 2.4 GHz is -25.78 dB meanwhile -16.87 dB of return loss for 3.5 GHz.

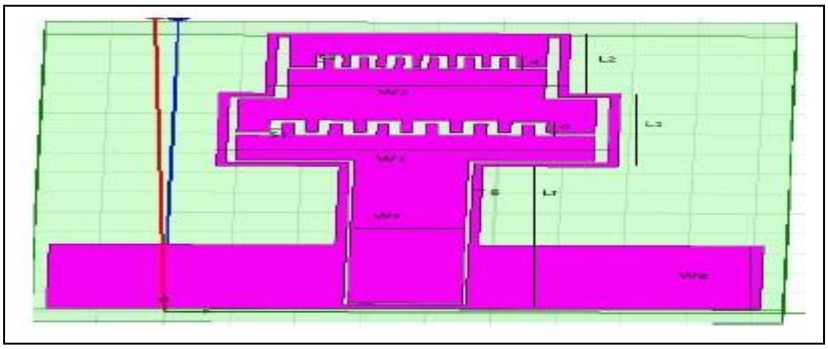


Figure 2.16: Dual Band Antenna Design using HFSS [14]

Ashish Pandey et al., (2016) were designed meander line antenna with multi band polarized. The design layout of the antenna from top view shown in Figure 2.16 (a). This research has fabricated on FR-4 substrate as shown in Figure 2.16 (b). This design covers 2.3 GHz, 2.5 GHz, 4.5 GHz and 5.8 GHz bands and the E Plane with H Plane shown below in Figure 2.18. Using microstrip transmission line feed and capacitive probe feed, dual feeding was provided.

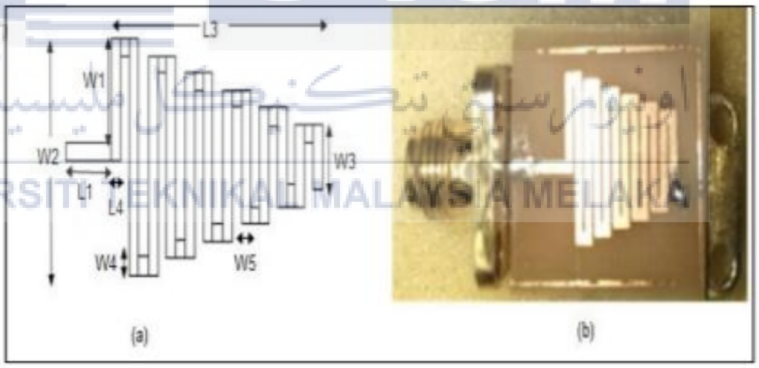


Figure 2.17: Configuration and Geometry of the Antenna (a) Top View (b) Fabricated Antenna [15]

The radiation pattern is in omnidirectional. Gain that has attained for 5.7 GHz is 5.56dBi. And return loss is -35dB. Figure 2.18 shows the radiation pattern for different frequency.

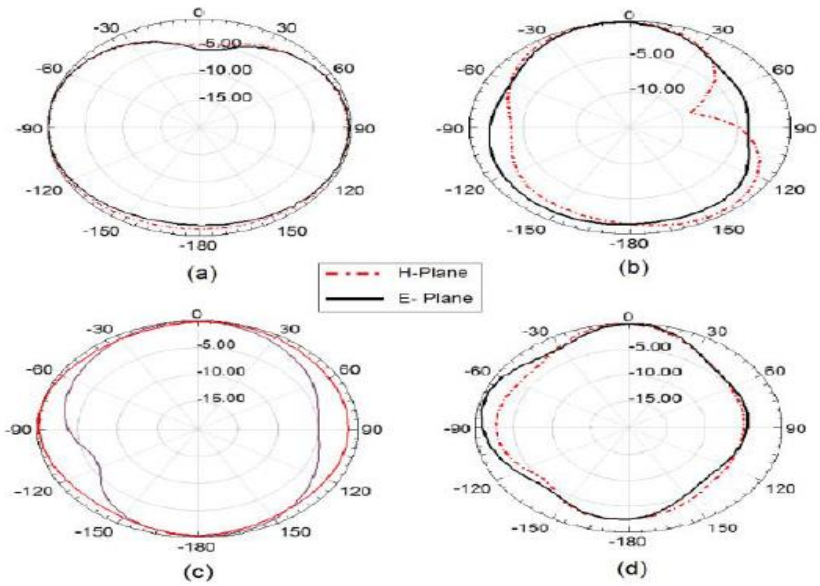


Figure 2.18: Radiation Pattern of Antenna (a) 1.6 GHz (b) 2.9 GHz (c) 4.5 GHz (d) 5.7 GHz [15]

MinJie et al, (2010) were designed and evaluate the geometry of one and two standard meander line antenna. There had three different types of antenna design. All three design is simulate with permittivity of 4.4. Table 2.1 shows return loss and antennas gain for different design.

Table 2: The Performance Parameter Antenna [17]

Design	Bandwidth	Return Loss	Gain
Board 1	39 MHz	-20.36	1.05
Board 2	30 MHz	-24.67	-1.27
Board 3	5 MHz	-34.8	-1.06

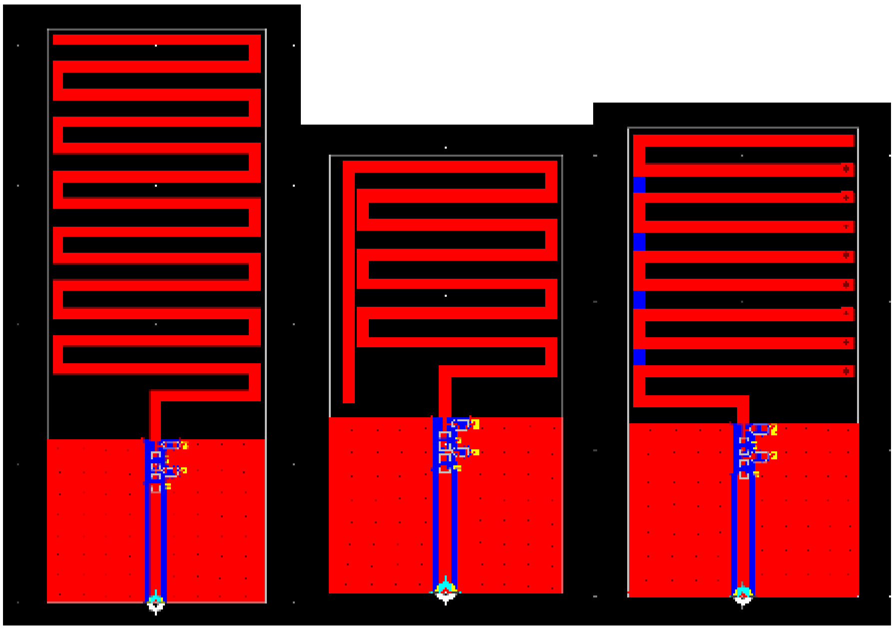


Figure 2.19: The Structure Design of the Antenna [17]

Tareq A. Najm et al, (2018) were designed a triple-band meander line with two rectangular shapes planar monopole antenna. This antenna design for frequency of 1.55 GHz, 3.5 GHz, 5.2 GHz, 5.5 GHz and 5.8 GHz. It shows that the directivity of simulated results are 1.55 GHz is 2.9 dB, 3.5 GHz is 3.6 dB and 5.2 GHz is 5.1 GHz. Figure 2.20 shows designed of antenna. And Figure 2.21 show s radiation pattern in 3D forms. The antennas develop slanting polarization

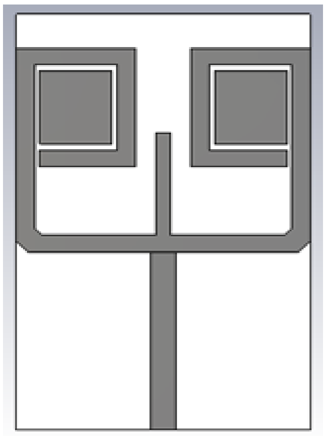


Figure 2.20: The Proposed Antenna of A Triple-Band Meander Line With Two Rectangular Shapes Planar Monopole Antenna

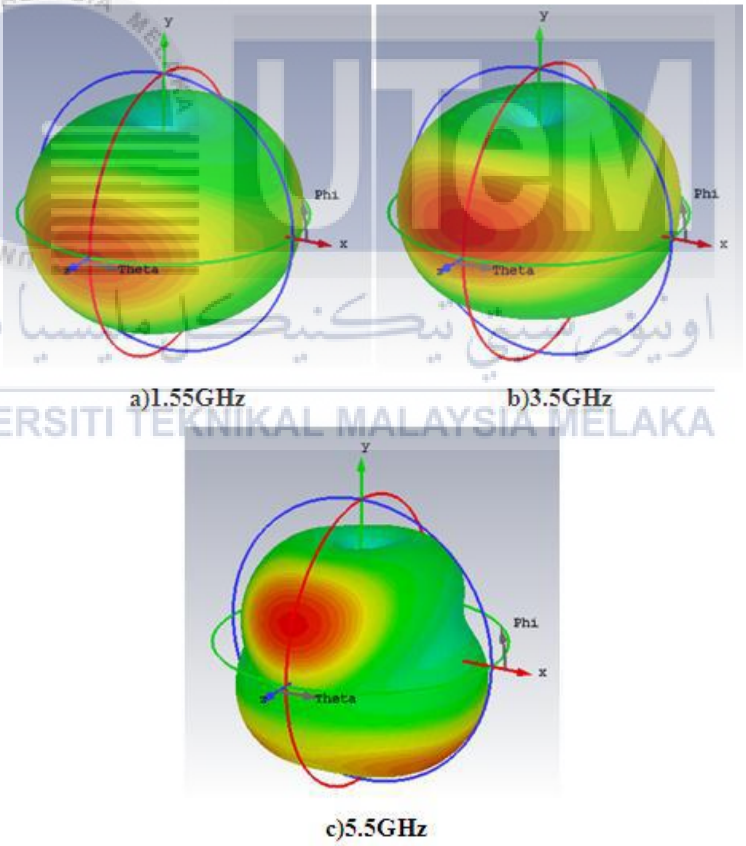


Figure 2.21: The 3D Radiation Pattern of The Proposed Antenna [18]

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, method is discussed on how antenna develop of Meander Line Antenna at 3.5 GHz. During the antenna development process, this project requires the theoretical concept and experimental approach. Figure 3.1 shows methodology chart explained throughout this chapter.

Methods used to complete this project are through journal studies, internet, books, and other related sources. The related journals and article to Meander Line Antenna such as the method that needed to use as a basic design and calculations of parameters. This journal obtained to help understand of the project related.

The simulation results is done by using (CST). This simulation is to simulate all the parameters that needed such as return loss, gain and radiation pattern. Antenna was designed with various design such as vertical plane of meander line, horizontal plane of antenna and also combine antenna of both plane. The antenna was also illustrate with the phone casing to show how antenna can perform well in ideal and practical condition. The simulated results analyzed and be compared.

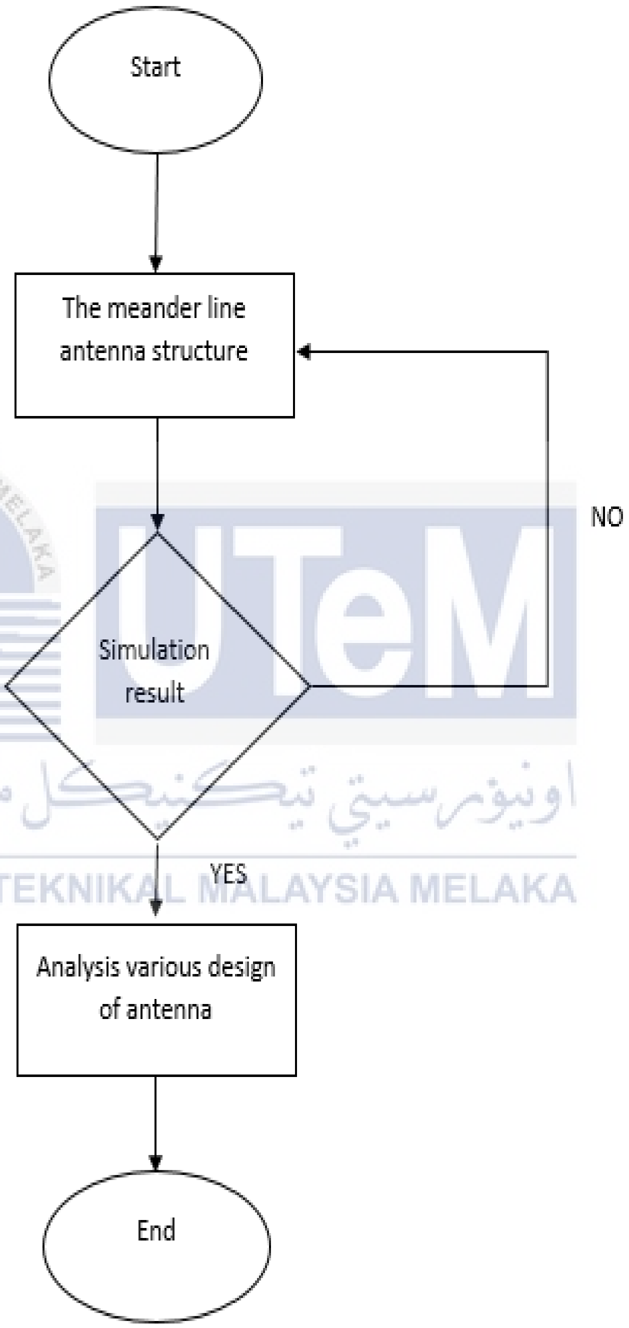


Figure 3.1: Methodology Flow Chart

3.2 Literature Review

Recent invention of meander line antenna and its implementation was described in the background study. The method to build meander line antenna, leading to the extent of the research, should be followed. The design criteria for this project was defined by the former researcher as a guide to design.

