# DESIGN AND ANALYSIS THE PERFORMANCE OF HIGH GAIN ARRAY ANTENNA AT 3.5GHZ FOR 5G COMMUNICATION

**THIVYA A/P KANNIAH**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

# DESIGN AND ANALYSIS THE PERFORMANCE OF HIGH GAIN ARRAY ANTENNA AT 3.5GHZ FOR 5G COMMUNICATION

**THIVYA A/P KANNIAH**

**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**



**2022**

# DECLARATION

I declare that this report entitled "Design and analysis the performance of high gain array antenna at 3.5Ghz for 5G communication" is the result of my own work except for quotes as cited in the references.



Signature : ……………………………………

Author : Thivya a/p Kanniah

Date : 10/06/2022

# 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 Mohamad Harris Bin Misran

Date : 10/06/2022

# DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this project. To my beloved father and mother, Mr Kanniah Subramaniam and Mrs Santa Venggattasamy and my sister, Piriya Kanniah. This thesis is purely of your tremendously support and sacrifice. I dedicate this to all of you. May God always bless every each of you.

# ABSTRACT

The fifth-generation wireless 5G is the repetition of cellular technology, engineered to greatly increase the prospective, speed and responsiveness of wireless network. Moreover, 5G communication let a substantial increase in the amount of information's sent through the wireless system receivable to a greater bandwidth and advanced antenna technology. These days antennas suffer from poor radiation features that limit used in many active applications. Such wireless system required an array antenna with high realized gain. Due to these issues, this project will be concentrated to design a high gain array antenna at 3.5GHz for 5G communication. A directional patch antenna will be designed for a specific base station to provide high-capacity network connectivity and high quality of communication. Furthermore, high gain array antenna at 3.5GHz is more focused to be used at long distance point to point connections. In this project, 4x4 patch antenna will be designed in CST software and fabricated on FR4 epoxy material to achieve high gain for long distance signal transmission.

# ABSTRAK

5G tanpa wayar generasi kelima ialah pengulangan teknologi selular, yang direka bentuk untuk meningkatkan prospek, kelajuan dan responsif rangkaian wayarles dengan banyak. Selain itu, komunikasi 5G membolehkan peningkatan yang ketara dalam jumlah maklumat yang dihantar melalui sistem wayarles yang boleh diterima kepada jalur lebar yang lebih besar dan teknologi antena termaju. Pada masa kini, antena mengalami ciri sinaran yang lemah yang mengehadkan penggunaan dalam banyak aplikasi aktif. Sistem wayarles sedemikian memerlukan antena tatasusunan dengan keuntungan yang direalisasikan tinggi. Disebabkan oleh isu-isu ini, projek ini akan tertumpu untuk mereka bentuk antena tatasusunan keuntungan tinggi pada 3.5GHz untuk komunikasi 5G. Antena tampalan berarah akan direka bentuk untuk stesen pangkalan tertentu untuk menyediakan sambungan rangkaian berkapasiti tinggi dan kualiti komunikasi yang tinggi. Tambahan pula, antena tatasusunan bergain tinggi pada 3.5GHz lebih fokus untuk digunakan pada sambungan titik ke titik jarak jauh. Dalam projek ini, antena tampalan 4x4 akan direka bentuk dalam perisian CST dan direka pada bahan epoksi FR4 untuk mencapai keuntungan tinggi untuk penghantaran isyarat jarak jauh.

# ACKNOWLEDGEMENTS

In the present world of competition, there is a race of existence in which those are having the will to come forward to succeed. Project is like a bridge between theoretical and practical working. With this willing, we joined this project. First, i would like to thank the supreme power the Almighty God who is obviously the one has always guided us to work on the right path of life. Without his grace, this project could not become reality. Next to him are our parents, whom we greatly indebted for us brought up with love and encouragement to this stage. We are feeling oblige in taking the opportunity to sincerely thanks to Dr. Mohamad Harris Bin Misran as my supervisor in this project whose help, suggestions and encouragement also helped us to coordinate the project. At last, but not least I'm thankful to all lecturers and friends who have been always helping and encouraging us throughout this semester even though we are currently facing unprecedented situation due to covid-19. We have no valuable words to express our thanks, but our heart is still full of the favors received from every person. Lastly, we would like to appreciate the guidance given by another supervisor as well as the panels especially in our project presentation that has been improved our presentation skills by their comments and tips.

**TABLE OF CONTENTS**

**CHAPTER 2 LITERATURE REVIEW 9-29**

## LIST OF FIGURES

## LIST OF TABLES

## LIST OF SYMBOLS AND ABBREVIATIONS

$\varepsilon r$ : Dielectric Constant of Substrate

W : Width of Patch

L : Length of Patch

Wg : Width of Ground Plane

Lg : Length of Ground Plane

hs : Thickness of Dielectric Constant

ht : Thickness of Conductor

Wf : Feedline Width

Lf : Feedline Distance

$\boldsymbol{\lambda}$ : Width of Substrate

$\boldsymbol{sreff}$ : Effective Dielectric Constant

$\Delta \boldsymbol{L}$ : Extension in Length

G : Gain

D : Directivity

RL : Return Loss

I : Inner of the hexagonal slotted

O : Outer of the hexagonal slotted

r : Distance from patch-to-patch

Ws : Width of Substrate

Ls : Length of Substrate

# CHAPTER 1

# INTRODUCTION



## 1.1 Project Background

The fifth generation (5G) of communication has been widely discussed to provide high-speed connectivity in the future. The design and validation of the 5G communication system are dependent upon an understanding of the propagation channels [1]. Beyond the 4G standards, 5G Technology is a term used in many research publications and projects to describe the next most crucial stage of mobile communication standards. Currently, there is no official term for 5G specs.3GPP standard release beyond 4G and LTE [2]. At current, the 5G mobile system are broaden their range to improve high data rate. The World Radio Communication Conference (WRC) in 2015 discussed 5G possible frequency bands below 6GHz, as well as the frequency ranges that go with them. 470-694MHz, 1427-1518 MHz, 3300-3800 MHz, and 4500-4900 MHz are among the frequency the frequencies recommended. Among these, 3.5GHz has been widely considered, as it is widely recognized for its superior performance.

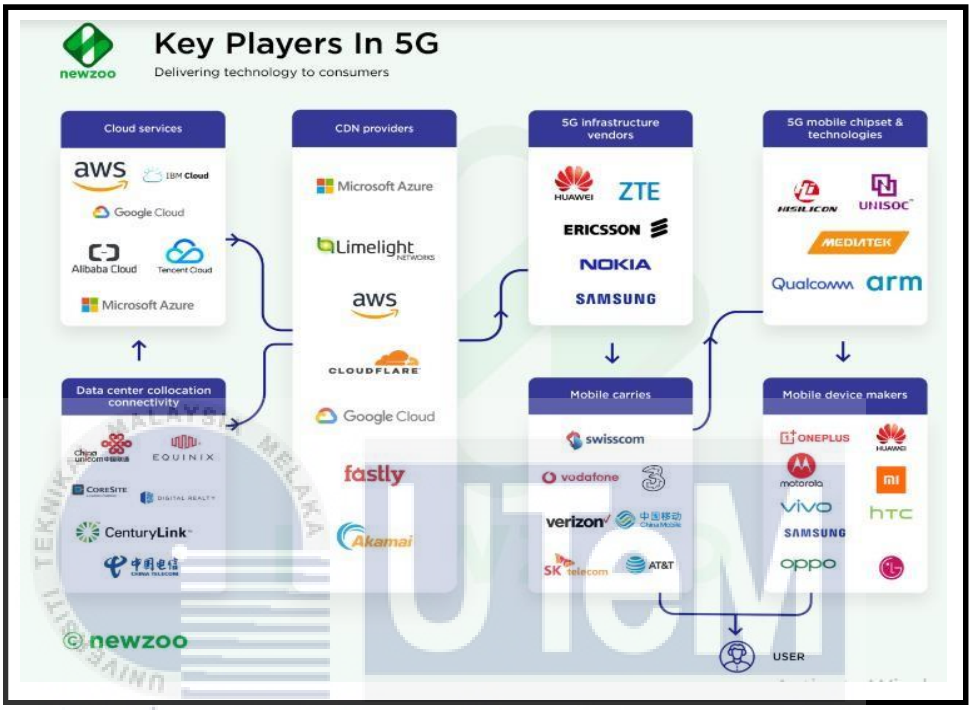


**Figure 1.1: The 5G Ecosystem (The Key Players Involved)**



The main advantages of 5G are data rates that can reach and exceed 10 Gbps, which can provide a better client experience and increase the download and upload speeds. Aside from that, 5G will boost resolution and enable bi-directional large bandwidth shaping. 5G mm-wave will be capable of achieving an inactivity rate of less than 1ms, allowing for faster connection establishment and delivery with the 5G organization by 5G cell phones, as well as a reduction in traffic load. Furthermore, 5G has the potential to provide a global network that is consistent, stable, and continuous. 5G technology allows all networks to be consolidated into a single platform, resulting in a 10x reduction in latency, a 100x increase in traffic capacity, a 10x increase in connection density, a 3x increase in spectrum efficiency, and a 100x increase in network competency. In comparison to previous generations, the fifth generation is easier to manage.

Because of fast advancements in communication technology, researchers have been drawn to high frequencies and high gain antennas. Lossless long-range communication higher received signal strength, and a less crowded environment are all required by the increasing growth of communication networks. Because of their large capacity and ability to enable high transmission speeds, millimeter-wave (MMW) frequency bands have become more important [3]. These frequency ranges have large path losses, according to Friis' formula [4]. To offset these route losses, high gain antennas or arrays are necessary, which may be easily included into millimeter wave circuitry. The MMW bands have been standardized globally by the Federal Communications Commission (FCC). The FCC has recommended regulated bands of 28, 37, and 39 GHz, as well as an unlicensed spectrum of 64-71 GHz, as prospective Fifth Generation (5G) candidates [5]. Antennas developed for 5G must have a minimum gain of 12 dBi and a bandwidth of 1 GHz [6].



Wireless communication was coined in the nineteenth century, and wireless communication technology has advanced in the years thereafter. The electromagnetic exchange of data between at least two centers that are not connected by an electrical connection is known as wireless communication. Antenna is a type of wireless communication. An antenna, also known as an aerial, is an electrical device that converts electric energy into radio waves and vice versa. It's usually used in conjunction with a radio transmitter or radio receiver.

## 1.2 Problem statement

In the years of the twentieth century, all aspects of wireless communications are subject to rapid change throughout the world. As networks become dense, the expense of having fiber into each small cell turns out to be restrictively expensive, consume more time and need more manpower. Moreover, when the gain is poor and its might be not sufficient for a base station, because the coverage is extremely limited due to the narrow wavelength. In some rural areas, the network coverage is very low and the people living there might not having better telecommunication system.

According to research, the fifth generation (5G) of communication has been widely discussed to provide high-speed connectivity in the future. The design and validation of the 5G communication system are dependent upon an understanding of the propagation channels. In the upcoming 5G cellular standards, it is pin one's hopes on upon to satisfy the rapidly developing needs for information by network densification utilizing small cells with high gain limit.

To overcome these issues, a high gain array antenna needs to be proposed to provide greater gain than 10dB which guarantees the antenna catches a greater amount of the signal, again extending signal strength. Then by obtaining return loss value less than -10dB, it offers high quality and capacity network connectivity. Other than that, high gain antenna may cover the more extensive distance concerning 5G communications.

## 1.3 Objective

- To design a high gain array antenna for 5G wireless communication at 3.5 GHz frequency band with a greater gain of 10 dB.
- To investigate the performance of high gain array antenna for 5G wireless communication at 3.5GHz including gain, return loss, directivity, and radiation pattern.

## 1.4 Antenna design specification

The specification references Table 1.1 as it pertains to the research. The specification will serve as the major source of information for constructing the antenna prototype.

| Parameter | Value |
|---|---|
| Operating Frequency, fr | 3.5 GHz |
| Gain, G | >10 dB |

**Table 1.0: Antenna Parameter**



## 1.5 Scope of work

The main goal of this project is to design a high gain array antenna at 3.5GHz for 5G communication by achieving all the objectives. In the process of the designing high gain array antenna for 5G communication, the fundamental achievement of this project is to provide high quality and capacity network connectivity with more gain than 10 dBi for 3.5 GHz.

For the simulation part, CST software 2020 will be utilized to design and simulate the proposed antenna. By using CST software, the antenna design will be more perfect high yielding because this software is provided with variety tools, shapes, and more specifications.