3.3 Design of Single Meander Line Design Layout

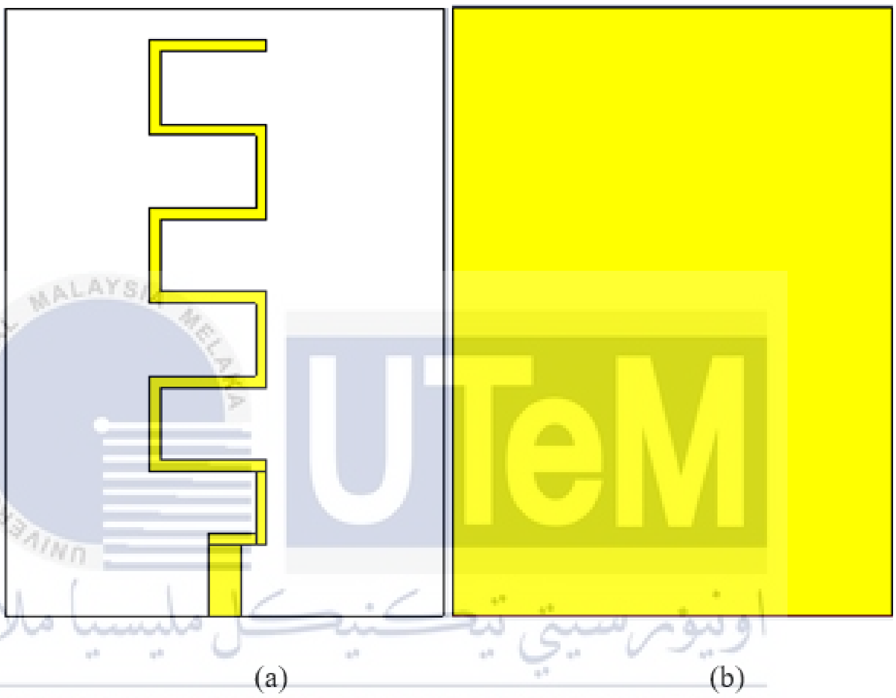


Figure 3.2: Antenna Structure: (a) Front View (b) Back View

Computer simulation software software is used for the simulation, it produced design consisting of vertical and horizontal lines that consist of uniform space and interconnection. The position of feeder is at centre bottom of the substrate. Table 3.1 show specification of simulated design.

Table 3: The Specification of Simulated Antenna

Parameter	Value
Operating frequency	3.5 GHz
Substrate dielectric constant	4.3
Cavity of thickness	1.6mm
No. of turn	6
Thickness of radiating surface (surface)	0.035 mm
Height substrate	50 mm
Width substrate	50 mm
Width length, La	2 mm
Vertical length, Lb	15.2 mm
Horizontal length, Lc	21.4 mm
Height of feeder, H	15 mm

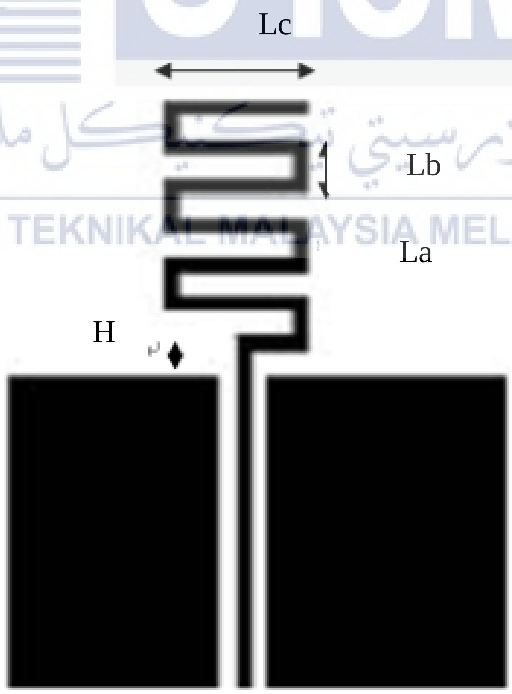


Figure 3.3: Shape of Meander Line Antenna (MLA) [17]

On the surface of radiating antenna had been drawn shape of Meander Line Antenna (MLA) has been shown on the Figure 3.3. To determine the value of La, Lb, Lc, there actually have their own calculation equation. Where the equation can be determined as below:

$$\lambda_o = \frac{c}{fc} \tag{3.1}$$

$$\lambda_o = \frac{3 \times 10^8 \, m/s}{3.5 \, GHz}$$

$$\lambda_o = 85.70 \, mm$$

Hence, to get the reading of the antenna structure depend on the frequency desired, the equation as below is required:

$$L_c = \frac{\lambda_O}{4} = 20.02 \text{ mm} \tag{3.2}$$

$$Lb = \frac{\lambda_O}{5} = 16.00 \, mm \tag{3.3}$$

Moreover, the antenna structure is design on the CST software with diameters of La is 2 mm, Lb is 15.2 mm Lc is 21.4 mm and height of feeder is 15 mm from center of substrate to get the best simulation result.

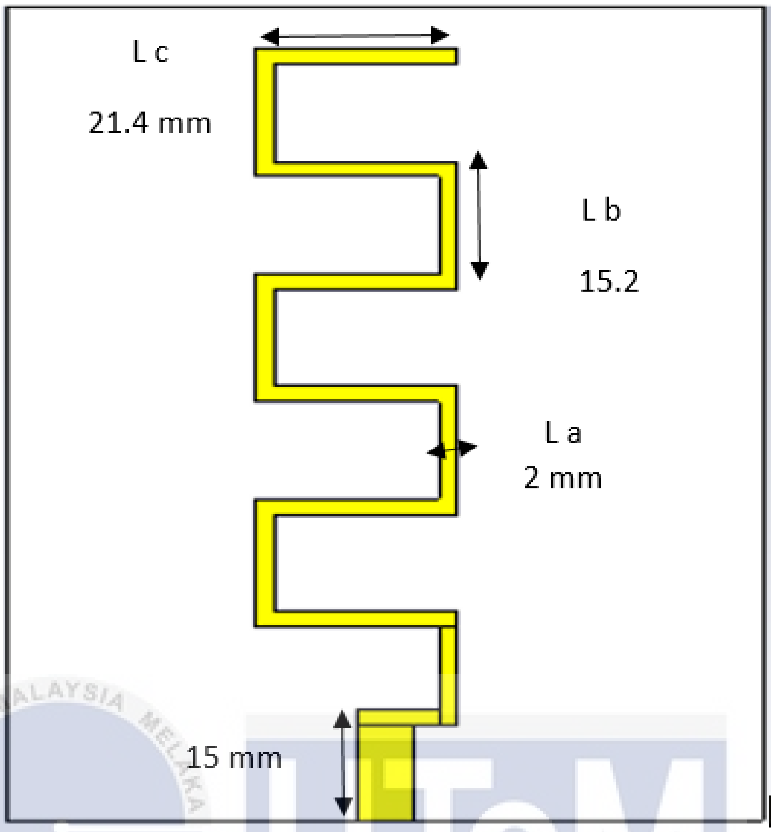


Figure 3.4: The Antenna Structure

3.4 Results of Single Meander Line Antenna

3.4.1 Introduction

This chapter presents preliminary outcome captured from. The structure of design simulated by CST. Simulation of return loss, S_{11} Parameter and radiation pattern of antenna were gained.

3.4.2 Simulation of Return Loss, S11 Parameter

Return loss reflects a loss in power of signal that reflects a device's insertion in a transmission line. The return loss is a diagram which shows how much radio wave arrives at the antenna input that is rejected relative to the accepted ones. It is defined in decibels (dB) in relation to a 100% short-circuit or refusal.

The graph below on Figure 4.1 mentions the S_{11} waveform, which define the return loss. Return loss at 3.5 GHz is below -45dB. This shows this design has operates very low return loss at 3.5 GHz. This means a large amount of the signal is transmitted by the antenna.

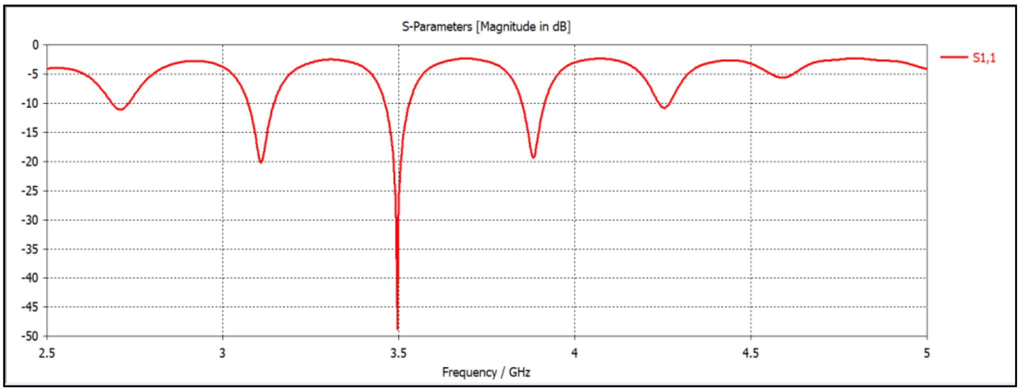


Figure 3.5: The Simulation of Return Loss of Antenna

3.4.3 Simulation of Radiation Pattern

This simulation display the main lobe is bigger than the side lobes and back lobes. It means, the main lobe has more power than other directions. The smaller the lobe, the greater the radiation intensity. The parameter value for radiation pattern were shown in Figure 4.2, 4.3 and 4.4. Figure 4.2 shows the farfield directivity when Phi=90 or E-Field. Meanwhile, Figure 4.3 shows the farfield radiation when Phi=0 or H-Field. And antenna gain shown below in Figure 4.4.

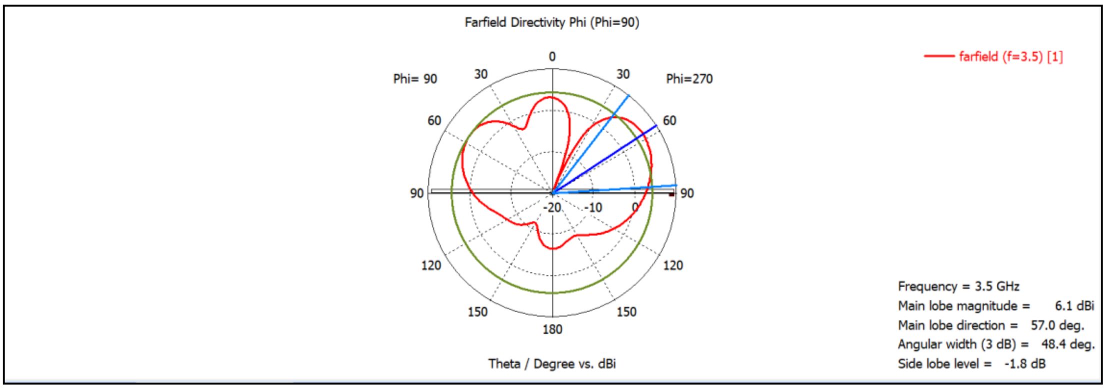


Figure 3.6: E-Field or Farfield Directivity (Phi=90)

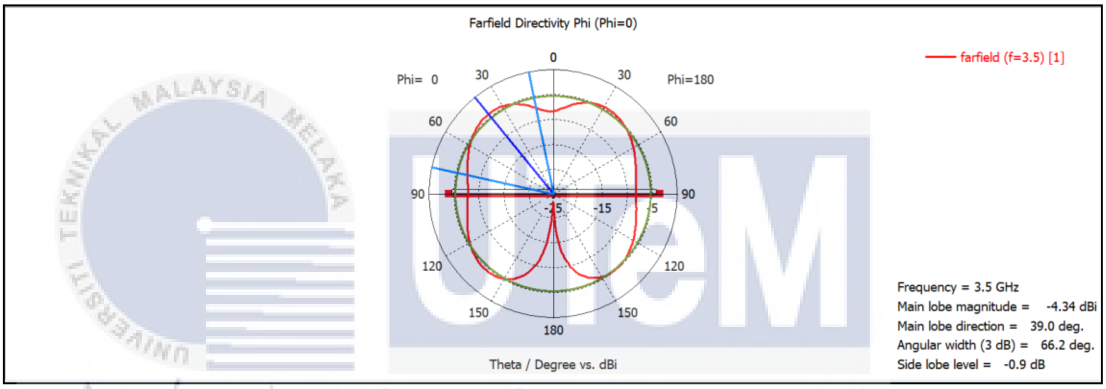


Figure 3.7: H-Field or Farfield Directivity (Phi=0)

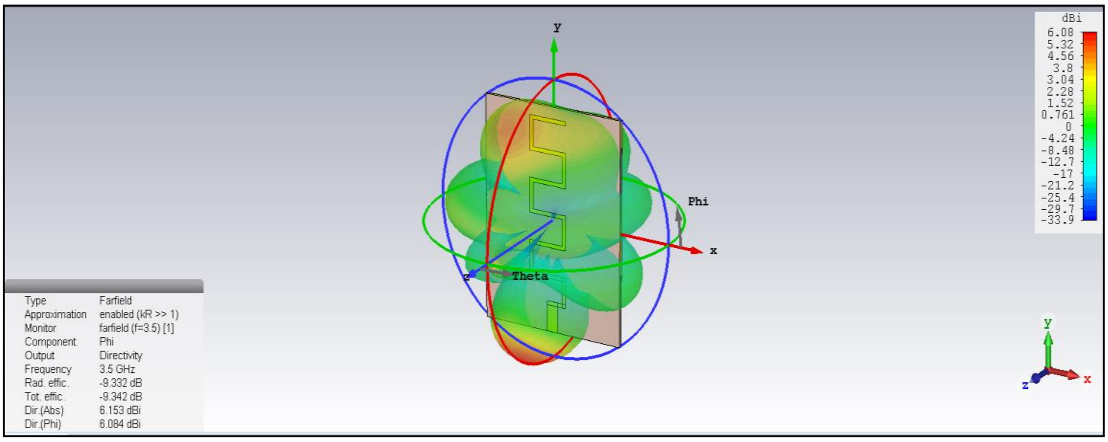
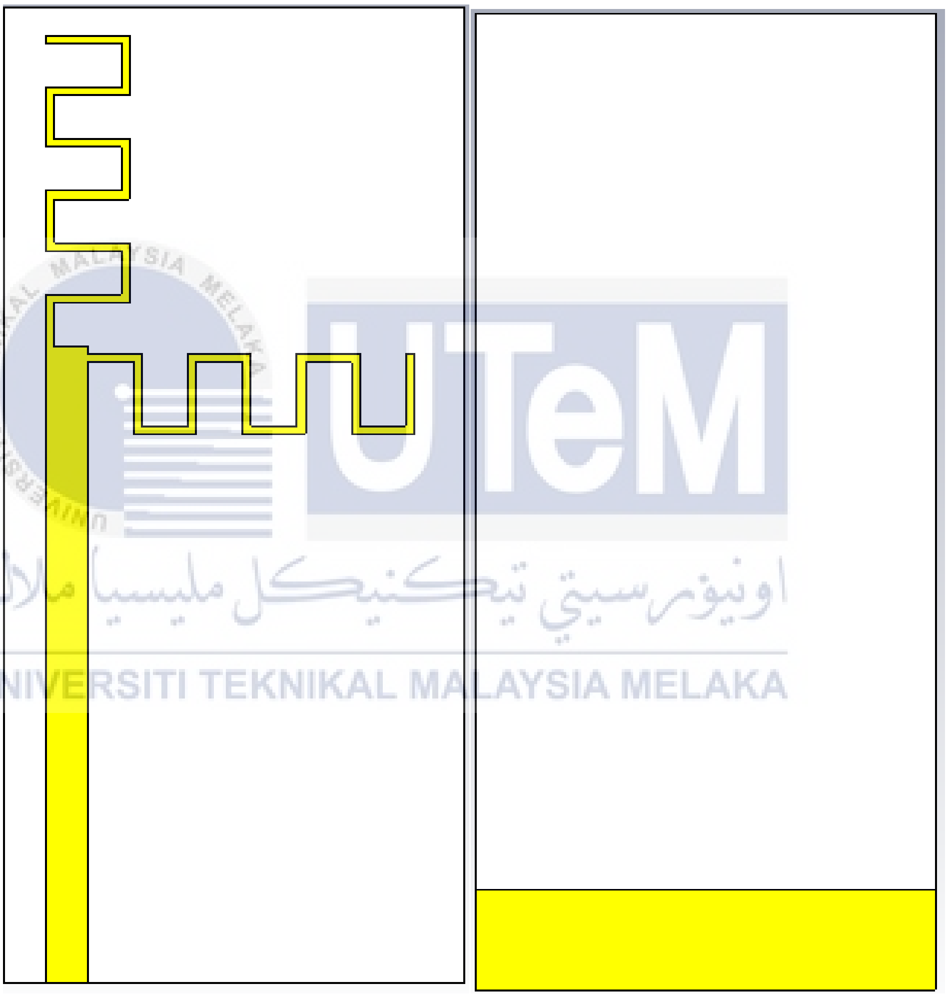