At the fabrication part, the ideal antenna configuration will be manufactured by using FR4 epoxy material with 4.4 permittivity of FR4 is appropriately the most utilized material in PCB construction. Basically, FR4 boards are strong enough, water safe, and give great protection between copper layers that limits impedance and helps great signal integrity. Then the array antenna printed FR4 board will be fixed with SMA port to be connect and test using vector network analyzer. Finally, the software and fabrications output results will be measured and compared to come out with a conclusion.

## 1.6 Project planning

This project starts with a literature search based on the project title, such as 5G Development, 5G Application and design of Array Antenna for 3.5 GHz, from a journal, article, or a website.



The antenna's design and details are likely to be determined in the next step. Several studies will be conducted to determine the best antenna for the millimeter-wave bands of the 3.5 GHz 5G communication. The findings of the studies will be compared to identify the antenna design and specification that will be the focus of this study.

Following the selection of an appropriate antenna design and specification, the antenna will be modelled using CST programming to get the desired result. This method employs a trial-and-error approach to selecting and comparing the best and most appropriate antenna design. Using the CST Software for simulation, the predicted gain should be greater than 10 dBi and the expected return loss should be below -10 dB. If the findings differ significantly from what was intended, the antenna will be redesigned using CST software until it achieves the desired gain and loss, resulting in good coverage quality.

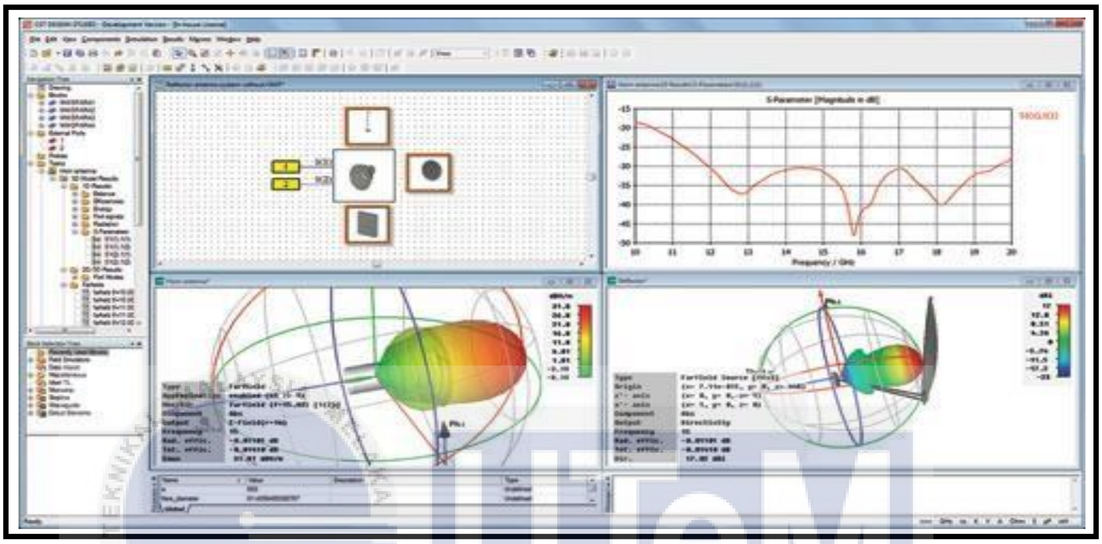

**Figure 1.2: CST Software**



After completing the simulation part, the optimal antenna design will be built using FR4 with a permittivity of 4.4. The readings from measurement and simulation are compared at this step. The final step in completing this project is to write the thesis, which is likely the most important activity in the entire study endeavor. It is a continuous process that documents the early phases of a project all the way to completion.

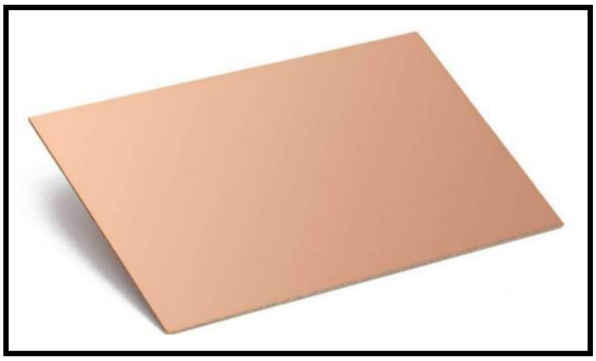

**Figure 1.3: FR4 PCB Board**

## 1.7 Report Structure

The project report is divided into five main chapters. The first chapter is the introduction of the project which contains introduction of the project, objectives, problem statement, scope of work, project planning and report structure. Moving on, the second chapter is about the literature review. It comprises of a literature study of the projects that discuss the genuine title of the project that was completed by previous researchers and is acknowledged as the current title of the project.

The third chapter explains the project's flow, as well as how the design and simulation are done using CST Microwave Studio and how the antenna will be produced. It includes all the technical design of the software and hardware as well, electronic components used in the project, shapes of antenna that will be designed and software that we used to run the simulation.

Following that is chapter four, which contains the outcomes and discussions that have helped to achieve the project's goals. The results of the proposed antenna in terms of gain, efficiency, and directivity have also been examined. Finally, conclusion and recommendation of the project are explained in Chapter five. At the end of the report, the references are included with research paper and online journals explanation which is the final part of this report.

# CHAPTER 2

# BACKGROUND STUDY

## 2.1 Introduction

Writing a literature review is an important step before beginning any project because it provides all the relevant information on the project. As a result, the proper heading in the project's development can be accomplished competently. The system that will be implemented, as well as previous related work, will be clarified in this section.



## 2.2 Previous Related Study

### 2.2.1 Microstrip Rectangular 4x1 Patch Array Antenna for WiMax Applicationat 2.5GHz

For the future, the authors of (Norfishah Ab Wahab et al., 2010) devised a microstrip rectangular patch antenna for WiMAX use with a central frequency of 2.5GHz. A single microstrip patch antenna is shown in Figure 2.10, which comprises of a patch, quarter wave transformer, and feedline. This single antenna is following the length and breadth measurements. Furthermore, FR-4 was employed as the paper's substrate, with a dielectric constant of 4.9 and a thickness of 1.6mm [7].

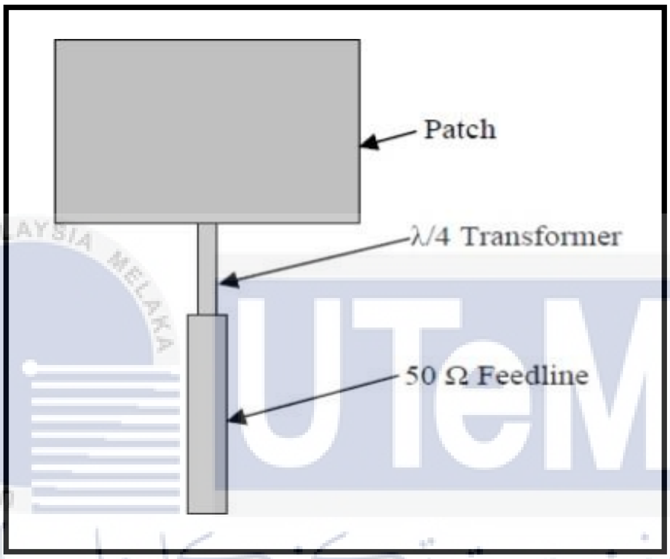


**Figure 2.1: The single microstrip patch antenna**



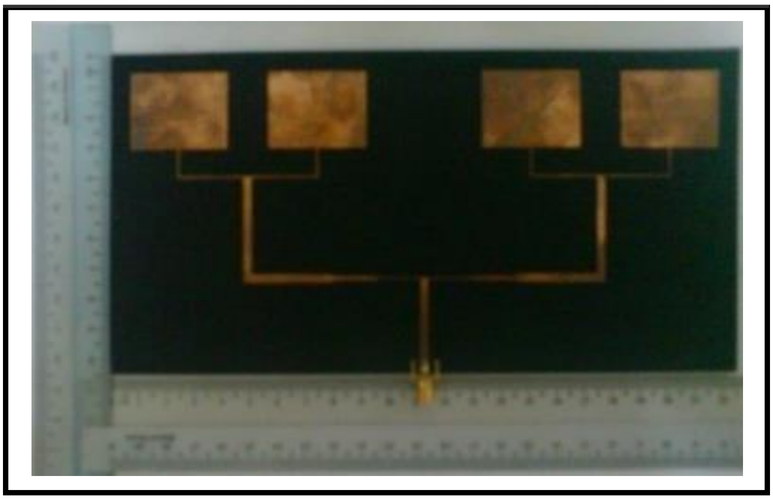

**Figure 2.2: Fabricated 4 elements microstrip rectangular patch array antenna**

A four-component rectangular array antenna was printed and built on FR-4 substrate, as shown in Figure 2.2. For this array antenna, the authors employed the same dimensions as a single patch. To obtain the results, CST Microwave software was used to simulate single and array antennas. The authors declare in Figure 2.3 that this return loss simulation demonstrates little losses at the highlighted moment. The pointed marks represent the corresponding frequency, with the marker at 2.5 GHz and a return loss of -20.24 dB for simulation and - 22.22 dB for measurement at 2.67 GHz.

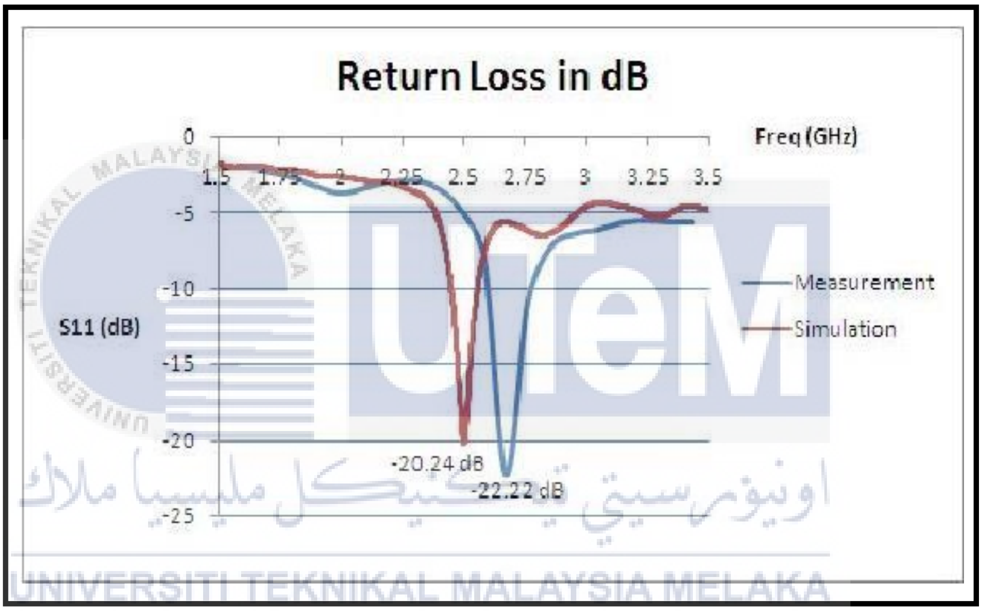


**Figure 2.3: Return loss of 4 elements rectangular patch array antenna**

The radiation pattern for a single antenna with a directivity of 5.898 dB and a gain of just 0.837 dB is shown in Figure 2.4. Figure 2.5 shows the simulated radiation pattern of an array antenna, which shows that the array design antenna provides more intensity or center at the focal point of the radiation with directivity and gain of 10.25 dB and 5.732 dB, respectively, compared to a single patch.

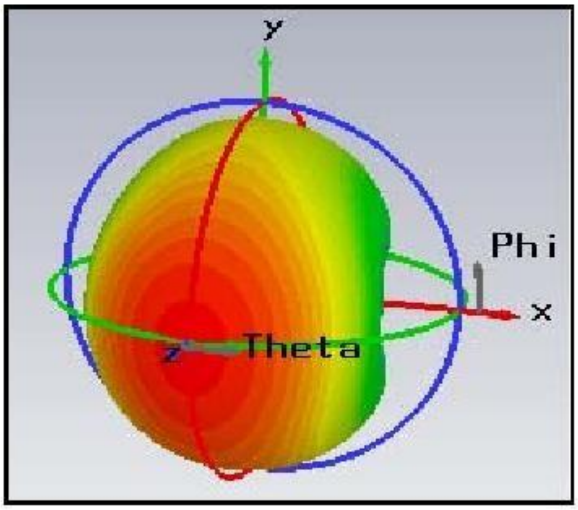


**Figure 2.4: The radiation pattern of single antenna**

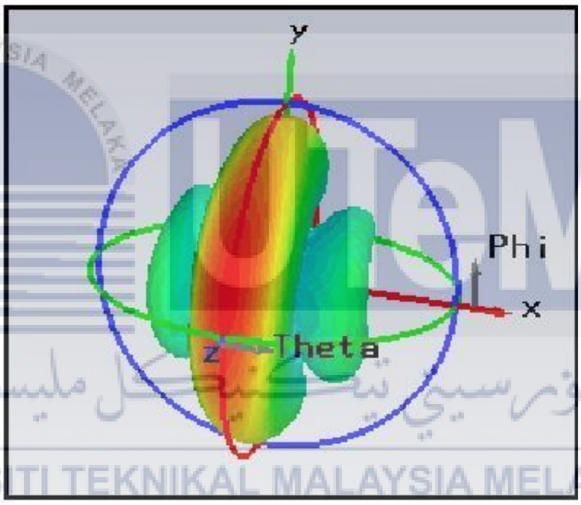




**Figure 2.5: The radiation pattern of array antenna**

### 2.2.2 FR-4 Substrate Based Modified Ultra-Wideband Antenna with Gain Enhancement for Wireless Applications

FR-4 Substrate Based Modified Ultrawideband Antenna with Gain Enhancement for Wireless Applications was developed by K. G. Tan and published in the year 2019. The FR-4 Substrate Based Modified Ultrawideband Antenna with Gain Enhancement for Wireless Applications was explored in this study. The suggested single layer UWB, with overall dimensions of 55 mm by 56 mm and a relative permittivity of 4.3, is constructed from a low-cost FR-4 substrate. The antenna, according to the data, has an impedance bandwidth of 2.2 GHz to more than 12 GHz (138%), which is wider than the conventional UWB band. [8]. Because this research focuses on a single UWB antenna element, an array of UWB antennas could be considered for a greater gain value.

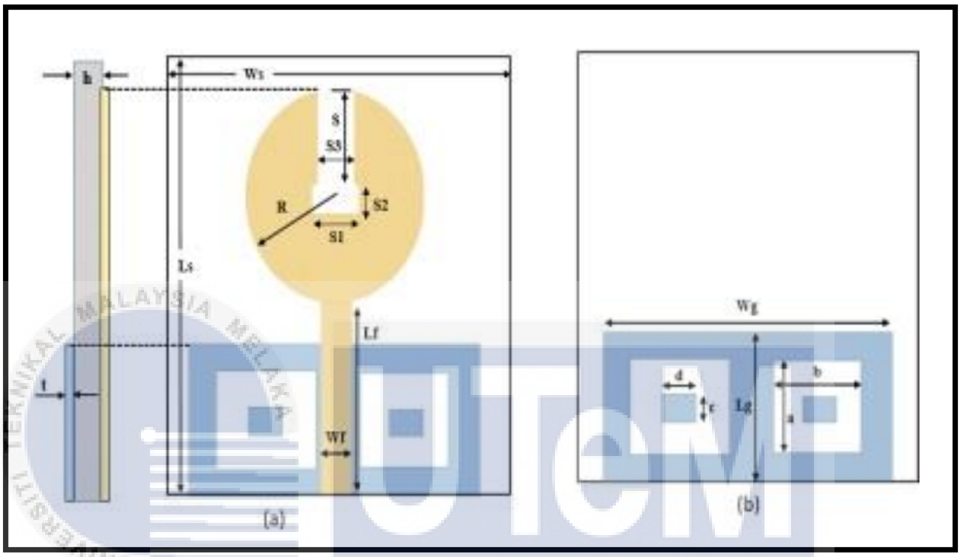


**Figure 2.6: Modified UWB antenna geometry. (a) Antenna front and side views, (b) Antenna back view**



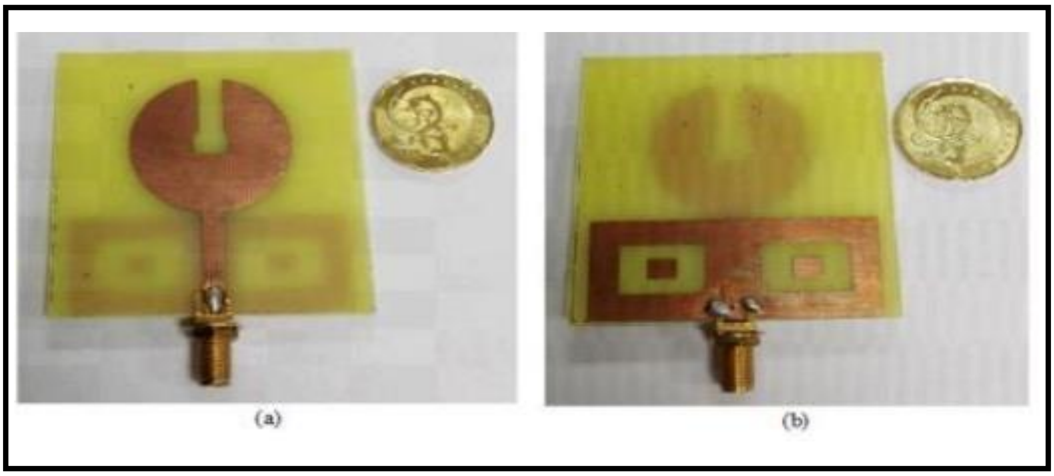


**Figure 2.7: Fabricated modified UWB antenna using FR4. (a) Prototype front view, (b) Protype back view**

As shown in Figure 2.8, the antenna gains of the proposed modified UWB and standard UWB antennas are compared over a wide frequency range. At 8 GHz, the antenna with the modified form may attain a maximum gain of more than 6.5 dB, whereas the maximum gain of a standard UWB antenna is only 5.5 dB [8]. As a result of the incorporated slots in the patch and ground plane, the UWB antenna gain has increased. At the Wi MAX working frequency, a gain of more than 3 dB is realized (5.4 GHz).

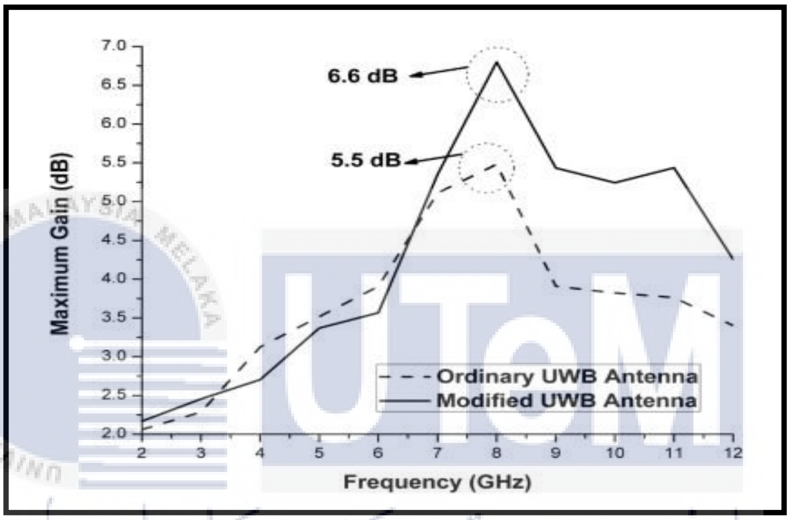


**Figure 2.8: Gains comparison of the modified UWB antenna and ordinary UWB antenna.**



Figure 2.10 depicts a comparison of modelling and measurement results for a redesigned UWB antenna. The manufactured antenna has a wide bandwidth, but it starts at a higher frequency than the simulated findings. The permittivity tolerance variation of the FR-4 board is responsible for this movement.

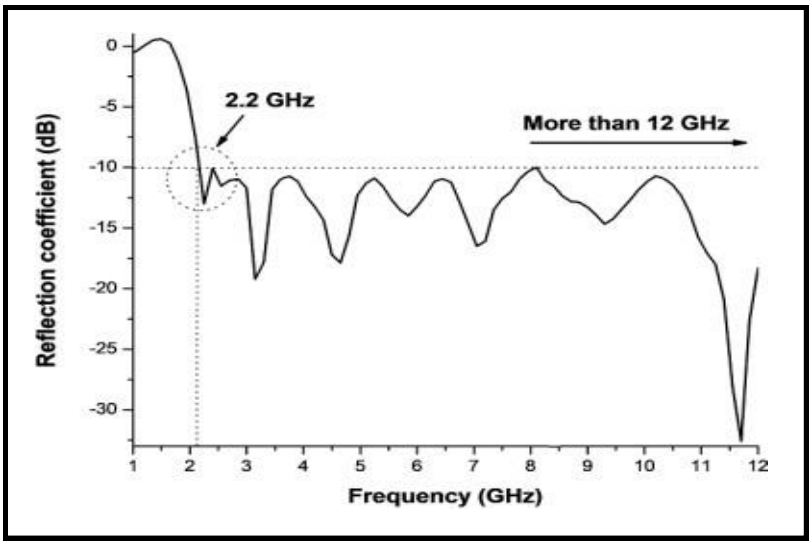


**Figure 2.9: Proposed ultrawideband antenna measured reflection coefficient and bandwidth**

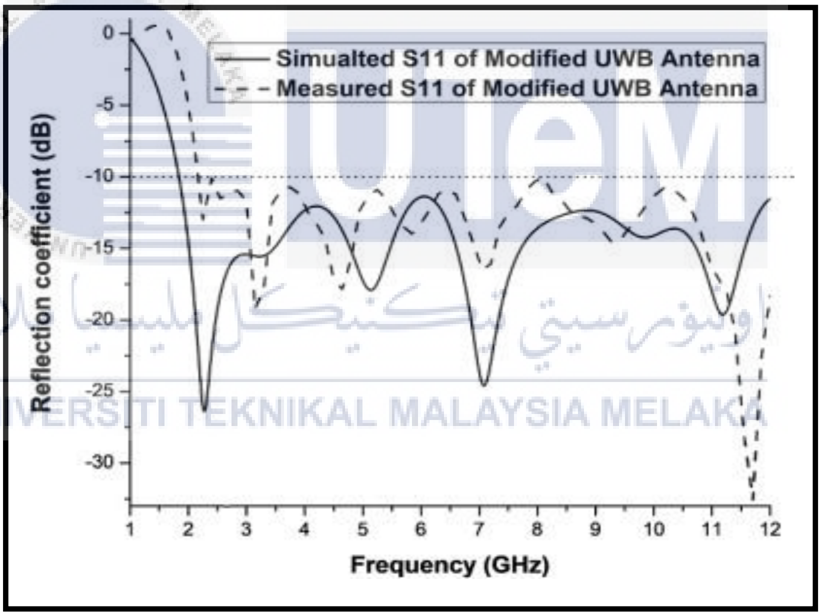




**Figure 2.10: Simulated and measured reflection coefficient and bandwidth of modified UWB antenna**

The radiated patch and partial ground plane were modified to provide a wide impedance bandwidth and high realized gain. This UWB antenna has a -10 dB bandwidth of 2.2 to more than 12 GHz, which is equivalent to 138 percent fractional bandwidth. Furthermore, the modified UWB antenna has a gain of more than 6.5 dB at its maximum [8]. Because this research focuses on a single UWB antenna element, an array of UWB antennas could be considered in the future. Furthermore, more efficient substrates, such as Roger boards, can be employed to improve UWB antenna performance.

### 2.2.3 Array of Circular Microstrip Patch Antenna

Urwashi Vithal Miringkar and Asst.Prof. Palhavi Kerkar published an array of circular microstrip patch antennas in April 2019. The antenna is made up of 1x4 arrays. The antenna runs at a frequency of 3.5GHz. Circular antennas provide a lower return loss, higher gain, and greater directivity than rectangular antennas [9]. The basic goal of employing the array is to increase antenna gain. To design, an inset feed is used. Design formulae dictate the size and feed technique, and simulation is performed using le3d software.

Antenna arrays are commonly employed because they boost radiated power and create a high directed beam, preventing power loss in other directions. The arrays are mostly used to enhance the radiation pattern. Arrays improve the antenna's directivity and enable electrical steering, which removes the need for servo motor-based mechanical steering. As a result, the beam may be moved in milliseconds or less. Radar and surveillance systems both employ arrays for tracking. A basic arrangement of items constitutes array configuration.