Figure 3.8: Gain of the Antenna

3.5 Design of Proposed Dual Polarized Meander Line Antenna

The antenna model designed with the CST software. The Meander Line antenna has been developed on the FR-4 board. During the simulation phase there are optimization and the place of the feeder to be rethought. The design was simulated with CST to achieve performance parameters. These are three designs of antenna for double polarization meander.

3.5.1 Prototype of Design 1 Layout



(a) (b)

Figure 3.9: Design 1 Antenna Structure: (a) Front View (b) Back View

From simulation result, it was produced Design 1 consisting of dual polarization of meander line antenna. The position of feeder is at side of substrate. Figure 3.10 show dimension of antenna structure of Design 1.

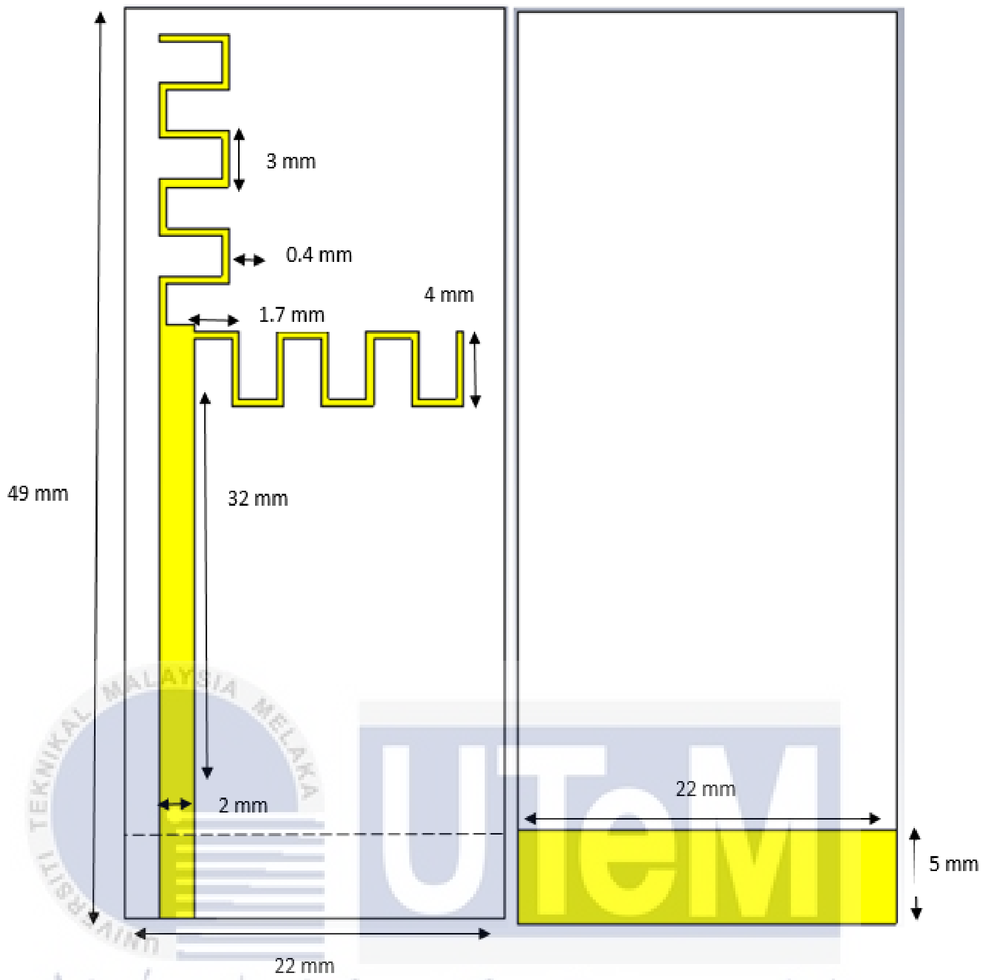
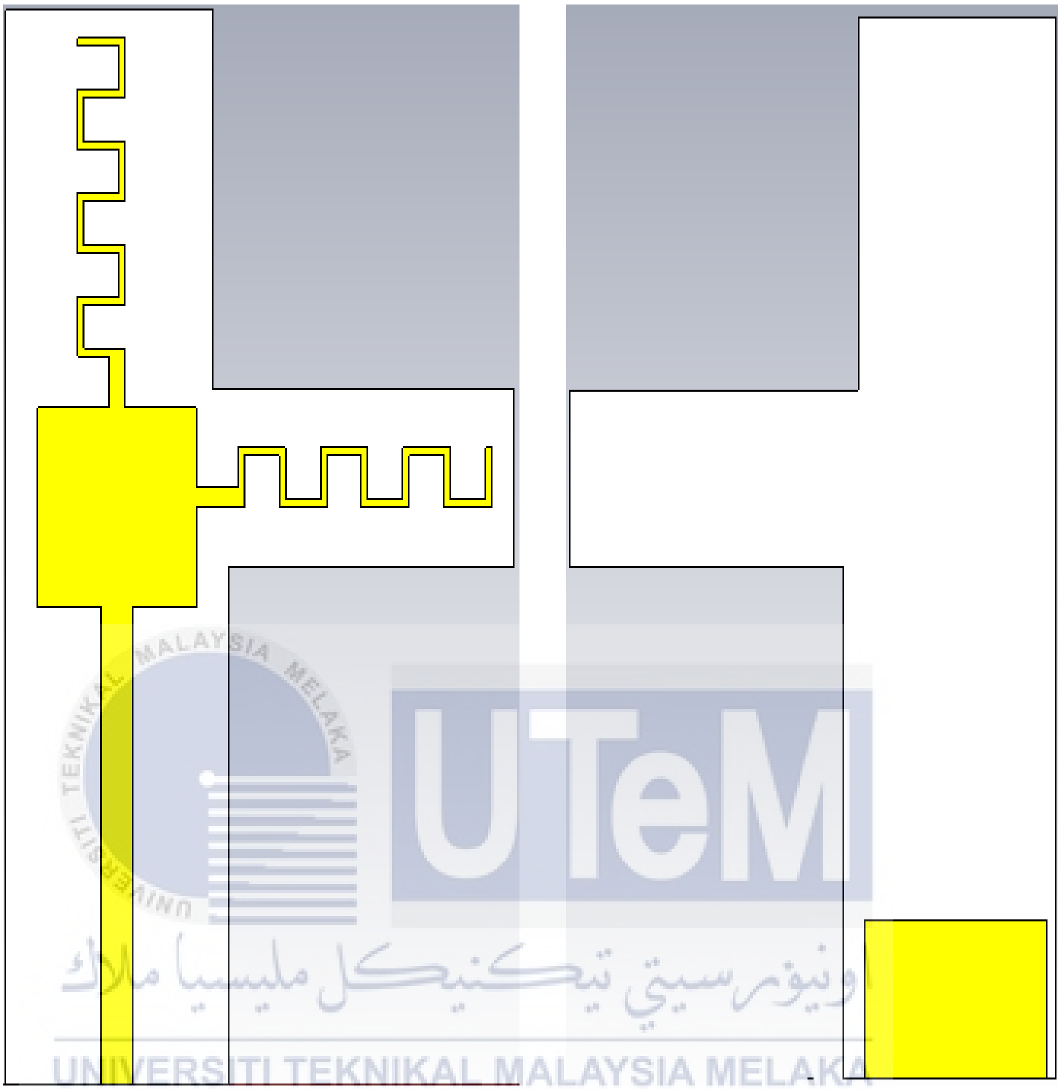


Figure 3.10: Dimension of antenna

3.5.2 Prototype of Design 2 Layout



(a) (b)

Figure 3.11: Antenna Structure of Design 2: (a) Front View (b) Back View

From the simulation result, it was produced Design 2 consisting of dual polarization of meander line antenna which the substrate shape followed the antenna designed. Figure 3.12 shows the dimension of antenna structure of Design 2.

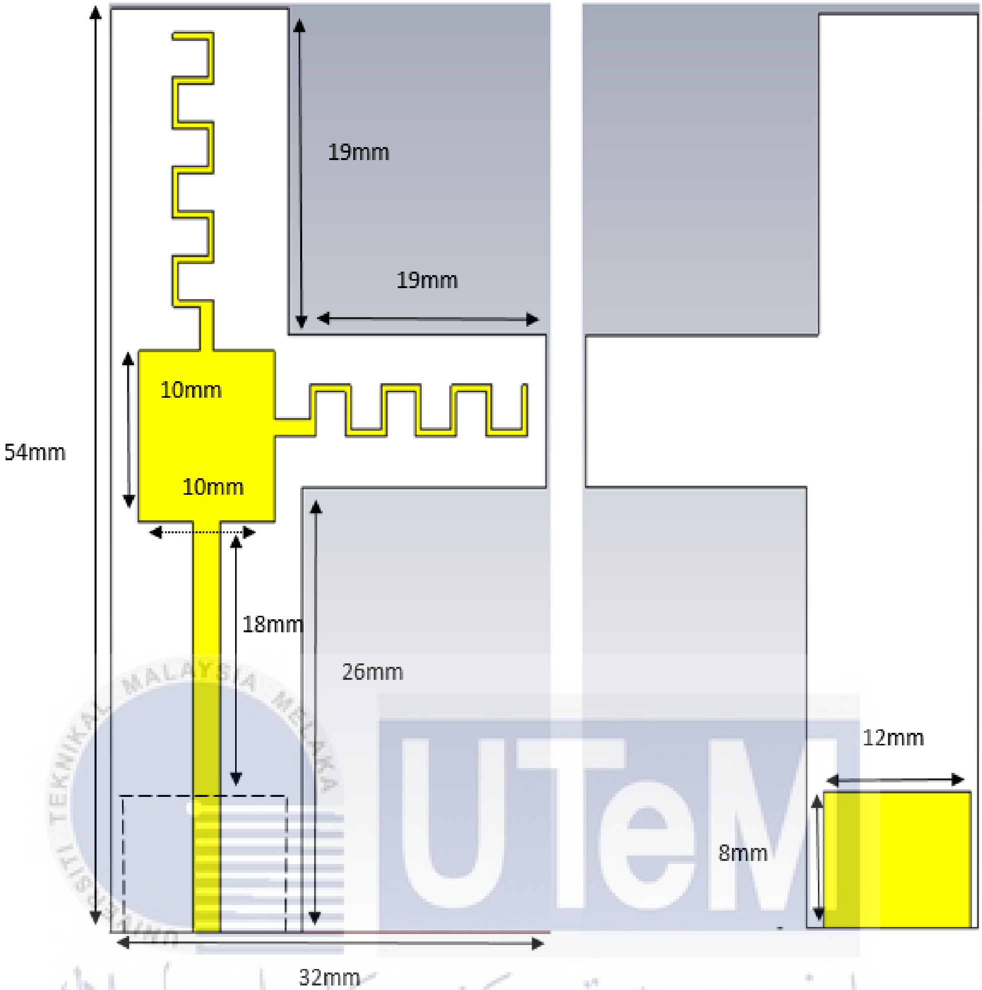


Figure 3.12: Dimension of Antenna Structure of Design 2

3.5.3 Prototype of Design 3 Layout

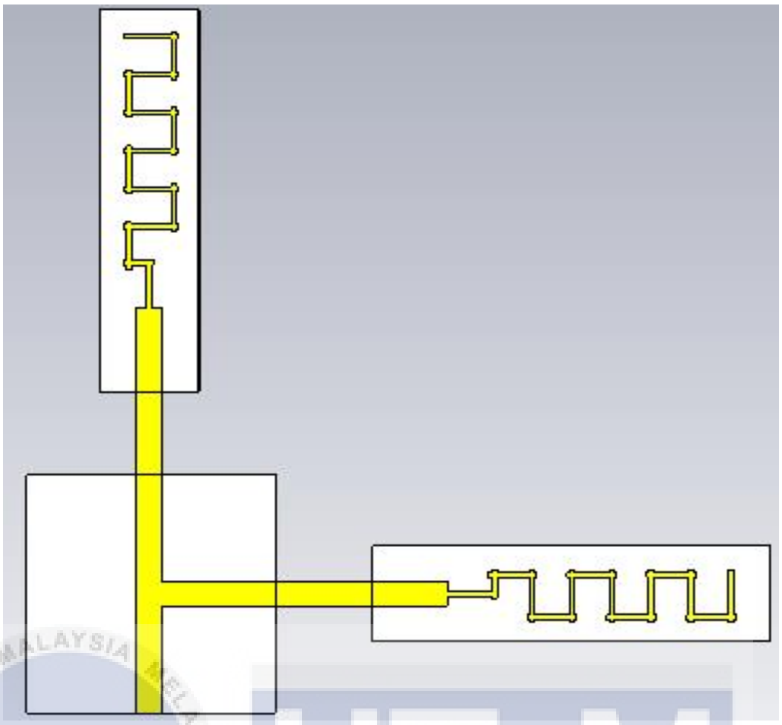


Figure 3.13: Antenna Structure of Design 3 (Front view)