The resonance frequency of the antenna array is 3.5GHz, and this study has designed a patch antenna array made of FR4 substrate. The relative permittivity of the FR4 substrate is 4.4. Fr4 has a loss tangent of 0.02 and a thickness of 1.6mm. A circle patch with a radius of 12mm is created, and one circular element is used to create a 1x4 array.

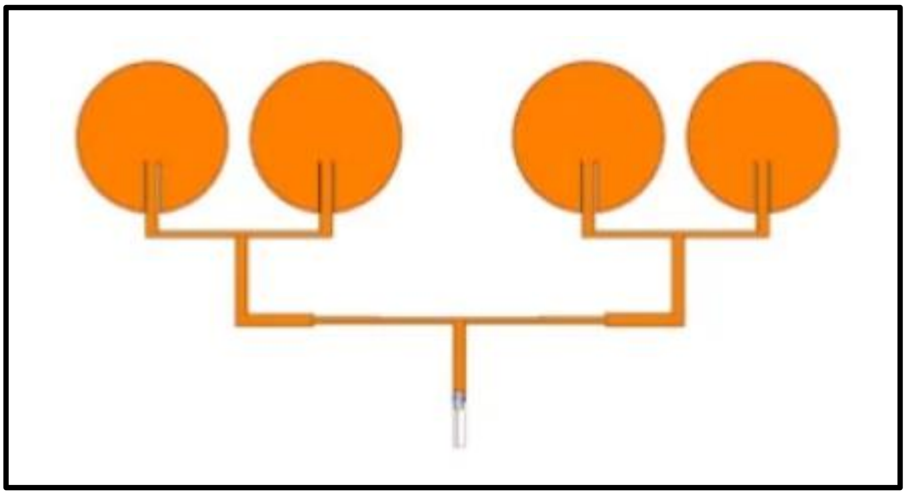

**Figure 2.11: 1x4 array antenna**

This is a 1x4 antenna array design. On a FR4 substrate, it comprises of four circular patch antennas with inset feed techniques. This antenna is designed using the inset feed approach. The line feed has a width of 25.8mm and a length of 3mm, which is determined using the relevant formulas.

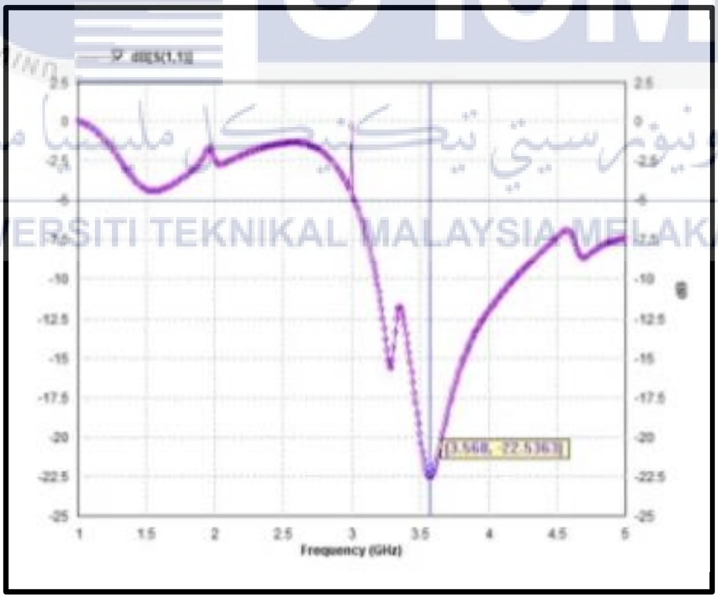


**Figure 2.12: Return loss (S11 parameter)**

The above figure shows the return loss of 1x4 antenna array. The return loss of -22.5dB is obtained at 3.5GHz. The desired return loss for the antenna must be less than -10dB.

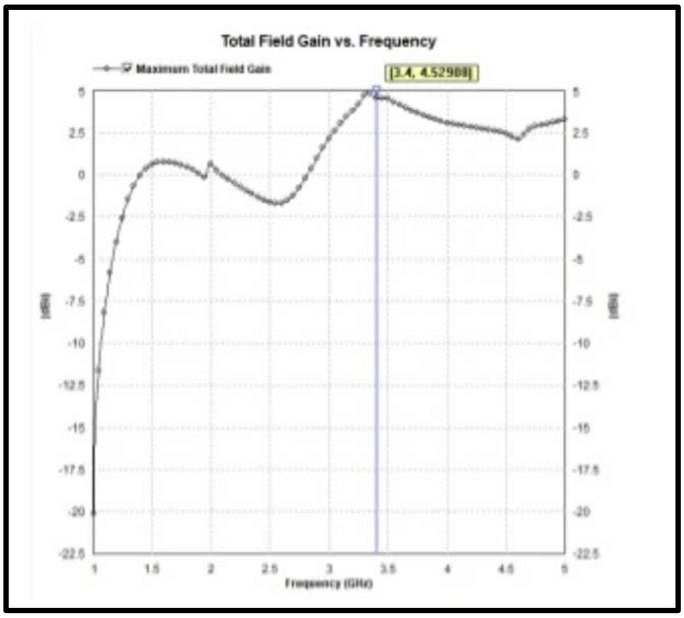


**Figure 2.13: The simulated gain for the proposed configurations**

The graph of gain vs. frequency is shown in Figure 2.13. An antenna's gain is a critical characteristic that determines how much total power is emitted in each direction. Gain is measured in decibels (dBi). 4.52dBi gain is realized.

As a result, a 1x4 microstrip patch array antenna operating at 3.5GHz has been constructed in this study. Several antenna characteristics, including as gain and return loss, are calculated. The increase attained is 4.52dBi, which is significantly higher than the single patch. The gain of single patch antennas is 2-3dBi. The obtained return loss is -22.5dB. The findings show that the performance is satisfactory. As a result, we may infer that a 1x4 array antenna enhances the antenna's gain and performance.

### 2.2.4 Design of A Small Patch Antenna At 3.5 GHz for 5G Application

The Microstrip Patch antenna is made up of three main components: Substrate, Patch, and Ground Plane. A low-profile patch antenna for 5G applications has been developed by (Nayla Ferdous et al., 2019) [10]. For 5G deployment, the resonating frequency for this project is 3.5GHz. To create this antenna, FR4 epoxy material with a permittivity of 4.3 was used. For the simulation result, the suggested antenna is designed using CST microwave studio software. The z-axis height (h) of the FR4 substrate is 1.6 mm. Figure 2.15 depicts the suggested microstrip patch antenna design.

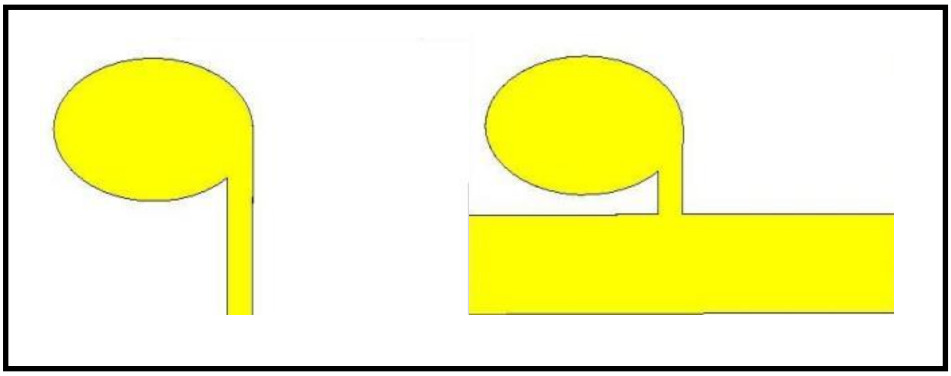

**Figure 2.14: Front and back view of proposed microstrip patch antenna**

At 3.5 GHz, this antenna has a return loss of -30dB. The results show that the antenna has a very low return loss at 3.5 GHz, as shown in Figure 2.16, implying that the antenna will transmit a significant quantity of signal. At the resonance frequency, the antenna gain is 5.01 dB, as shown in Figure 2.19. In the meanwhile, the antenna has a very high efficiency of 96.67 percent.



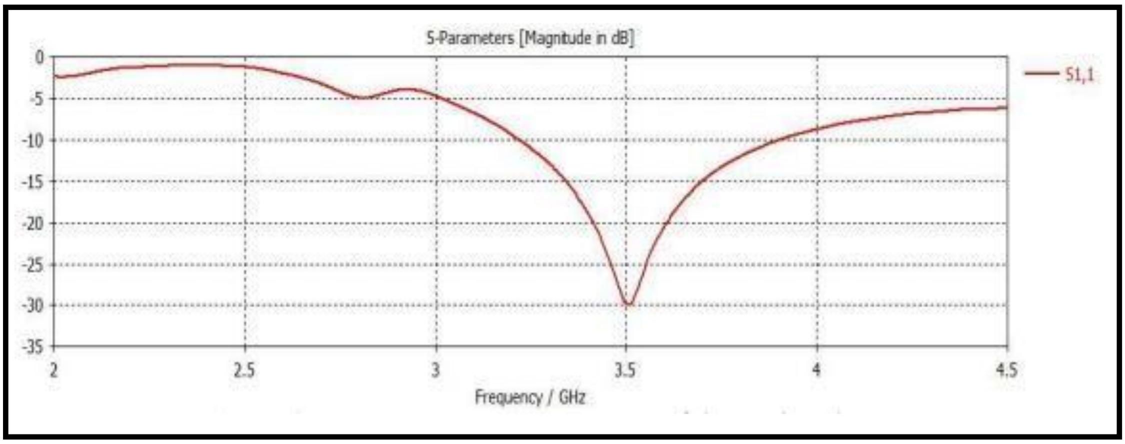


**Figure 2.15: S11 Parameter of the Designed Antenna**

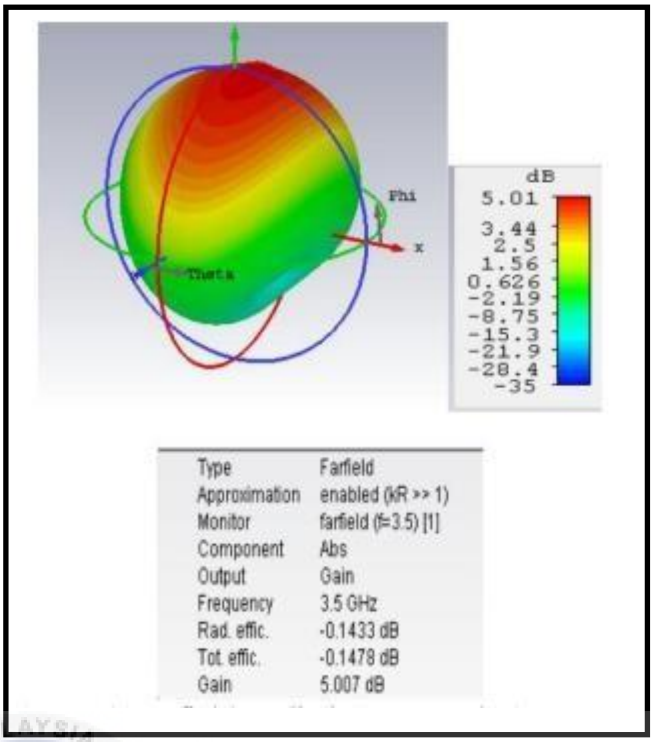


**Figure 2.17: Radiation Pattern in Three Dimensions**

A compact elliptical antenna has been built for use at 3.5 GHz for 5G applications in this research. The antenna's physical dimensions are 25.2 X 45 mm2. At 3.5 GHz, it has a return loss of -30dB. The gain of the antenna is 5.01 dB. The antenna's efficiency is quite high, at 96.67 percent.



**2.2.5 U-slot Microstrip Patch Antenna for Wi-Max Applications**

On a resonant frequency of 3.6 GHz [11], (Saraff Sahithi, S.Ashok Kumar, and T. Shanmuganantham, 2018) developed a U-slot microstrip antenna design. This antenna is intended to boost bandwidth performance and is suitable for WiMax applications. The suggested antenna was created with the help of the IE3D software simulator [11]. The substrate is a 1.6mm thick RT/ Duroid 5880 with a dielectric constant of 2.2 and a loss tangent of 0.0009. Figure 2.18 shows the microstrip patch u slot antenna construction.

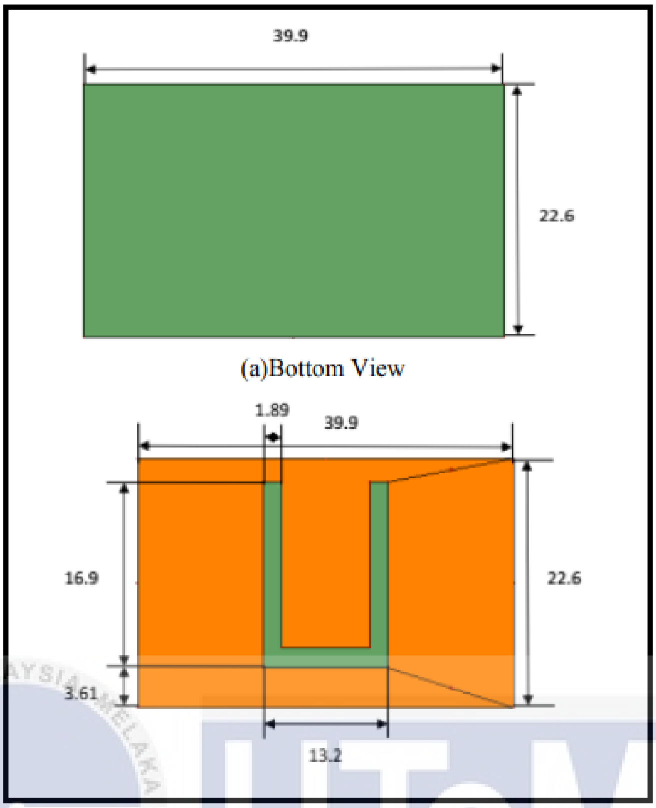


**Figure 2.18: Antenna structure**

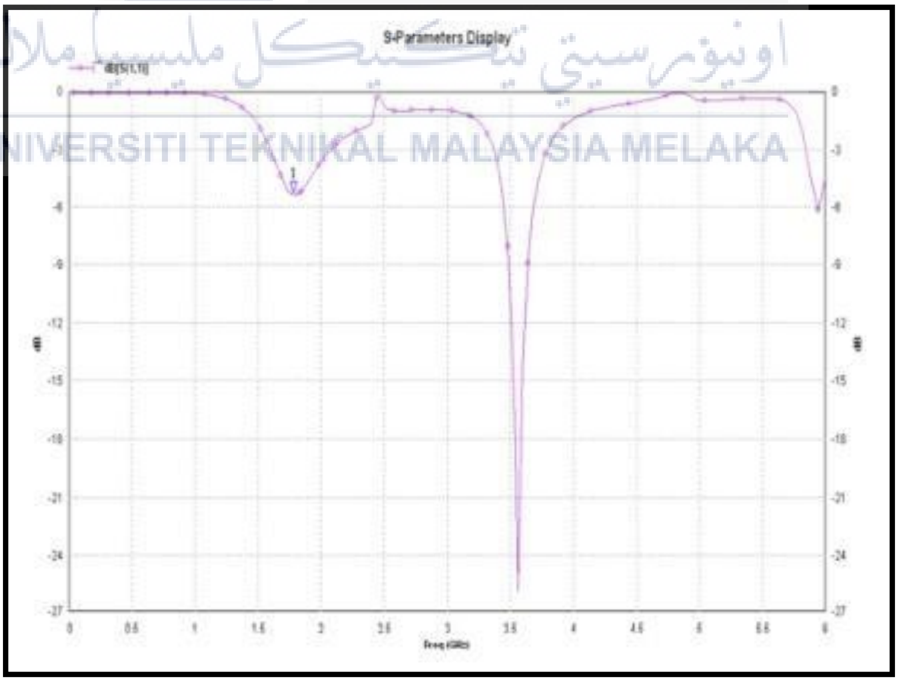


**Figure 2.19: Characteristic of return loss**

At the resonance frequency of 3.6GHz, the antenna return loss is -26 dB, which is a fantastic result as shown in Figure 2.19. The lower the return loss, the fewerthe interferences between the signals, and the smaller the reflection, the better the execution. Meanwhile, the antenna has an incredibly high efficiency of 80%, which is superior to the planned antenna's features and performance.

### 2.2.6 E shape Patch Array Antenna

E shape patch antenna array without DGS is proposed for WIMAX use by Priyanka R. Sonkar and Prof Arbitrator from the Department of Electronics Engineering, Yeshvantrao Chavan College of Engineering Nagpur. For the frequency ranges 5.66GHz and 7.12GHz, the reflection coefficient is less than -10dB [12]. To increase antenna parameters like as gain, bandwidth, and directivity. The frequency of operation for this antenna is broad band.

An antenna is a specialized transducer that converts radio frequency (RF) signals into alternating current (AC) fields or the other way around. Because of their tiny size and ease of fabrication, microstrip patch antennas are commonly employed. It is light in weight and has a cheap fabrication cost. Create a two-by-two E-shape array ground.

Figure 2.20 depicts the antenna from the front. It is made from a 2by2 array. 5.66GHz and 7.2GHz are the operational frequencies. The goal is to create a broad band frequency design with the following specifications, FR4 lossy dielectric constant 4.4mm, h=1.6 loss tangent =4.4. The circular DGS defective ground structure is used to prevent the antenna from interfering. The rear perspective of the E shape patch antenna is illustrated in Figure 2.21.

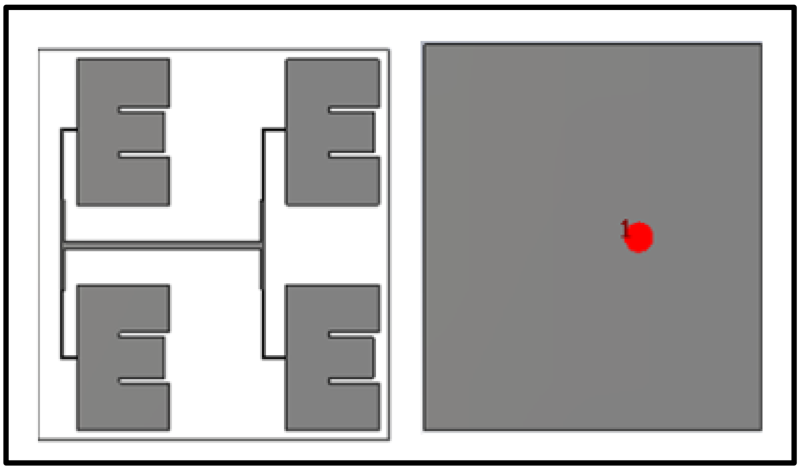


**Figure 2.20: Front and back view**

The scattering parameter (S) describes how the travelling current and voltages in a transmission line are distributed. The S11 parameter, also known as the reflection coefficient, measures how much power is reflected from the antenna. If S11 is equal to 0dB, all the power is reflected by the antenna and no power is broadcast. If S11 is -10db, this means 3dB of power is given to the antenna and -7dB is reflected power.