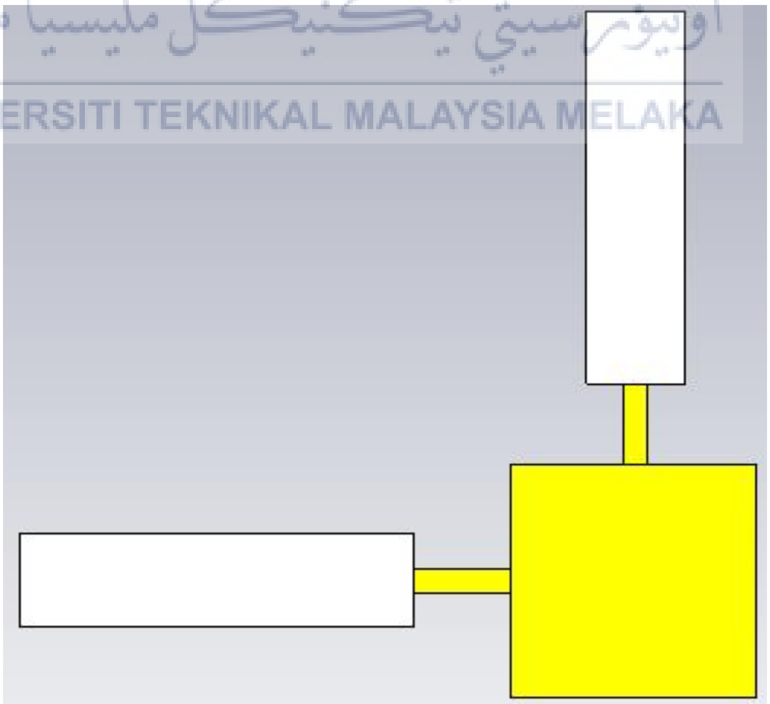


Figure 3.14: Antenna Structure of Design 3 (Back view)

From the simulation result, it was produced Design 3 consisting of dual antenna of meander line antenna with same substrate. The antenna is combined of vertical and horizontal of antenna. The feeder of substrate connected to the both antenna. Figure 3.15 shows dimension of structure of Design 3.

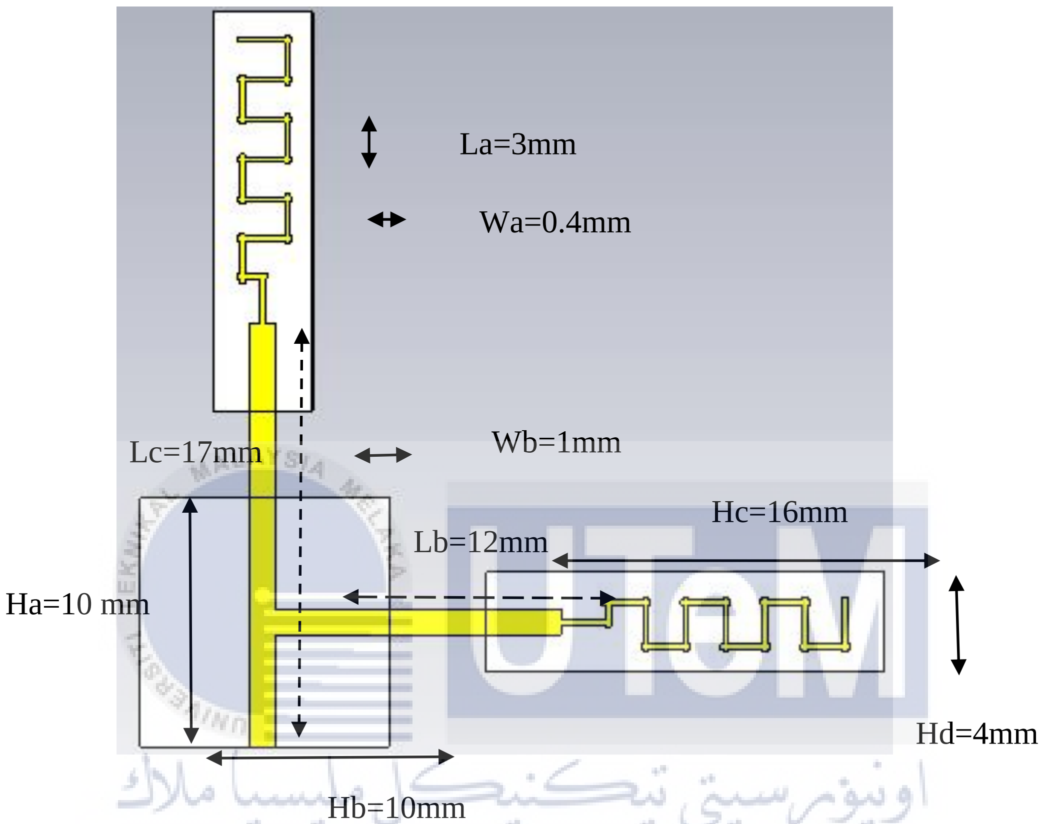


Figure 3.15: Dimension of Antenna Structure of Design 3

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter describe the results analysis of the project. The performance parameters that has been studied are gain, directivity, return loss and radiation pattern. Table of vertical plane, horizontal plane, and all three of the designs were drawn and analyzed for the single and dual polarized meander line antenna.

When the design is done, the antenna is simulate through the Computer Simulation Technology. The performance parameters obtained from the simulation result were frequency, gain, directivity, return loss and radiation pattern. The results demonstrated by a simulation regulating the signal strength transmitted through are the remarkable figure of single plane of meander line antenna, Design 1, Design 2 and Design 3 of dual polarization meander line antenna.

S11 parameter is defines as return loss of antenna. Cumulative return loss of this research is 2 GHz to 5 GHz with less than -10dB of return loss. And the strength of the received signal is enough stable for a consistent data diagram during transmission.

The principal basic characteristics of an antenna are antenna gain. An antenna has a very good match, but if it does not radiate, it will be useless. The antenna increase is a measurement of whether a well-designed or exposed antenna can radiate or receive a power. The antenna power gain will influence the signal's potential to the body.

The directivity that mention to region where the strongest emission of signal radiated and maximum gain processed. Radiation pattern of dual polarization meander line antenna contains main, side and back lobes. The smaller the main lobe stipulates the greater intensity of radiation.

4.2 Horizontal Polarization Meander Line Antenna

The antenna was designed with single meander line antenna in vertical position and antenna radiates with the horizontal polarization. The Figure 4.1 shows the horizontal polarization meander line antenna.

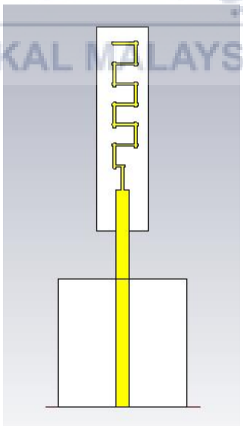


Figure 4.1: Front View of Designed Antenna

4.2.1 S11 Parameter or Return Loss

From the simulated result, the obtained frequency at 3.1419 GHz and return loss is –22.064dB. From simulated result antenna has accepted return loss that operates at 3.1419 GHz and it is the accepted return loss for the antenna performance. Figure 4.2 shows S11 Parameter.

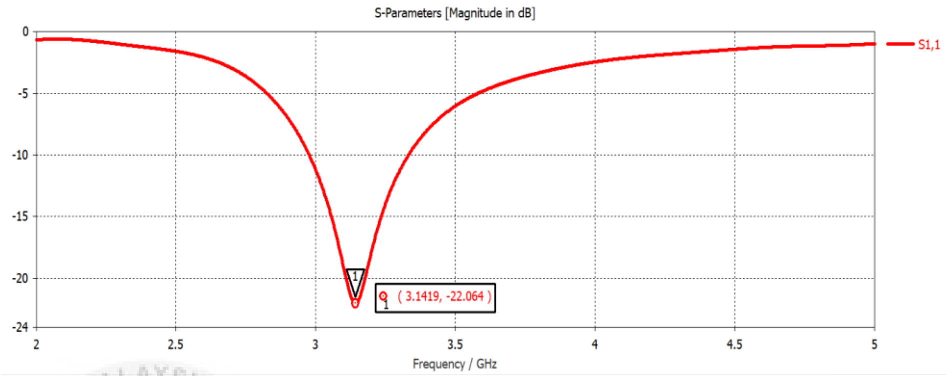


Figure 4.2: S11 Parameter or Return Loss The Designed Antenna

4.2.2 Gain and Directivity

From the farfield radiation pattern the antenna develop horizontal polarization. Horizontal polarization is a linear polarization which the electric field of light is along direction of propagation of the horizontal plane. As at the operating frequency of 3.149 GHz antenna gain is 1.406dB. Meanwhile antenna directivity of 2.297dBi. From the farfield radiation pattern in Figure 4.3 and Figure 4.4 shows that antenna radiates horizontal polarization when feed in vertical meander line antenna.

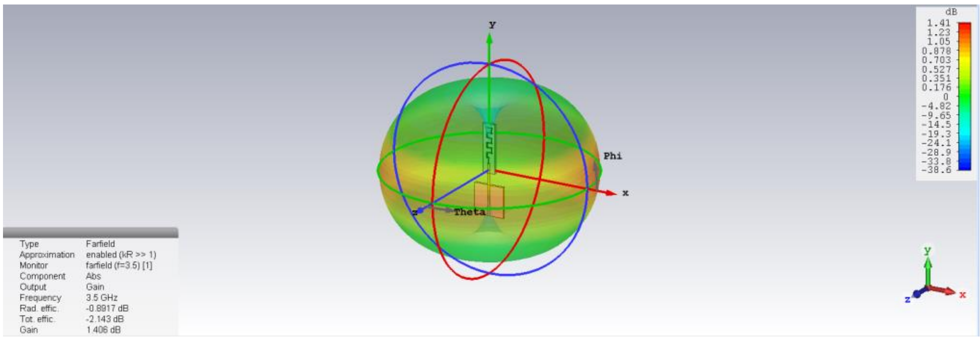


Figure 4.3: Gain of Designed Antenna

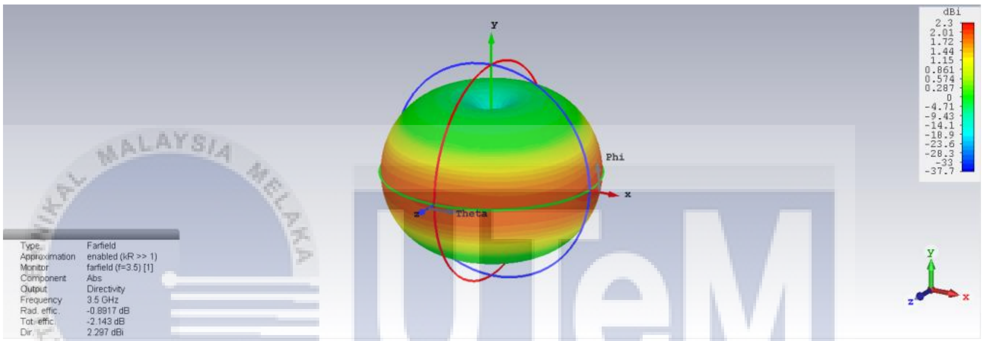


Figure 4.4: Farfield Radiation Pattern in 3D Form

4.2.3 Radiation Pattern Directivity

Radiation pattern directivity defines as radiation intensity in a particular direction. Figure 4.5 shows simulated result that main lobe of antenna produced is 1.98dBi at 359 degree in direction. The least the value of main lobe the largest intensity of direction.

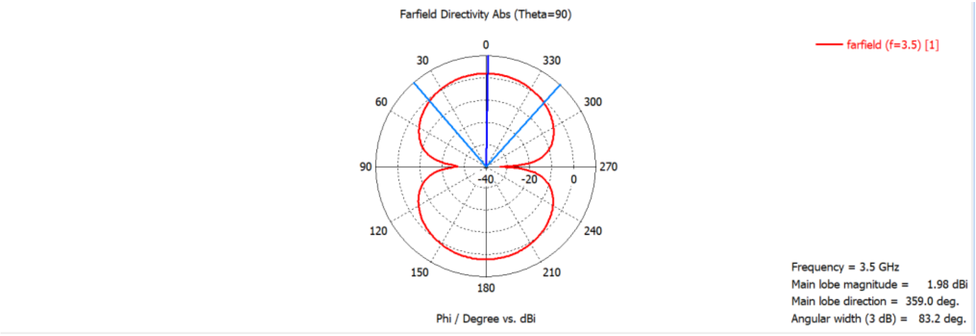


Figure 4.5: Radiation Pattern in Polar Form

4.3 Vertical Polarization meander Line Antenna

Antenna was designed in horizontal single MLA and antenna radiates in vertical polarization. The Figure 4.6 shows the antenna design.

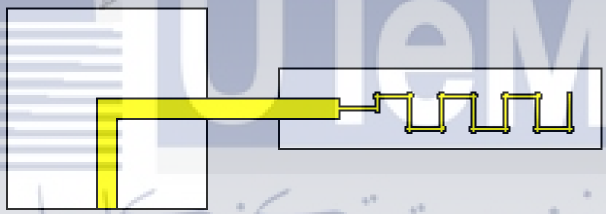


Figure 4.6: Front View of Designed Antenna

4.3.1 S11 Parameter or Return Loss

From the simulated result, the obtained frequency is 3.2255 GHz and return loss is –23.91dB. The antenna has accepted return loss when operates at 3.2255 GHz. And it is the acceptance value of return loss for antenna. Figure 4.7 shows the S11 Parameter.