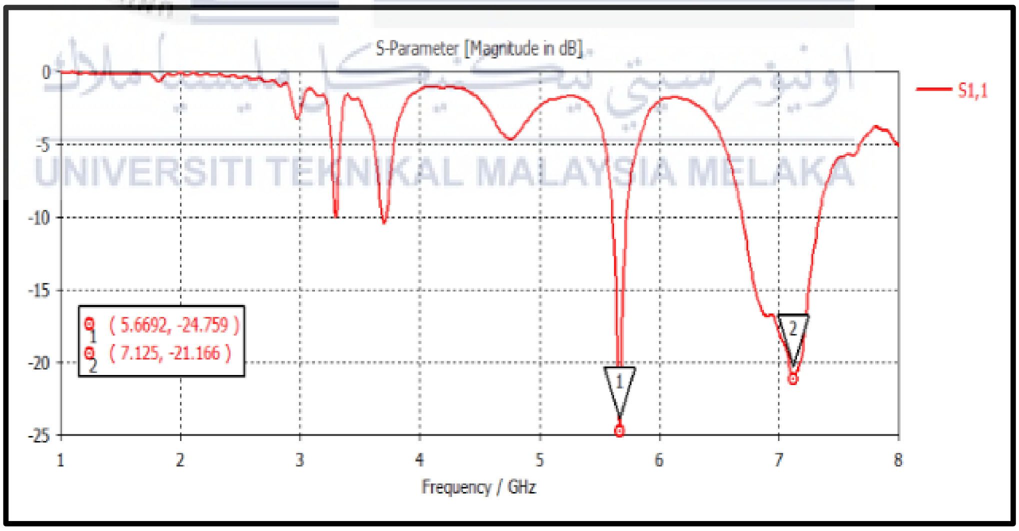


**Figure 2.21: S11 parameter of proposed antenna**

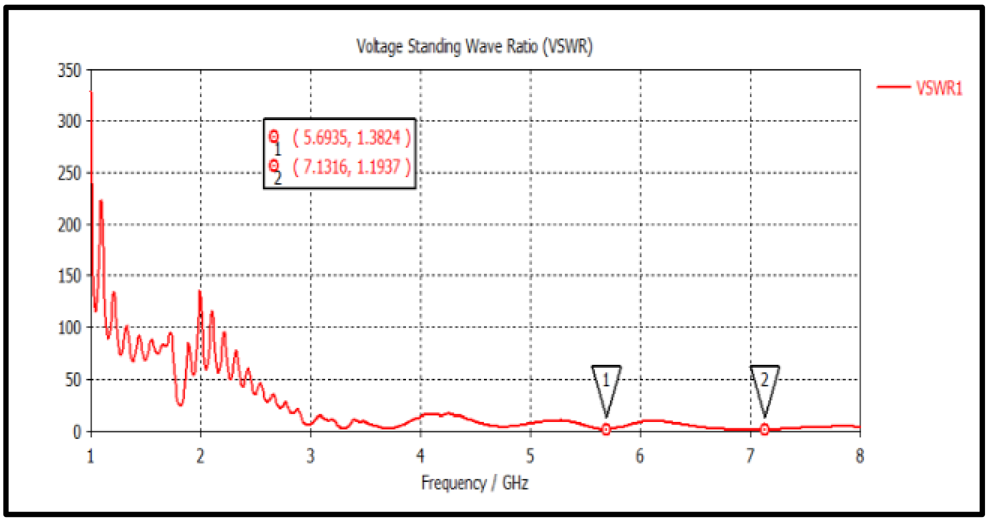


Figure 2.22: VSWR of proposed antenna

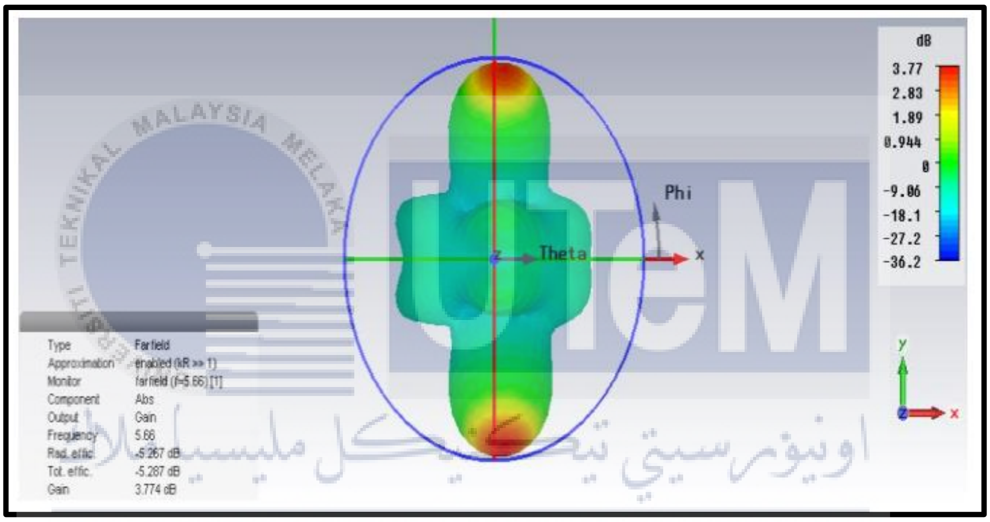




Figure 2.23: Gain value at 5.66GHz of proposed antenna

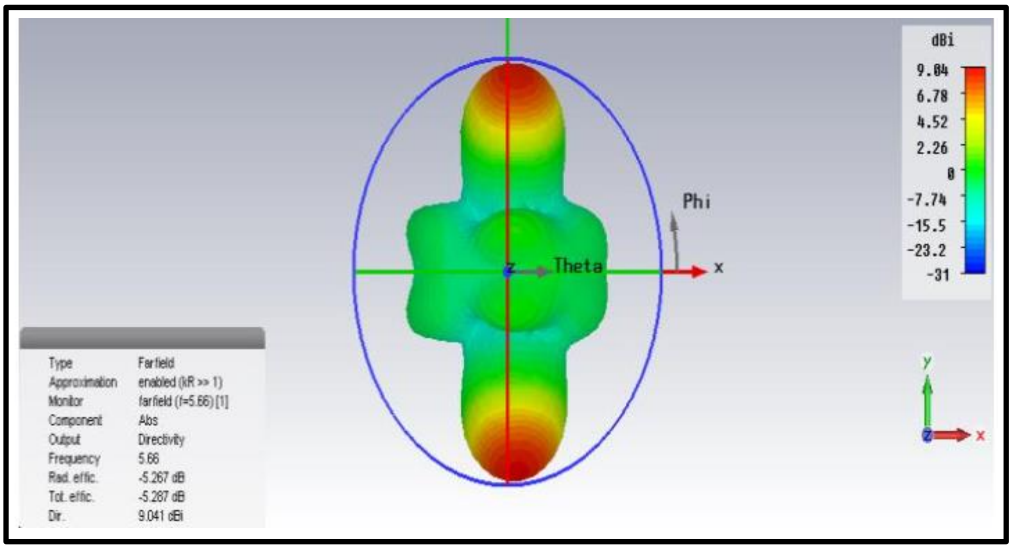


Figure 2.24: Directivity value at 5.66GHz of proposed antenna

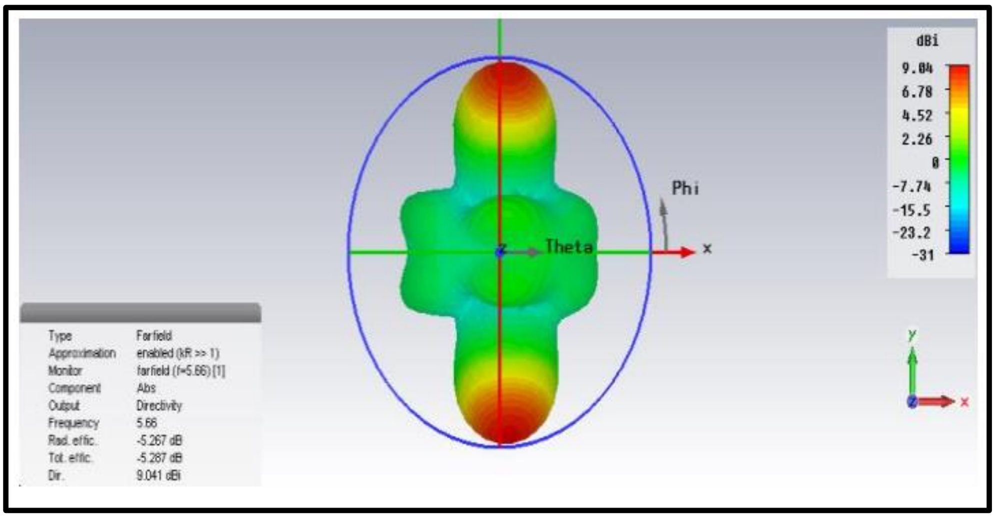


**Figure 2.25: Gain value at 7.12GHz of proposed antenna**

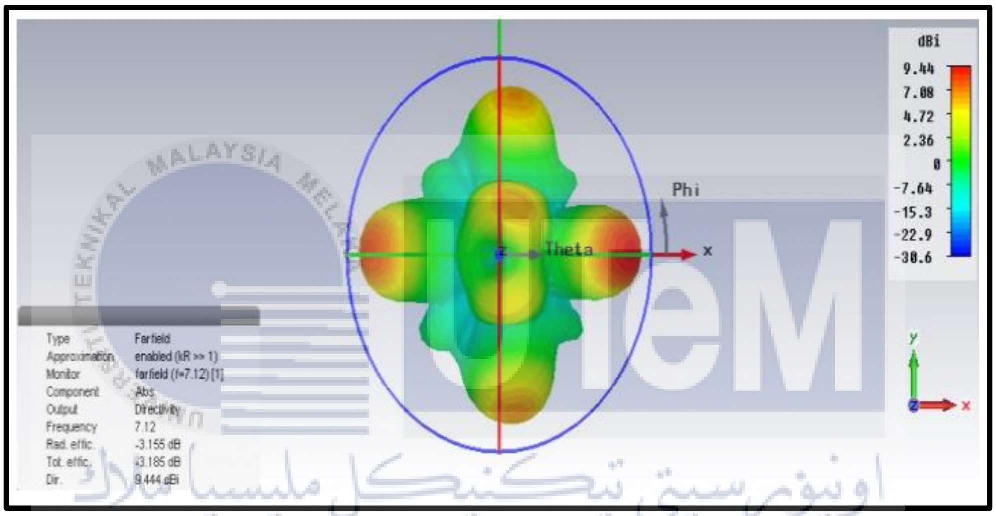


**Figure 2.26: Gain value at 7.12GHz of proposed antenna**



| Total Field Property | |
|---|---|
| 5.66GHz | |
| Gain | 3.7 |
| Directivity | 9.04 |
| 7.12GHz | |
| Gain | 6.2 |
| Directivity | 9.4 |

**Figure 2.27: Characteristics of the proposed model**

At frequencies of 5.6GHz and 7.12GHz, the Eshape microstrip patch antenna performs better. The antenna can be used to communicate wirelessly.

## 2.3 Analysis of Different Substrate Material & Frequency on Microstrip Patch Antenna

Antenna radiation capability is improved by using substrates [13]. Substrate identification is important for building a microstrip patch antenna, according to (Shankar and Chaurasiya, 2016). A decent antenna may be made by choosing the right parameters, such as length, breadth, height, and constant dielectric. An antenna must meet the following criteria to get the greatest results: size, efficiency, and cost [14]. The gain of a microstrip antenna will often decrease when the antenna size is reduced. The dielectric constant and the loss tangent are two essential parameters for substrate material, according to (Srivastava and Pradhan, 2017). FR-4, Roger 4350, RT- Duroid, Foam, and other substrates are commonly used in microstrip patch antennas [15].



| Substrates | εr | Loss Tangent | Resonance frequency | Return Loss (dB) | Gain (dB) |
|---|---|---|---|---|---|
| FR-4 | 4.4 | 0.018 | 5.8GHz | -14.73 | 9.8 |
| Roger 4350 | 3.48 | 0.004 | 2.586GHz | -25.29 | 4.62 |
| RT-Duroid | 2.2 | 0.0009 | 10GHz | - | 12.03 |
| Foam | 1.05 | 0 | 454MHz | -16.732 | 2.73 |
| Nylon Fabric | 3.6 | 0.0083 | 989MHz | -35.42 | 6.11 |
| Benzocyclobutane | 2.6 | 0 | 2.04GHz | -18.124 | 5.5 |

**Table 2.1: Comparison on Various Substrate of Antenna**

| Substrates | Efficiency (%) |
|---|---|
| FR-4 | 99.60 |
| Roger 4350 | 99.66 |
| RT-Duroid | 88.64 |
| Foam | 61 |
| Nylon Fabric | - |
| Benzocyclobutane | 96.51 |

**Table 2.2: Comparison based on Efficiency**

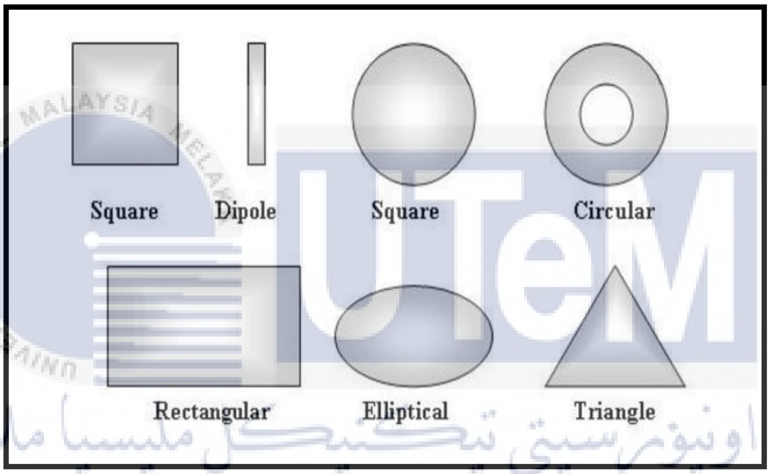


**Figure 2.28: Common available shapes of Microstrip patch**

## 2.4 Feeding Techniques and Methods

For antenna feeding approach, a variety of methodologies and measuring procedures have been presented. According to the author (Sharma, 2017), there are two types of this technique: contacting and non-contacting. The factor of effective power transmission between the radiation structure, feeding structure, and their impedance matching affects the feeding strategy. Microstrip line feed, coaxial feed, gap coupledfeed, and proximity couple feed are the four most well-known feeding methods. According to the study article, the inset feed microstrip will produce the best results because the impedance matching in inset feed antennas is acceptable [16].

## 2.3 Summary of Literature Review

| Research Title | Authors | Year | Results | Limitations |
|---|---|---|---|---|
| Microstrip Rectangular 4x1 Patch Array Antenna at 2.5GHz for WiMax Application | Norfishah Ab Wahab, Zulkifli Bin Maslan, Wan Norsyafizan W. Muhamad, Norhayati Hamzah | 2010 | Directivity =10.25 dB<br>Gain = 5.732 dB<br>Return loss = -20.24 dB | Rectangular 4x4 Patch Array Antenna at 2.5GHz might be investigated for increased gain. |
| FR-4 Substrate Based Modified Ultrawideband Antenna with Gain Enhancement for Wireless Applications | K. G. Tan, S. Ahmed, Abdelsalam Hamdi, C. X. Ming, K. Abdulwasie, Ferdous Hossain, Choo-Peng, H. Basarudin, Mohd Khairil Rahmat and Vinesh Thiruchelvam | 2019 | Maximum gain of more than 6.5 dB. Provide -10 dB bandwidth ranging from 2.2 to more than 12 GHz. | Roger boards can be employed to improve UWB antenna performance. An array of UWB antennas could be consider for greater gain. |
| Array of circular microstrip patch antenna | Urwashi Vithal Miringkar and Asst.Prof. Palhavi Kerkar | 2019 | Peak gain of 4.52dBi.<br>Return loss is -22.5dBi | For a higher gain value, a circular 2x4 array antenna might be explored. |

| | | | | |
|---|---|---|---|---|
| Design of A Small Patch Antenna At 3.5 GHz for 5G Application | Nayla Ferdous, Goh Chin Hock, Saidatul Hamidah A.Hamid, M. Nazri A. Raman, Tiong Sieh Kiong, Mahamod Ismail | 2019 | Return loss = -30 dB<br>Gain = 5.01 dB | The return loss is ideal, but the gain is below expectations; perhaps the patch antenna size could be increased. |
| U-slot Microstrip Patch Antenna for Wi-Max Applications | Saraff Sahithi, S.Ashok Kumar and T. Shanmuganantham, | 2018 | Return loss = -26 dB | There is relatively little gain, andantenna dimensionsmay alter. |
| E shape Patch Array Antenna | Priyanka R. Sonkar and Prof Arbitrator | 2019 | Gain 3.7dBi at 5.66GHz<br>Gain 9.4dBi at 7.12GHz | For improved antenna gain, the size of an E shape antenna might be deemed large. |

**Table 2.3: The summary of Literature Review**

To sum up this section, choosing the right material for a good antenna with a good radiation pattern, efficiency, and gain is critical because it affects the antenna's performance.

# CHAPTER 3

# METHODOLOGY



## 3.1 Introduction

This chapter explored the procedures for advancing this research through all the processes. The number of ways used by researchers to complete their work of explaining, characterizing, defining, and predicting events is referred to as methodology. The next section will provide an overview of the work technique, followed by a more detailed description. Throughout the antenna creation process, this project necessitates the use of a theoretical concept and an experimental method.

A flow chart in Figure 3.1 is refined to explain the technique for the study to meet the goal stated in Chapter 1. The flow chart is significant since it shows how the study will be carried out in each stage and route. It goes into great information about what will be done, how it will be done, and what actions should have been taken to achieve the study's goals.