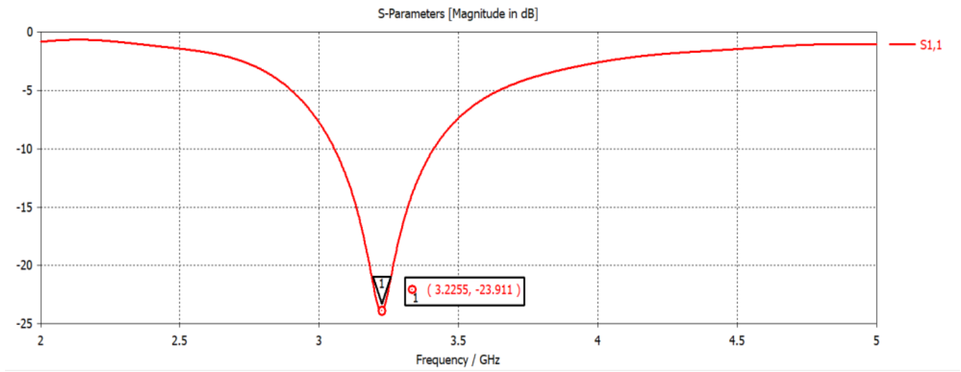


Figure 4.7: S11 Parameter or Return Loss of Designed Antenna

4.3.2 Gain and Directivity

From the farfield radiation pattern in 3D form, the antenna develop the vertical polarization which also called the linear polarization and direction propagation of electric field is radiates along the single vertical plane. Gain of antenna determines how efficient input power for that fall into the specified waves. Antenna gain is 1.158dB that on frequency of 3.225 GHz. Meanwhile the antenna has the directivity of 2.130dBi. From far-field radiation pattern in Figure 4.8 and Figure 4.9 it shows antenna radiates vertical polarization when feed in horizontal meander line antenna.

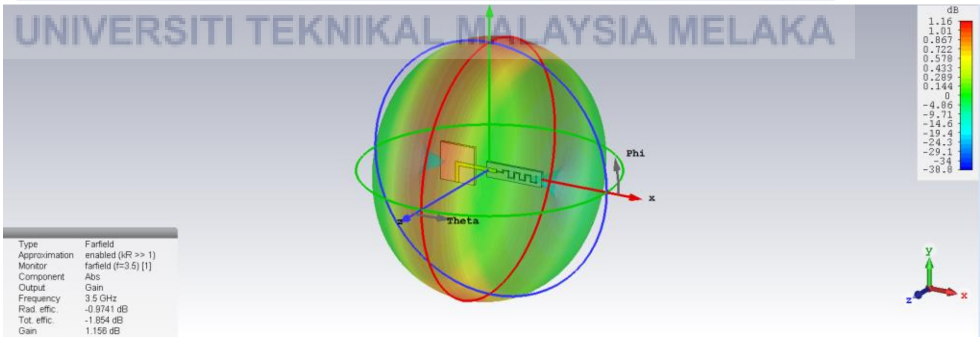


Figure 4.8: The Gain of Designed Antenna

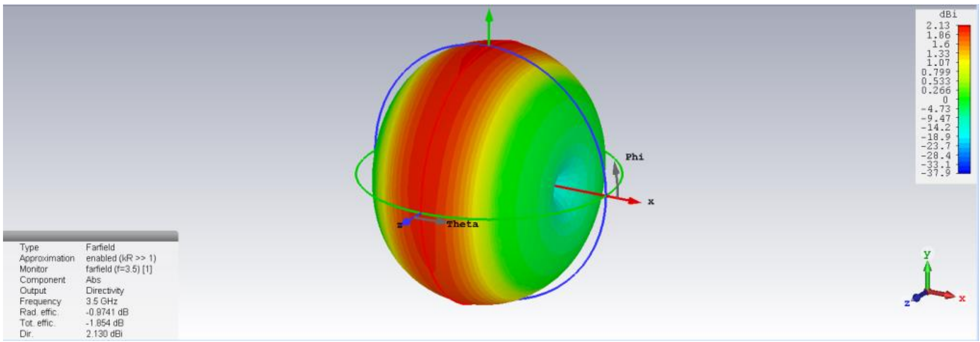


Figure 4.9: Far-Field Radiation Pattern

4.3.3 Radiation Pattern Directivity

Radiation pattern directivity defines radiation intensity in particular direction. From simulated result showed that the magnitude of the main lobe of antenna is 2.1dBi at 91 degree. The smallest the value of main lobe the largest the intensity of direction. Figure 4.10 show radiation pattern of antenna.

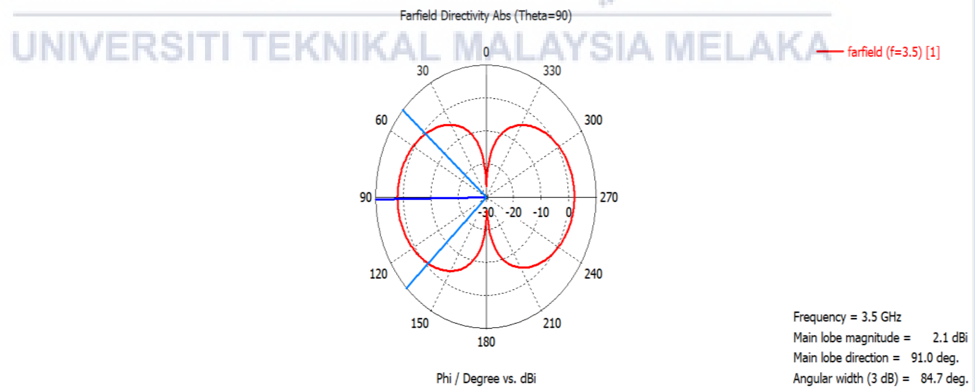


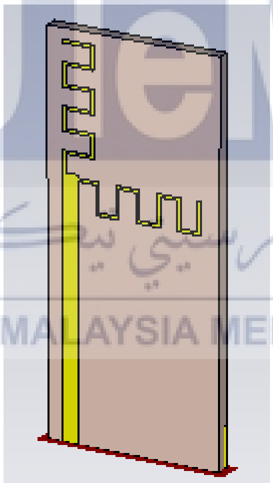
Figure 4.10: Radiation Pattern of Polar Form

4.4 Dual Polarization Meander Line Antenna

For a better improvement, the variation of design of antenna has been made for choose which one is the best. Table 4.1, 4.2 and 4.3 show the differences of antenna parameter and result simulation between Design 1, Design 2 and Design 3 with separate horizontal and vertical result simulation of Dual Polarization Meander Line Antenna.

The frequency for the project is 3.5 GHz for all designs. Simulation results is based on perspective view, front view, back view, return loss, gain and directivity.

Table 4: Antenna Parameter of Design 1

Antenna Parameter	Simulation
Design 1	 Perspective view

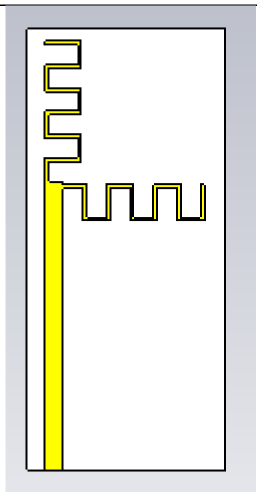
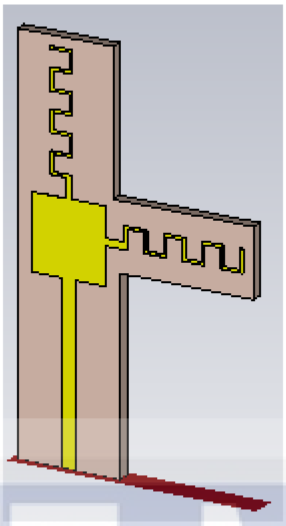
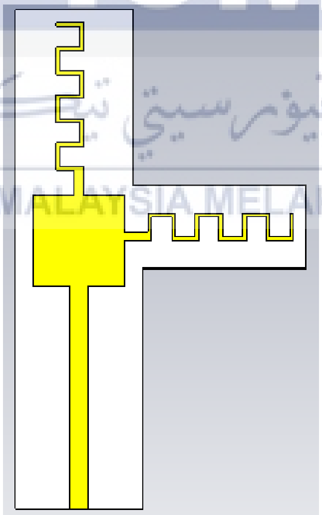
	 Front view  Back view

Table 5: Antenna Parameter of Design 2

Antenna Parameter	Simulation
Design 2	 Perspective view  Front view

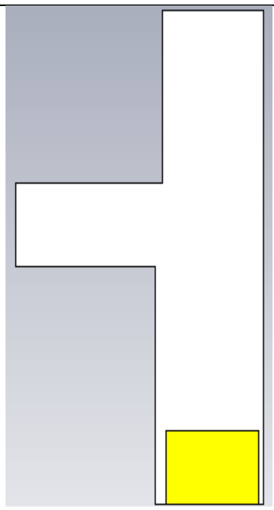
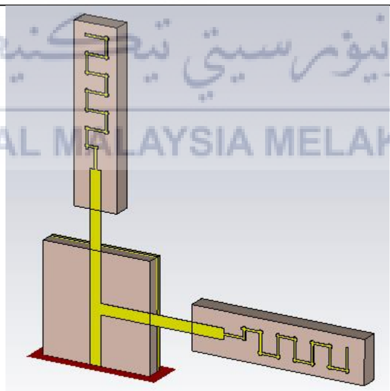
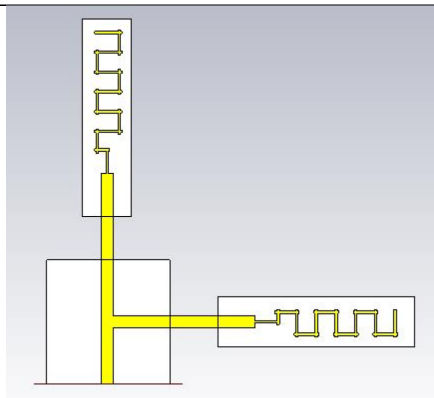
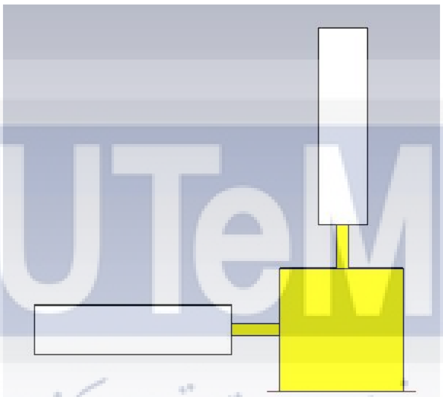
	 Back view

Table 6: Antenna Parameter of Combined Antenna of Design 3

Antenna Parameter	Simulation
Design3 (combined antenna)	 Perspective view

	 Front view  Back view

4.4.1 Simulation of Return Loss, S11 Parameter

Graph indicates S_{11} waveform which state return loss for all designs of dual polarization meander line antenna. Range value of return loss is 2 GHz to 5GHz which less than -10dB. This results obtained from simulation process and it is insist that strength of signal received during the transmission is solid enough to gain an enhanced figure of information It consider the antenna used in the mode of transmission. S11 parameter for Design 1 of dual polarization meander line antenna as shown in Figure 4.11.

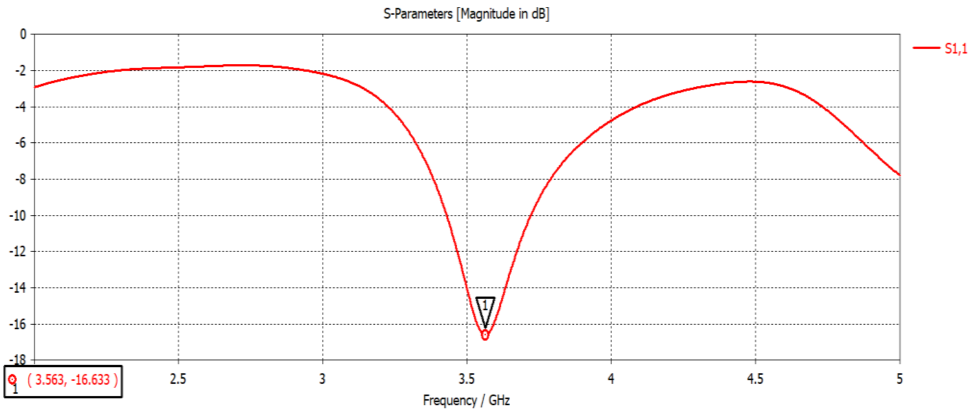


Figure 4.11: S11 Parameter for Design 1

The results of return loss presented is below that -10dB which is -18.23dB that most fallen value is at 3.563 GHz. The antenna operates at very low return loss at 3.5 GHz. This means that the antenna will transmit a good amount of the signal and accepted return loss.

After that, the optimization are made to Design 1 which the substrate shape is cut according to the shape of antenna and this design is pointed as Design 2. Design with square patch also added to see the results. For this design the results of S11 parameter is -18.23dB that fallen at value of 3.5426 GHz. It shows that this design operates at low return loss than the previous design. This means the better amount of signal that will transmit through this antenna. Figure 4.2 shows S11 parameter for Design 2 of dual polarization menader line antenna.

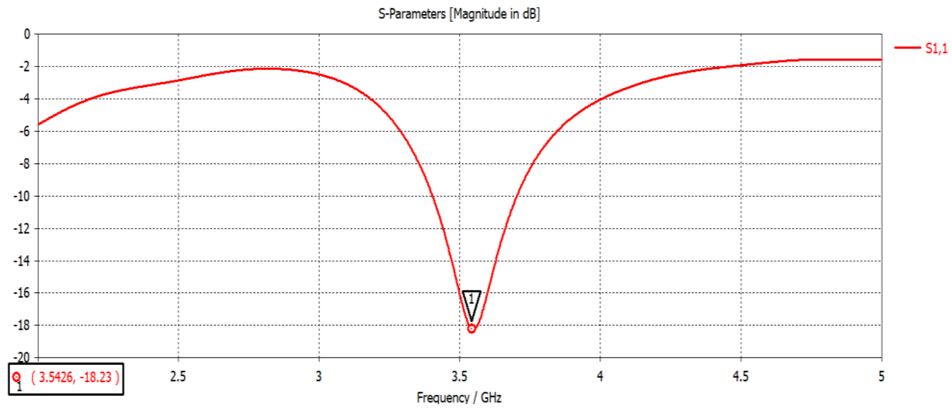


Figure 4.12: S11 Parameter for Design 2

After that, for Design 3 S11 the result of S11 parameter is -16.633dB. The frequency is fallen at value of 3.5491 GHz and mostly under -10dB. Figure 4.3 shows S11 parameter result Design 3 of dual polarization meander line antenna.

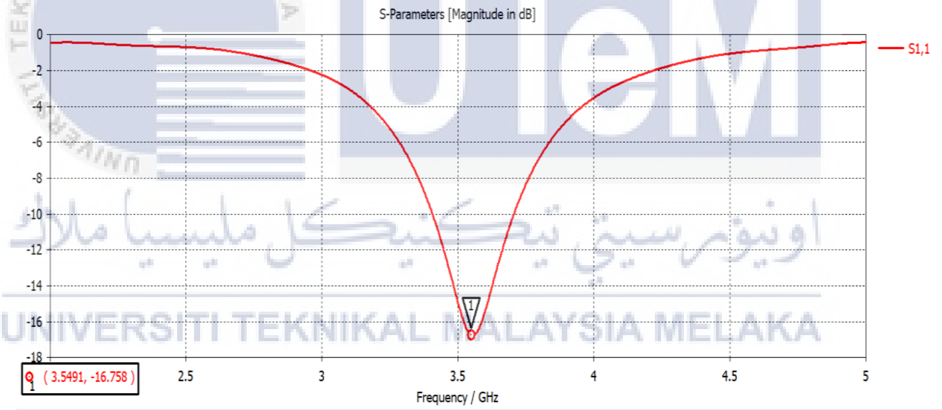


Figure 4.13: S11 Parameter for Design 3

4.4.2 Simulation of Directivity

The directivity determined from Design 1 simulation is 2.971dBi. Meanwhile, for Design 2 simulation is 4.665dBi and Design 3 simulation is 2.541dBi. Directivity is always depends to gain. As gain high, the directivity is also high. Figure 4.4, Figure 4.5 and Figure 4.6 below shows directional of antenna for Design 1, Design 2 and Design 3.

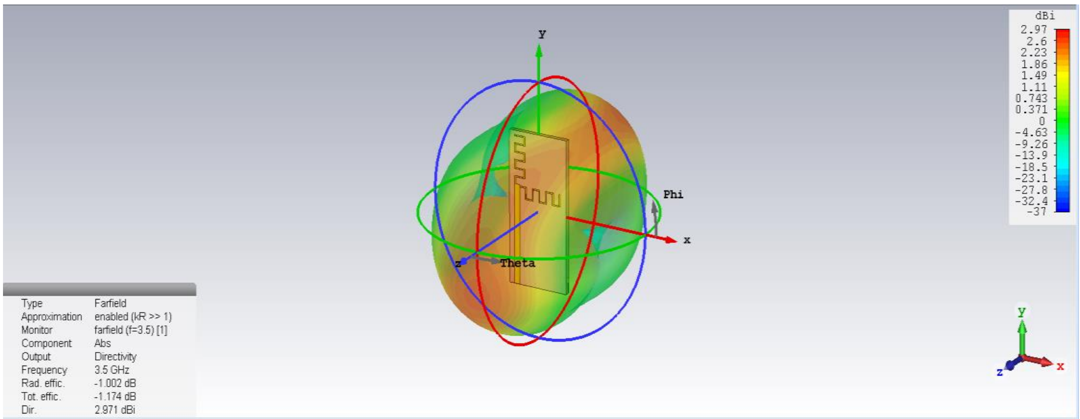


Figure 4.14: Directional of Antenna for Design 1

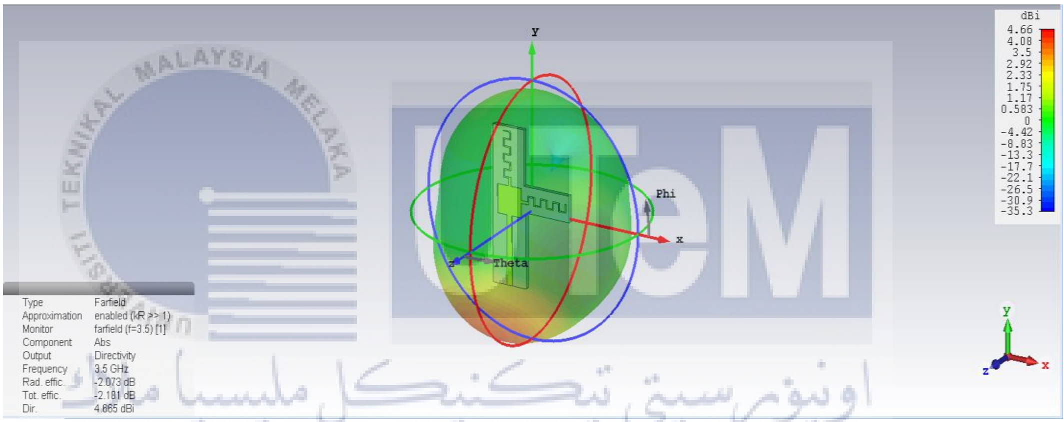


Figure 4.15: Directional of Antenna for Design 2

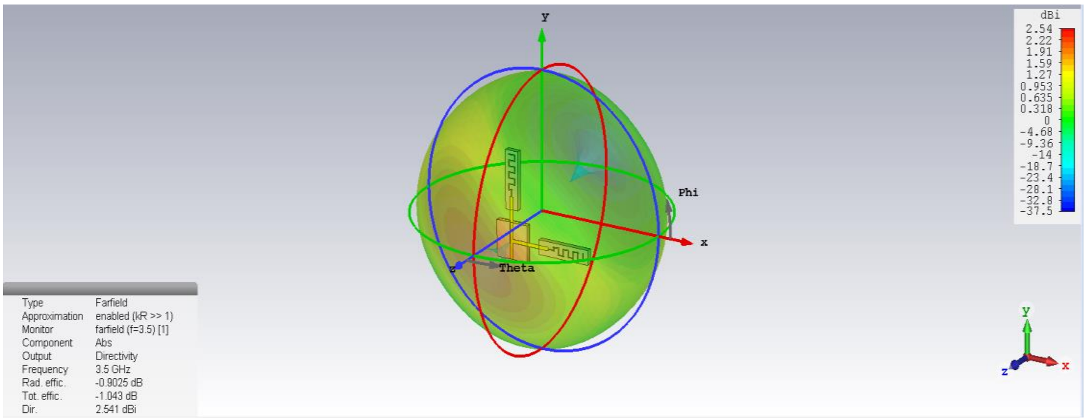


Figure 4.16: Directional of Antenna for Design 3

4.4.3 Simulation of Gain

Gain is the antenna's primary attribute. The antenna that matches well, but do not radiate, is useless. Antenna gain is function to demonstrate how often antenna is radiating or receiving power.

From the project simulation the gain of all designs of dual polarization meander line antenna is range 1.5 to 3 dB through simulation. For Design 1 the gain that produced is 1.969dB. Meanwhile gain for Design 2 is 2.592 dB and Design 3 is 1.639 dB. Figure 4.7, Figure 4.8 and Figure 4.9 below shows the gain of antenna for Design 1, Design 2 and Design 3.

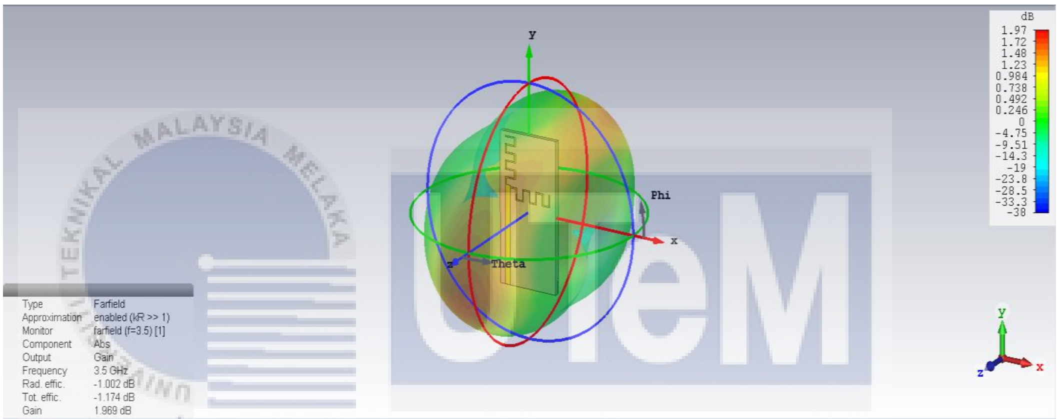


Figure 4.17: Gain of Antenna for Design 1

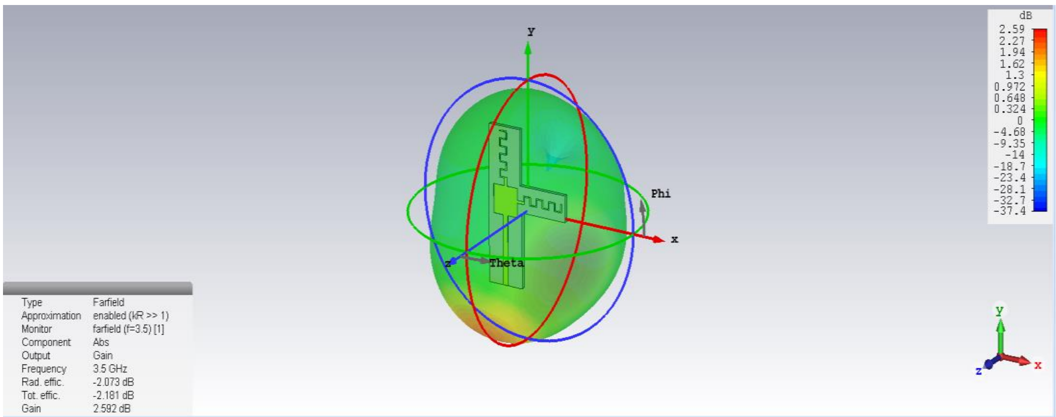


Figure 4.18: Gain of Antenna for Design 2

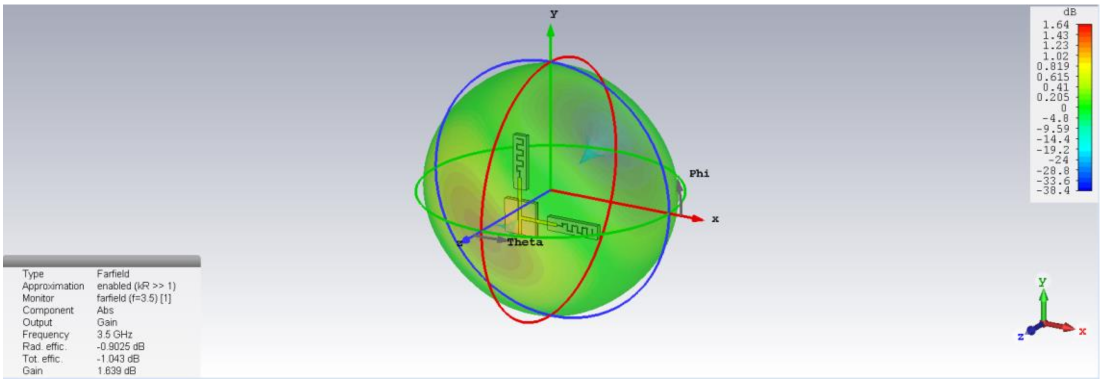


Figure 4.19: Gain of Antenna for Design 3

4.4.4 Simulation of Radiation Pattern

Radiation pattern is a three dimensional graphical display of antenna radiation to show function of direction. Radiation intensity is achieved from an antenna power track by solid angle per unit.

It display that the main lobe is bigger than the side lobes and back lobes. It means, more power is radiates the main lobe compared to other directions. The smaller the main lobe, the larger the intensity of radiation. Figure 4.10 shows the radiation pattern of Design 1.

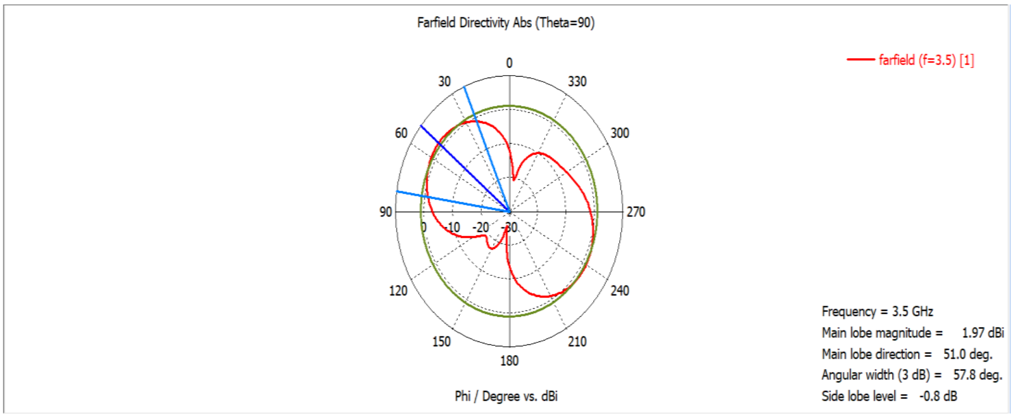


Figure 4.20: The Radiation Pattern of Antenna In Polar Form For Design 1.

The results shows magnitude of main lobe of Design 1 antenna is 1.97dBi at 51 degree. Meanwhile the side lobe is -0.8dB. Figure 4.11 shows results of simulation of radiation pattern of Design 2.

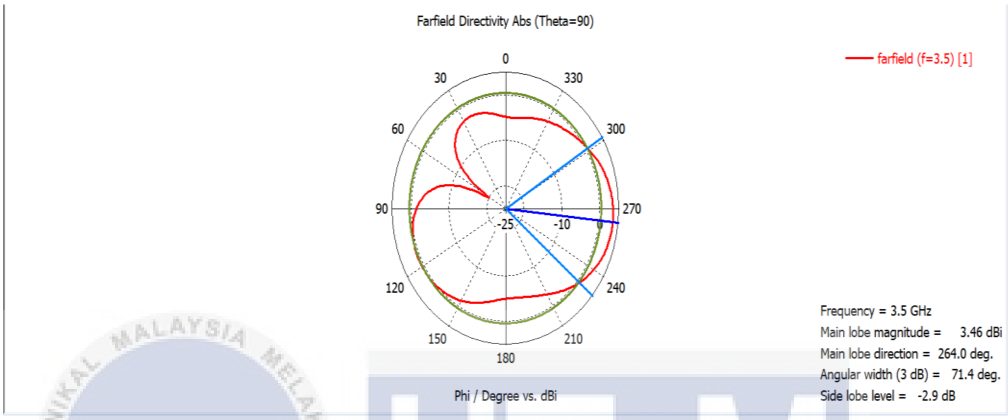


Figure 4.21: Radiation Pattern of Antenna In Polar Form For Design 2

From the radiation pattern the magnitude of main lobe of the antenna is 3.46dBi at 246 degree. The side lobe level is -2.9dB. Furthermore, figure shows the radiation pattern directivity of Design 3. From Figure 4.12, directivity of main lobe is 0.574dBi at 147 degree.