Before getting the results, a few steps were done to conclude this project by constantly referring to the study planning flow chart. Conducting research in a journal, article, book, or other related source is one of the steps. The journals and publications relevant to this project are expected to be used as an important design and parameter calculation for this project. This journal aided in the comprehension of the antenna.

The simulation results will be produced using Computer Simulation Technology (CST) Microwave Studio. All fundamental elements, such as return loss, gain, and radiation pattern, are replicated by this software. It is vital to examine whether this project has met its key objectives as it nears completion.

## 3.2 Project Flow Chart

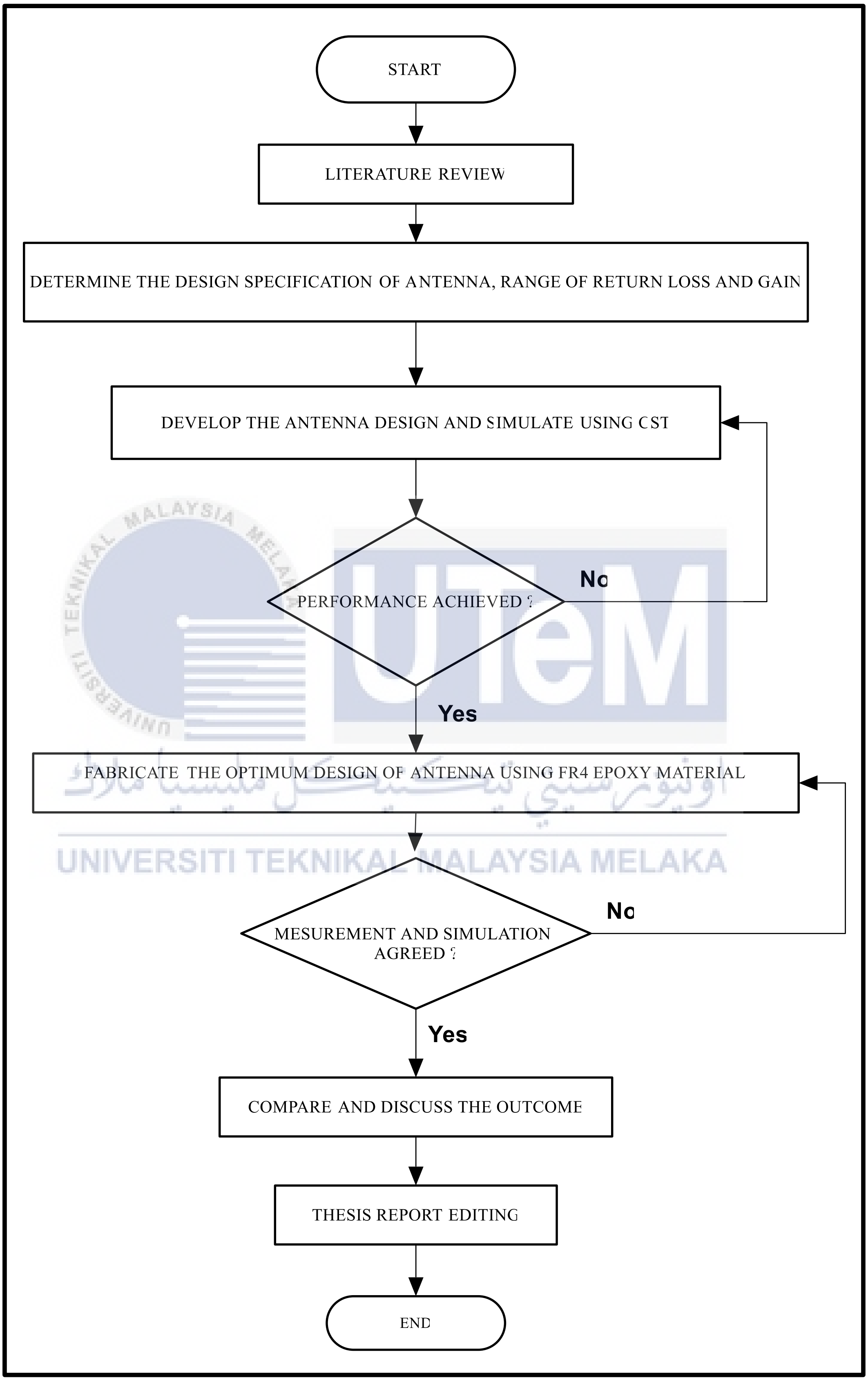


**Figure 3.1: Flow Chart**

## 3.3 Research Progress

To complete this project, the first stage will consist of a literature study, the second stage will consist of an array antenna design review, and the third stage will consist of assessing and optimizing findings at the operating frequency of 3.5 GHz.

### 3.3.1 Stage 1: Literature Review

The first step of this project should begin with literature research based on the project topic, such as 5G Development, 5G Application, and design of Array Antenna for 3.5GHz, from journals, articles, or websites. All the factors that were used in the prior project's study should be listed and described in the literature review section. The purpose of doing literature research is to find a similar project that involves designing a high gain array antenna at 3.5 GHz for a 5G communication. By doing this step, some hidden information, or tips for develop the project can be gathered. As a result, the specification and dimension design are resolved as a design reference in this study.

### 3.3.2 Stage 2: Design Review



The antenna will be modelled up using CST software after defining the appropriate design and specification of the antenna to meet the aim. This method uses a trial-and-error method to choose and compare the best and most appropriate high gain array antenna design. Using the CST Software for simulation, the predicted gain should be greater than 10dBi and the expected return loss is -10dB. If the findings differ significantly from what was intended, the antenna will be redesigned using CST software until it reaches the desired gain and loss, resulting in high coverage quality.

### 3.3.3 Step 3: Analysis of Simulation of Results

The last stage is to run a simulation on the suggested design, which is likewise done with CST software. Following the simulation results, the various designs will be compared and assessed to see if they are acceptable for the 5G communication's projected outcomes.

Because the primary goal of this project is to create a high-gain array antenna, the outcomes will be centered on the antenna's gain parameter. A perfect, suggested antenna should have a high gain and a consistent loss gain, as well as a better radiation pattern and directivity.

## 3.4 Antenna Parameter

The suggested antenna should adhere to the antenna's properties to the specific requirements, which might include gain, directivity, return loss, radiation pattern, VSWR and impedance. It is necessary to depict the significance of antenna using several characteristics.



### 3.4.1 Gain and Directivity

An antenna's gain is the ratio of the intensity in each direction to the radiation that would be received if the antenna's power was delivered isotropically. The power accepted (input) by the antenna divided by $4\pi$ equals the radiation intensity corresponding to the isotropically radiated power. The gain function is defined as follows:

$$G = 4\,\pi \frac{U(\theta,\emptyset)}{Pin} \tag{3.1}$$

Where:

$U(\theta, \emptyset) = Radiation\ intensity$

$Pin = Total\ input\ (accepted)\ power$

The ratio of radiation density intensity in a supplied guidance from the antenna to the radiation intensity average across the whole course defines an antenna's directivity. In a static situation, the antenna directivity might be used to focus the radiation beam on the desired direction. An omni-directional antenna is used in dynamic systems where the transceiver is not stationary, and the antenna should emit equally in all directions. The directivity of antenna is given as:

$$D = \frac{4\pi U}{Prad} \tag{3.2}$$

The relation between directivity and gain can be given as:

$$G = \eta D \tag{3.3}$$

Where:

$\eta = Antenna\ efficiency$

### 3.4.2 Return Loss

The return loss is the decibel ratio of the reflected power to the incident power (dB) [17]. This occurs when a signal is delivered down a transmission line and some of the signal power is continually reflected or returned to the source due to transmission line discontinuities. A connection to a system, another transmission line, or a connector might be the source of the break. As a result, return loss is the measurement of this reflected power. The return loss is assumed by:

$$Return\ Loss\ (RL) = 10\ log10 \frac{\text{Pout}}{\text{Pin}} \tag{3.4}$$

Where:

$Pin = The\ incident\ power$

$Pout = The\ reflected\ power$

Then, return loss can be expressed in term of the reflection coefficient r as:

$$Return\ Loss\ (RL) = -20\ log|\Gamma| \tag{3.5}$$

Where:

$\Gamma = Reflection\ coefficient$



And the r, reflection coefficient can be expressed as: $\Gamma = \frac{Vr}{\text{Vt}}$ (3.6)

Where:

$Vr = Reflected\ wave$

$Vi = Amplitude\ of\ incident\ wave$

The return loss should be less than -10 dB, for the antenna to radiate effectively.

### 3.4.3 Radiation Pattern

At a fixed distance from the antenna, the radiation pattern may be represented as the total intensity of the transmitted field in many ways. The radiation pattern may also be characterized as a three-dimensional graphical depiction of the antenna's radiation as a function of direction.

### 3.4.4 VSWR

VSWR stands for Voltage Standing Wave Ratio and is also known as SWR Standing Wave Ratio, which is a function that describes how much power is reflected from an antenna. The VSWR value is always a true and positive number of antennas. The lower the VSWR, the better the antenna matches the transmission line, and the more power is sent to the antenna. VSWR can be defined as:

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \tag{3.7}$$



### 3.4.5 Impedance

As stated in the conventional definition, "Impedance matching" occurs when the approximate value of a transmitter approaches the approximate value of the impedance of a receiver, or vice versa. The antenna and the electronics are connected using impedance matching. Impedance is set to match the maximum energy that moves between an antenna and a transmission line, as well as the transmission line's characteristic impedance and the antenna's input impedance, so that maximum power is transferred between the antenna and the receiver or transmitter.

The reflected wave will be produced by the antenna's terminal and will return to the source of energy it was not matched to. The standing wave ratio (SWR) is calculated by dividing the greatest power by the minimum power of a wave, with an ideal value of 1. SWR may be reduced by limiting the difference in impedance matching and limiting the amount of power sent through each section of the antenna system.

### 3.5 Determination of Antenna dimension

Before building a single microstrip patch antenna using various shapes, several thingsor important parameters should be considered, such as length (L), width (W), radius (a), height of the dielectric substrate (h) of the patch, dielectric constant of the substrate(r), and operating frequency. The suggested antenna is made from FR4 substrate material with a dielectric constant (r) of 4.4 and a thickness of 1.6 mm. The antenna's base layer is made from a totally ground plane made of copper with a thickness of 0.035mm. The parameter setup for antenna design is listed in Table 3.1.



| Parameter | Symbol | Value |
|---|---|---|
| Resonant Frequency | f | 3.5Ghz |
| Dielectric constant | εr | 4.4 |
| Thickness of substrate | hs | 0.035mm |
| Thickness of copper | ht | 1.6mm |
| Gain | G | ≥ 10dB |
| Return Loss | S11 | ≤ -10dB |

**Table 3.1: Parameter Setup for Antenna Design**

### 3.6 Shape of Microstrip antenna

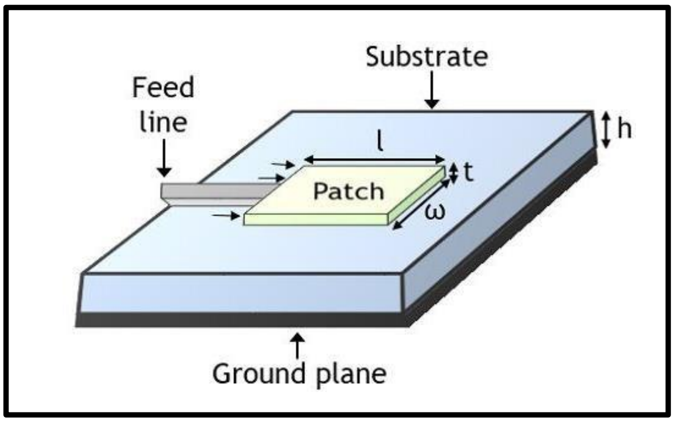


**Figure 3.2: Structure of Microstrip antenna**

This project created various designs of microstrip patch antenna with a 3.5 GHz as central frequency. A microstrip patch antenna, as shown in Figure 3.2, consists of a radiating patch, substrate, and ground plane. A thick dielectric is preferred because it has a higher efficiency, a wider bandwidth, and a better radiation pattern.

### 3.7 Designing 3.5 GHz Single Microstrip Patch Antenna

Before designing and simulating the operating frequency of 3.5 GHz for high gain array antenna, the theory of the issue was examined for the perfect shape of microstrip antenna. Throughout this designing journey, it takes various of values and suitable shapes to create the perfect basement for the project beginning [18]. The CST programme allows users to create antenna models, run simulations, and view the results. CST software was chosen for this project because of the precision demonstrated during the initial test and because of its wide-ranging use, which generates massive amounts of online documentation. To determine the components of a radiating patch, appropriate equations are employed, but the form of the patch, which rectangular shape patch antenna with inset feed is still considered [19].