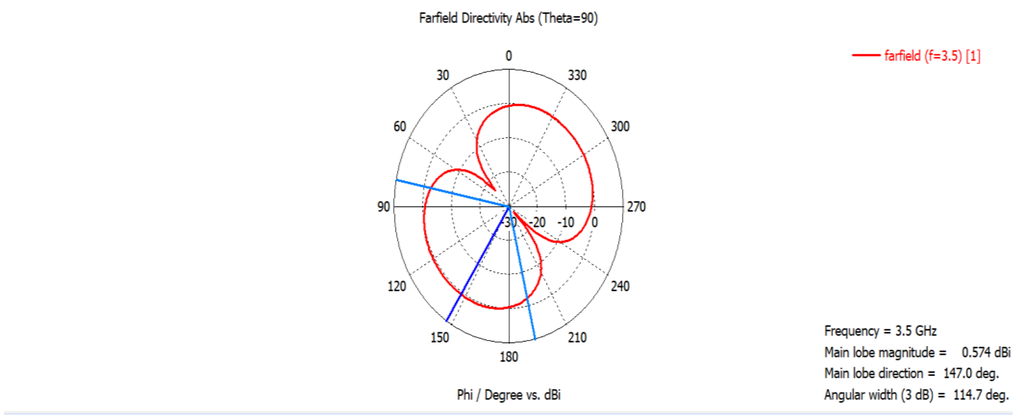
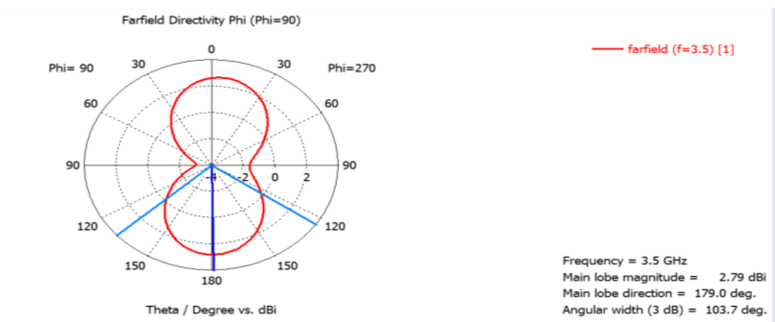
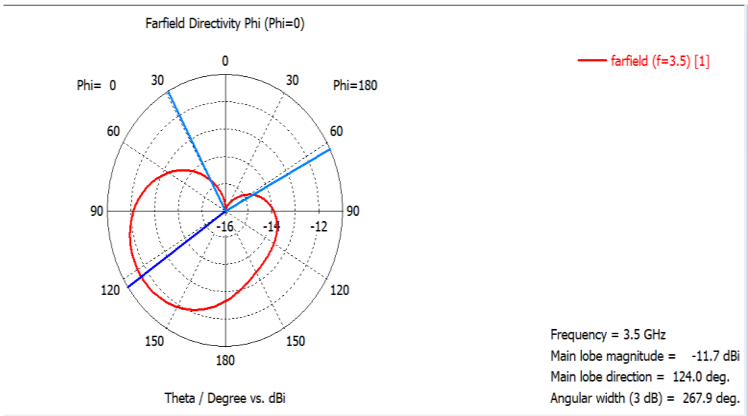


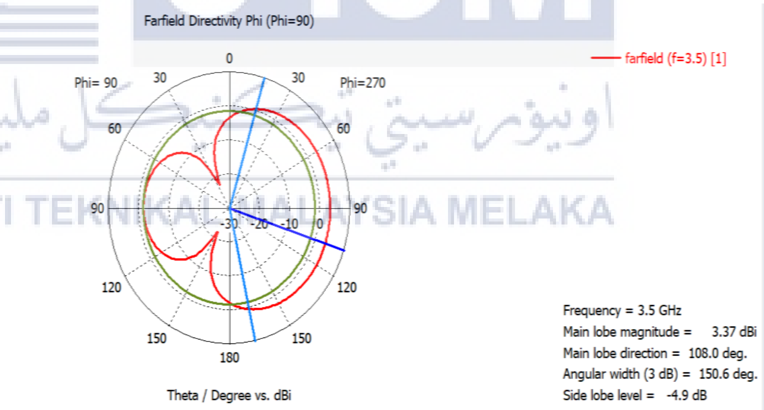
Figure 4.22: Radiation Pattern of Antenna In Polar Form For Design 3

Parameter value for radiation pattern of far-field directivity when Phi=90 and far-field directivity of Phi=0 were simulated. Radiation pattern of Phi=0 and Phi=90 as shown in Table 7.

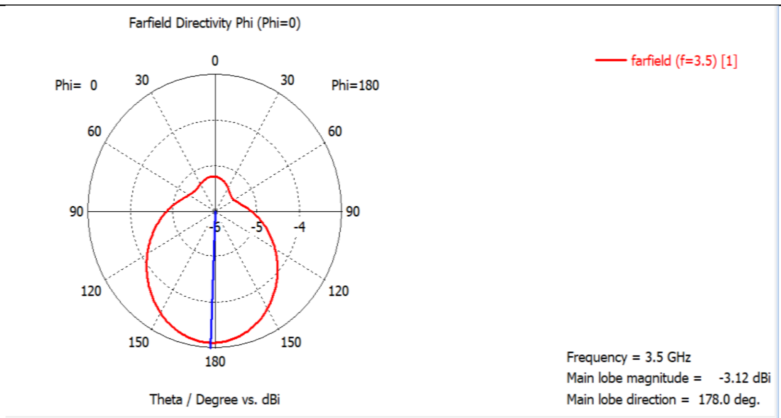
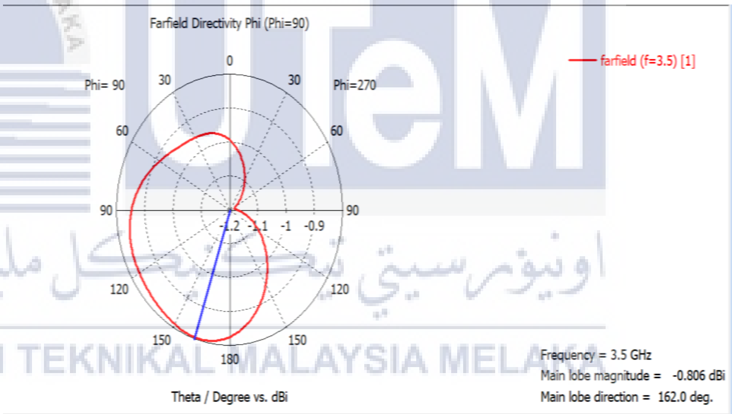
Table 7: The Radiation Pattern of Phi=90 and Phi=0

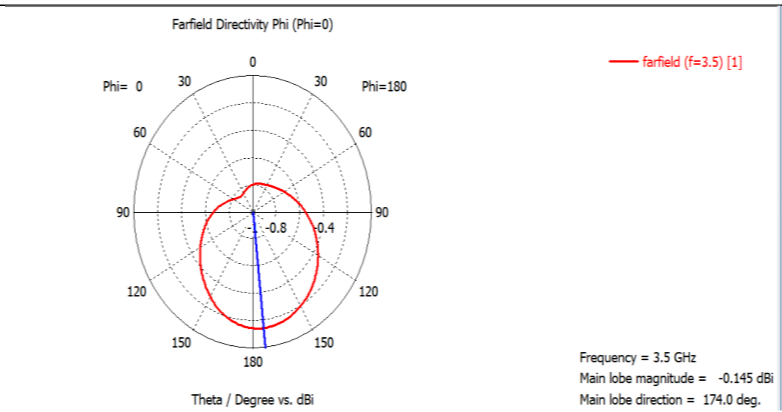
Antenna Parameter	Radiation pattern of Phi=90 and Phi=0
Design 1	 (Phi=90)

<table>
<tr>
<td></td>
<td>

(Phi=0)</td>
</tr>
<tr>
<td>Design 2</td>
<td>

(Phi=90)</td>
</tr>
</table>

	 (Phi=0)
Design 3	 (Phi=90)

	 (Phi=0)

4.5 Simulation of Antenna Surface Current

In this explanation, it shows how signal radiate from inside the dual polarization of meander line antenna. From the results it shows how the wave transmitted in directional way of antenna from the waveguide port. Figure 4.13, Figure 4.14 and Figure 4.15 shows simulation of Antenna Surface Current.

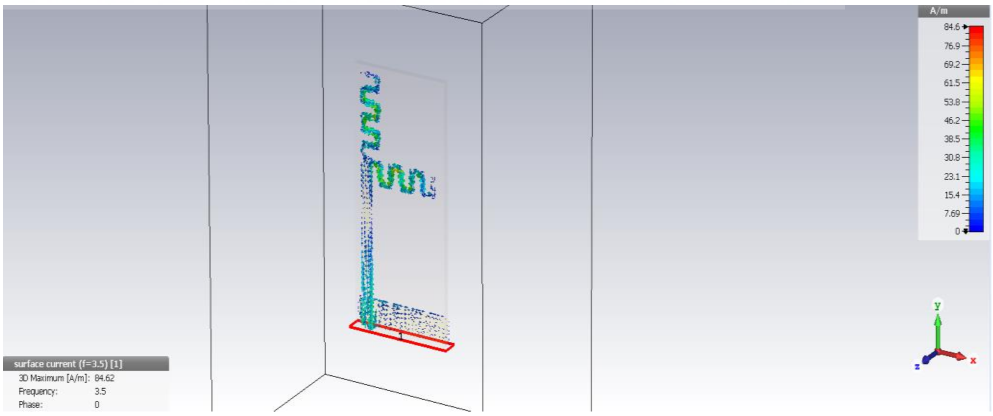


Figure 4.23: Simulation of Antenna Surface Current for Design 1

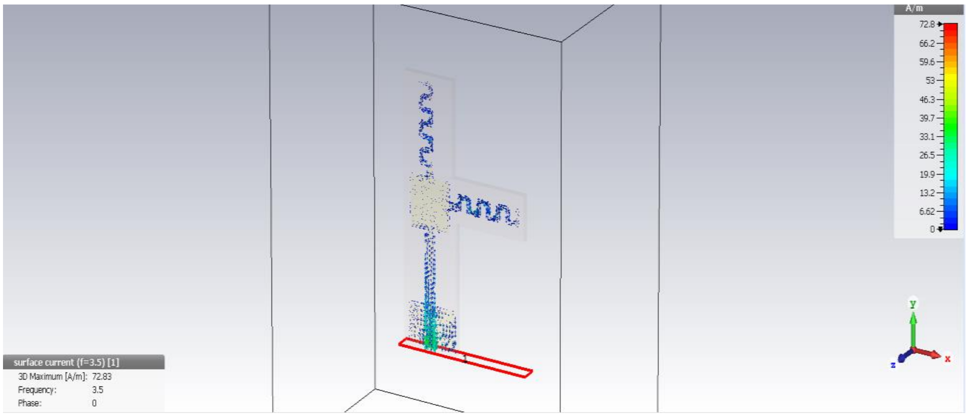


Figure 4.24: Simulation of Antenna Surface Current for Design 2

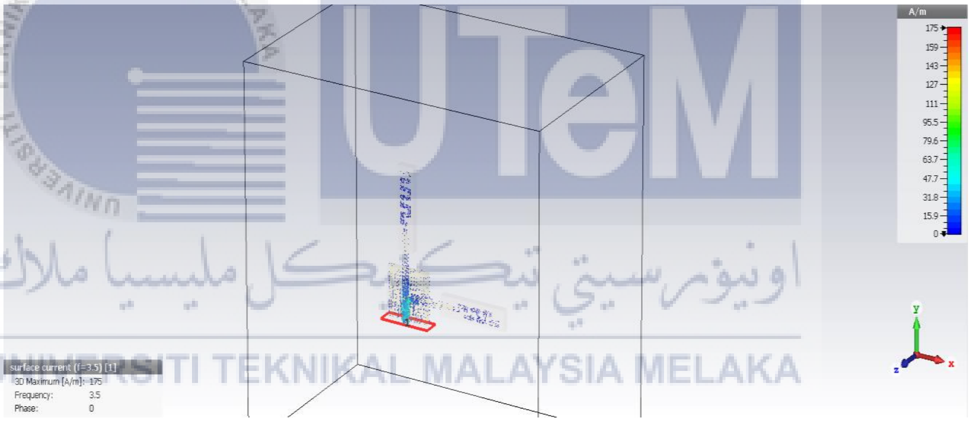


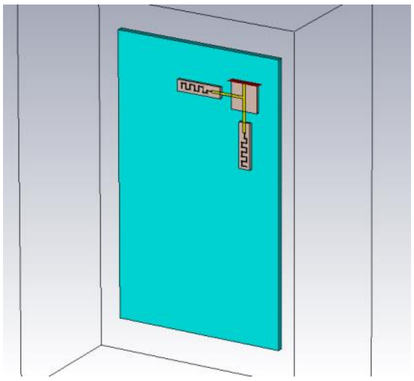
Figure 4.25: Simulation of Antenna Surface Current for Design 3

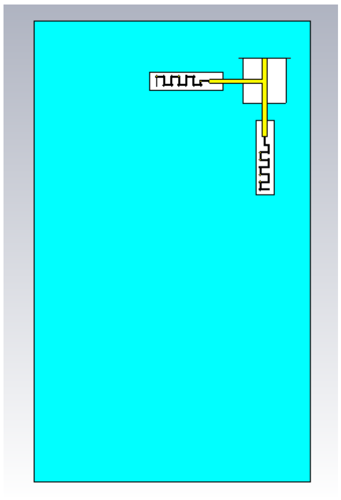
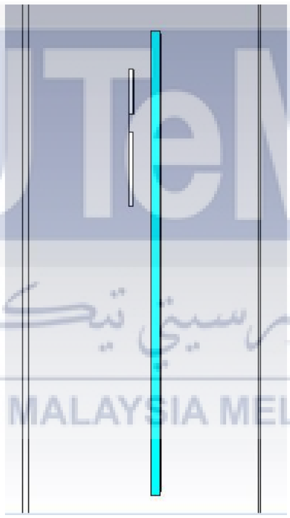
4.6 Illustration of Dual Polarized Meander Line Antenna Design 3 with phone casing

The simulation of antenna with phone casing aimed to observe how the antenna performed well in practical condition. In this simulation, the polypropylene material with dielectric 2.33 is used for the phone casing. The dimension of phone casing is 60x100 mm.

The stated results shows that the antenna simulated on phone casing and its work. This simulation using CST software. Table 4.6 shows result simulation of illustration with phone casing. From the side view, it shows that the antenna and the phone casing was not touch with each other. This is intended to prevent the disturbance to the reading of antenna. In fact, if the materials of casing is conductive material, the whole casing will become an antenna. The frequency turning and gain will be changed as well. To prevent the reading error the antenna and phone casing was designed to not touch with each other.

Table 8: Antenna Parameter of Illustration of Design 3 with Phone Casing

Antenna Parameter	Simulation
Design 3 with phone casing	 Perspective view

	 Front view  Side view

4.6.1 Simulation of Return Loss, S11 Parameter

From simulated result, the obtained frequency is 3.5706 GHz and return loss is –22.85dB. The antenna has accepted return loss when operates at 3.5 GHz. This means that the antenna will transmit a good amount of the signal and return loss is accepted. Figure 4.26 shows S11 Parameter of antenna.

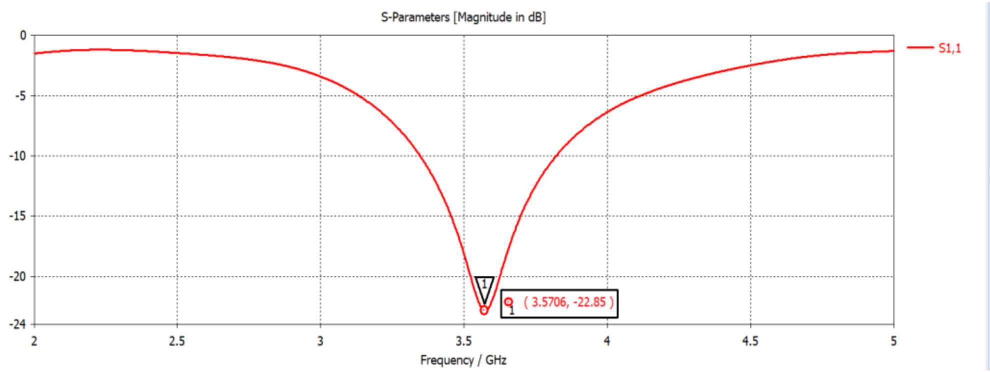


Figure 4.26: S11 Parameter or Return Loss Of Designed Antenna

4.6.2 Simulation of Gain and Directivity

Gain defines the effectively the antenna transmits the input power to a certain direction on the radio waves. At 3.5 GHz the antenna gain is 1.23dB. Meanwhile the antenna has the directivity of 2.45dBi. From far-field radiation pattern, it shows the radiation of antenna is a bit slanting same as antenna radiation without phone casing. It means the electromagnetic field is oscillate at 45 degree of the plane.

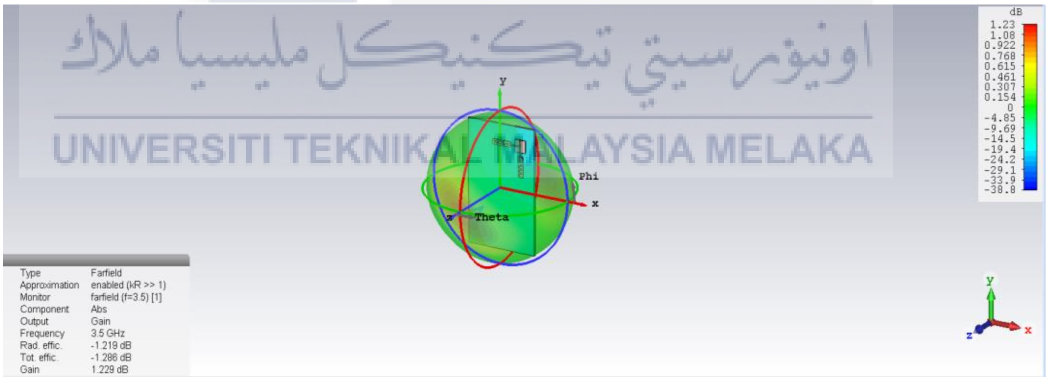


Figure 4.27: Gain of Designed Antenna

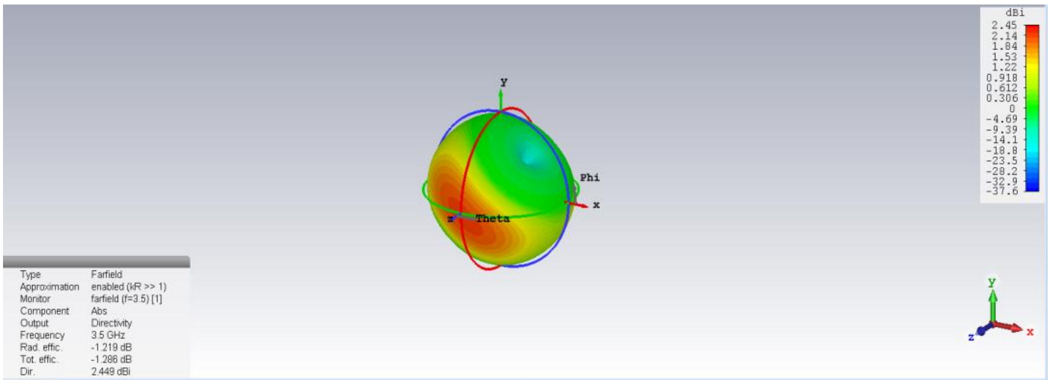


Figure 4.28: Farfield Radiation Pattern of Designed Antenna

4.6.3 Simulation of Radiation Pattern

From simulated result, magnitude of the main lobe is 2.44dBi at 177 degree. The smallest the main lobe the larger the intensity of direction. Figure 4.28 shows radiation pattern of antenna in polar form.

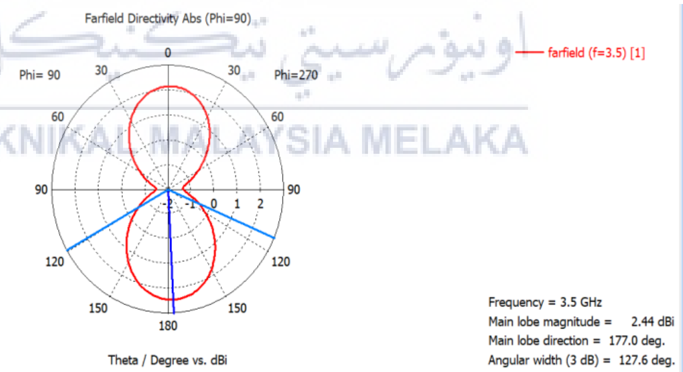
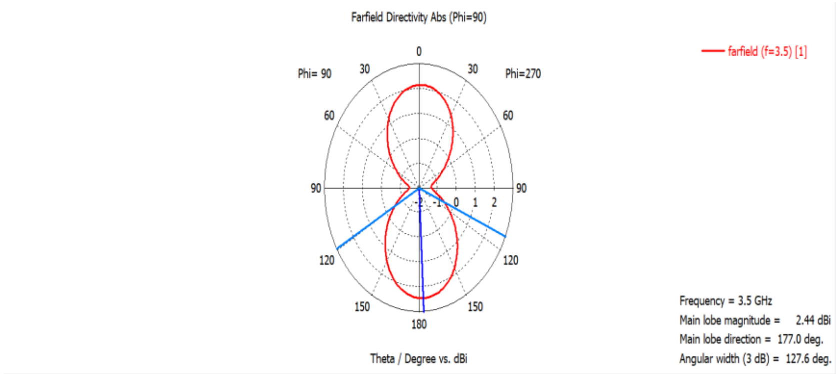
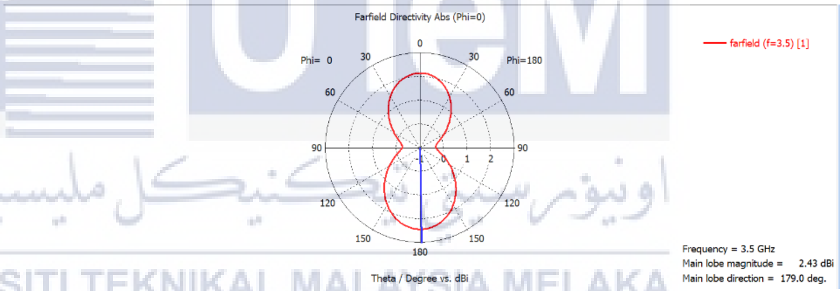


Figure 4.29: Radiation Pattern of Antenna In Polar Form

Parameter value for radiation pattern of far-field directivity when Phi=90 and far-field directivity when Phi=0 were also simulated. The radiation pattern of Phi=90 and Phi=0 shown in Table 9.

Table 9: The Radiation Pattern of Phi=90 and Phi=0

<table>
<tr><th>Antenna Parameter</th><th>Radiation pattern of Phi=90 and Phi=0</th></tr>
<tr><td>Design 3 with casing phone</td><td>


E-Field


H-Field</td></tr>
</table>

4.6.4 Simulation of Antenna Surface Current

In this explanation, it shows how signal radiate from inside dual polarization of meander line antenna. From the results it shows how the wave transmitted in directional way of antenna from waveguide port. Figure 4.29 shows surface current of designed antenna.

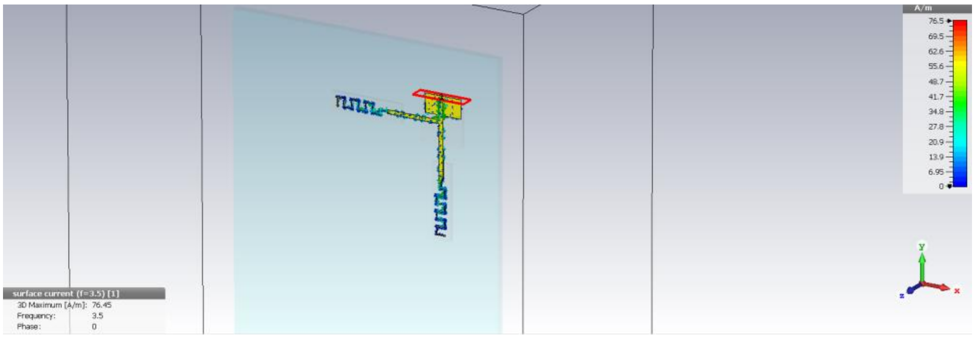


Figure 4.30: Surface Current of Designed Antenna

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

All works that has been completed are summarized and concluded in this chapter. Future work and recommendations that may finalized for further improve for this project also be discussed.

The dual polarization meander line antenna was designed with frequency of 3.5 GHz. This antenna is simulated using the application of Computer Simulation Technology (CST) Microwave Studio Software.

Performance parameters such as gain, directivity, return loss, radiation pattern are studied. From this project shows that Meander Line Antenna is an antenna for the application systems for communication with good gain for n-users and return loss that proportion of radio waves that arrive at the input of the antenna is below -10dB. Most of the radiation pattern is an omnidirectional and the polarization that produces is in linear polarization which is vertical polarization and horizontal polarization. Meander line antenna also can be size compact and fit with the phone dimension. This antenna can be used for the mobile terminal. These attribute will make the antenna a widely applications in 5G application systems in future.

5.2 Completed Work

The completed work in this thesis include, two design of antenna with vertical and horizontal Meander Line Antenna were designed. From the results, it shows that the vertical polarization of antenna radiation form when the antenna was designed in horizontal. Meanwhile, the horizontal polarization of antenna radiation was form when antenna designed in vertical design. To achieve the objective of this research which to design the dual polarization of antenna, this two antenna in vertical and horizontal antenna were combined. All three designs combined to form the Dual Polarization Meander Line Antenna which are Design 1, Design 2 and Design 3. All designs of antenna were designed using computer simulation technology and the performance for all antenna were differentiated. Calculation method has been used for design antenna to achieve appropriate optimized size by adjusting the antenna dimensions.

From the comparison of all designs, to produce as dual polarization meander line antenna or in vertical and horizontal polarization the antennas need to feed separately. Meanwhile, the combined antenna will develop slanting polarization. It means the electromagnetic field is oscillate at 45 degree of the plane.

Design 3 seems more acceptable for the research. Then, design 3 was illustrated with phone casing using CST and its work. This simulation intended to show the antenna can perform well in ideal and practical condition.

5.3 Recommendation on Future Work

Based on simulation result, design of dual polarization meander line antenna is satisfactory to operate on operational frequency of 3.5 GHz. The lower return loss will convince the signal that has been radiated to be almost in stable state.

In fact, the radiation pattern shown is to be fine. For the future work, radiation pattern can be improve to get radiation of signal along the dual polarization of the antenna. In addition, the meander line antenna can be stuffed with dielectric material so that gain and directivity results grow. Moreover, structure design of dual polarization meander line antenna should be modified and improvise so that to the results can be compared.

The simulation design results, all the parameters observed had almost achieved the good performance that operated on 3.5 GHz. Unfortunately the fabrication process cannot be done due to movement control order (MCO) from government due to pandemic covid19 that occurred in Malaysia and also around the world. The university has been closed so that only simulation process was done for this research. So this research have had 3 different design of dual polarization meander line antenna to be compared instead of fabrication process.

This project centred on study the analysis and simulation process using computer simulation technology. The results of gain and return loss can be improve when using different type of substrate materials for the future work. The different type of dielectric material can also effect the value of antenna parameter performance. Besides that, meander line antenna also can be design and simulate within the other frequency bands. The parameter results of this frequency range can be compared to achieve the good antenna so that this antenna can get the better performance. This consideration can helps to improve measurement and achieve good performance for antenna parameter such as good gain and useable 5G system.

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