## 3.8 Design Single Rectangular Microstrip Patch Antenna

The rectangular patch was employed as the basic beginning design in this study. As a result, the formulae for calculating rectangle patch dimensions are as follows [20]:

The patch's width can be estimated using the following formula:

$$W = \frac{c}{2f\,\frac{\sqrt{\varepsilon r + 1}}{2}} \qquad (3.1)$$

Where:

$c$ = $speed\ of\ light$ $(3 \times 10^{8})$

$f$ = $middle\ frequency$

$\varepsilon r$ = $material\ relative\ constant$

$\varepsilon r$ = the dielectric constant of the substrate (FR4 ($\varepsilon r$ = 4.4))



$$W = \frac{(3 \times 10^{8})}{2(3.5G)\,\frac{\sqrt{4.4 + 1}}{2}}$$

= 26.08mm

Next to calculate the width of substrate, the formula below is used:

$$\lambda = \frac{c}{f} \qquad (3.2)$$

Where: $c$ = $speed\ of\ light$ $(3 \times 10^{8})$

$f = middle\ frequency$

$$\lambda = \frac{(3 \times 10^8)}{3.5G}$$

$$= 0.09\text{mm}$$

For the effective dielectric constant is defined by:

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right) \qquad (3.3)$$

Where:

$W$ = $width\ of\ patch\ antenna\ \varepsilon$

$r$ = $material\ relative\ constant$

$$h = \frac{0.0606\lambda}{\sqrt{\varepsilon r}} \qquad (3.4)$$

$$= \frac{0.0606(0.09 \times 10^{-3})}{\sqrt{4.4}}$$

$$= 0.0026\text{mm}$$

$$\varepsilon reff = \frac{4.4 + 1}{2} + \frac{4.4 - 1}{2}\left(\frac{1}{\sqrt{1+\frac{12(0.0026 \times 10^{-3})}{26.08 \times 10^{-3}}}}\right)$$

$$\varepsilon reff = 2.7 + 1.9\ (0.999)$$

$$= 4.4$$

A patch antenna's electrical length is longer than its physical length. This normalized length extension is obtained using the following formula:

$$\Delta L = 0.412h \frac{(\varepsilon\text{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon\text{reff} - 0.258)(\frac{w}{h} + 0.8)} \qquad (3.5)$$

Where:

$W$ = $width\ of\ patch\ antenna$

$\varepsilon reff$ = effective dielectric constant

$$\Delta L = (0.412(0.0026 \times 10^{-3})\ ) \frac{(\varepsilon\text{reff} + 0.3)(\frac{26.08 \times 10^{-3}}{0.0026 \times 10^{-3}} + 0.264)}{(\varepsilon\text{reff} - 0.258)(\frac{26.08 \times 10^{-3}}{0.0026 \times 10^{-3}} + 0.8)}$$

$$= (1.0712 \times 10^{-3}\ ) \frac{(4.7)(10.03 \times 10^{3})}{(4.658)(0.0026 \times 10^{3})}$$

$$= 0.0012\ mm$$



For the actual length of a patch antenna, it is calculated using this formula:

$$L = \frac{c}{2f\sqrt{\varepsilon\text{reff}}} - 2\Delta\text{L} \qquad (3.6)$$

Where:

$c$ = $speed\ of\ light$ $(3 \times 10^{8})$

$f$ = $middle\ frequency$

$\varepsilon reff$ = effective dielectric constant

$\Delta L$ = *the length extension*

$$L = \frac{(3 \times 10^{8})}{2(3.5G)\sqrt{4.4}} - 2(0.0012 \times 10^{-3})$$

$= 20mm$

The antenna's structure was chosen as a rectangular patch made of copper (lossy) material. Copper (a lossy metal) was used to account for losses throughout the fabrication process. The width and length of the patch were then calculated using equations 3.1 and 3.6. The width and length of the patch are 26.08mm and 20mm, respectively, when the values are substituted into equations.

Once the patch's length and width and length have been determined, the inset length where 50 impedance is accessible is determined. The feed width is determined by the input impedance specifications. A quarter wave transformer is utilized to match the impedance while building the array antenna. The patch is 26.08mm by 20mm in size, with a 0.5mm inset feed from the feed line. The feed line is 3mm in width. A single element patch antenna with a resonance frequency of 3.5GHz and an input impedance of 50 ohm is shown in Figure 3.3.

The design for single rectangular microstrip patch antennas is shown in Figure 3.3, and the design is simulated based on the parameter value calculated. If the resonant frequency simulation yields a result of 3.5 GHz, the design and parameter may be considered data verification and approval. If the simulated antenna does not meet the resonant frequency, troubleshooting will be carried out by adjusting the antennas parameter.

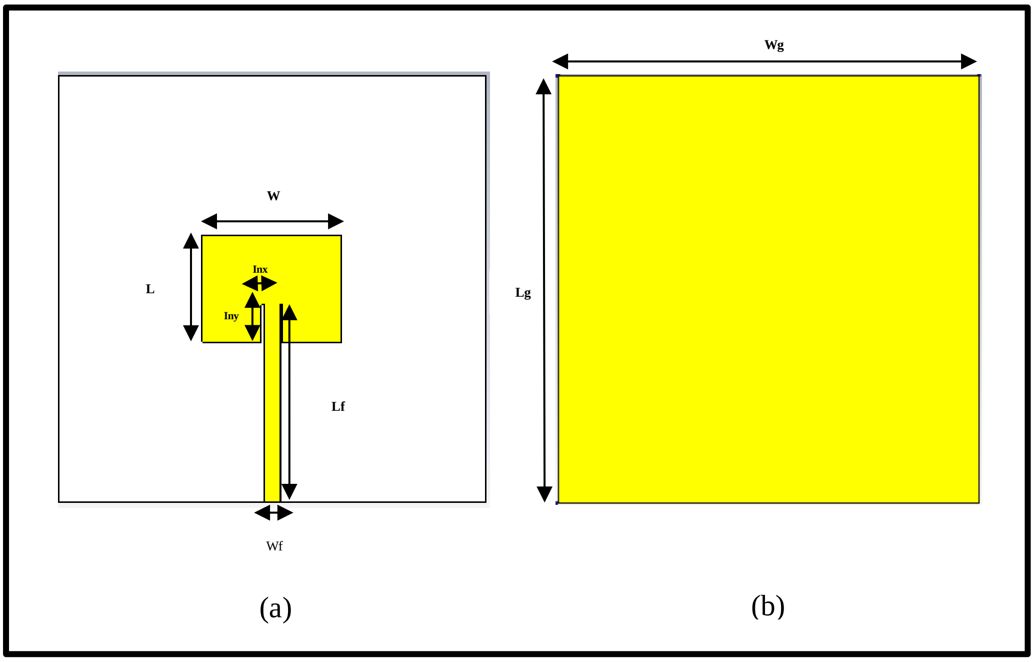


**Figure 3.3: Initial (a) Front (b) Back**

| Symbol | Parameter | Value (mm) |
|---|---|---|
| εr | Dielectric Constant of substrate | 4.4 |
| W | Width of patch | 26.08 |
| L | Length of Patch | 20 |
| Wg | Width of ground plane | 80.00 |
| Lg | Length of ground plane | 80.00 |
| hs | Thickness of dielectric constant | 1.6 |
| ht | Thickness of conductor | 0.035 |
| Wf | Feedline width | 3 |
| Lf | Feedline distance | 20.00 |
| Inx | Inset feed x | 0.5 |
| Iny | Inset feed y | 7 |

**Table 3.2: Parameters of single rectangular microstrip patch antenna**

### 3.8.1 Inset feed

The antenna's S11 and bandwidth are improved by using an inset feed [22]. This is because an inset feed can increase the antenna's impedance matching, which improves the S11. Parametric sweep research was conducted from 0.25mm to 1mm to determine the optimal width and 5mm to 10mm for ideal length of the inset feed that gives appropriate S11 characteristics, as illustrated in Figure 3.4 and Figure 3.5. Then, after looking at the S11 of each width and length, 0.5mm of width and 7mm of length was chosen because it had a better return loss at the 3.5GHz resonant frequency, as shown in Figure 3.6.

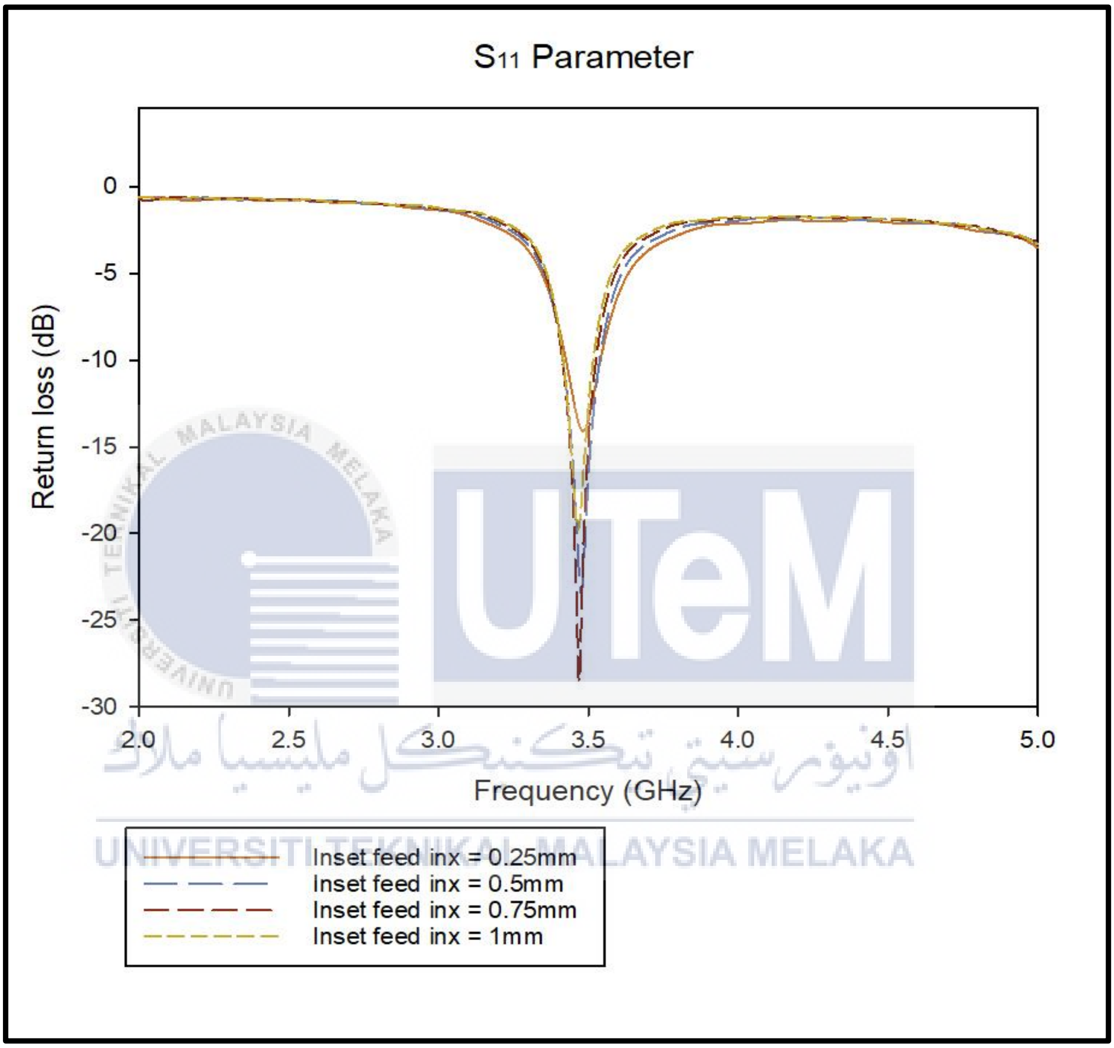


**Figure 3.4: S11 of inset feed width from 0.25mm to 1mm**

| Frequency (GHz) | Return loss (dB) | | | |
|---|---|---|---|---|
| | inx = 0.25mm | inx = 0.5mm | inx = 0.75mm | inx =1.0mm |
| 3.5 | -13.46 | -16.91 | -14.81 | -12.71 |

**Table 3.3: S11 of inset feed width parametric study**

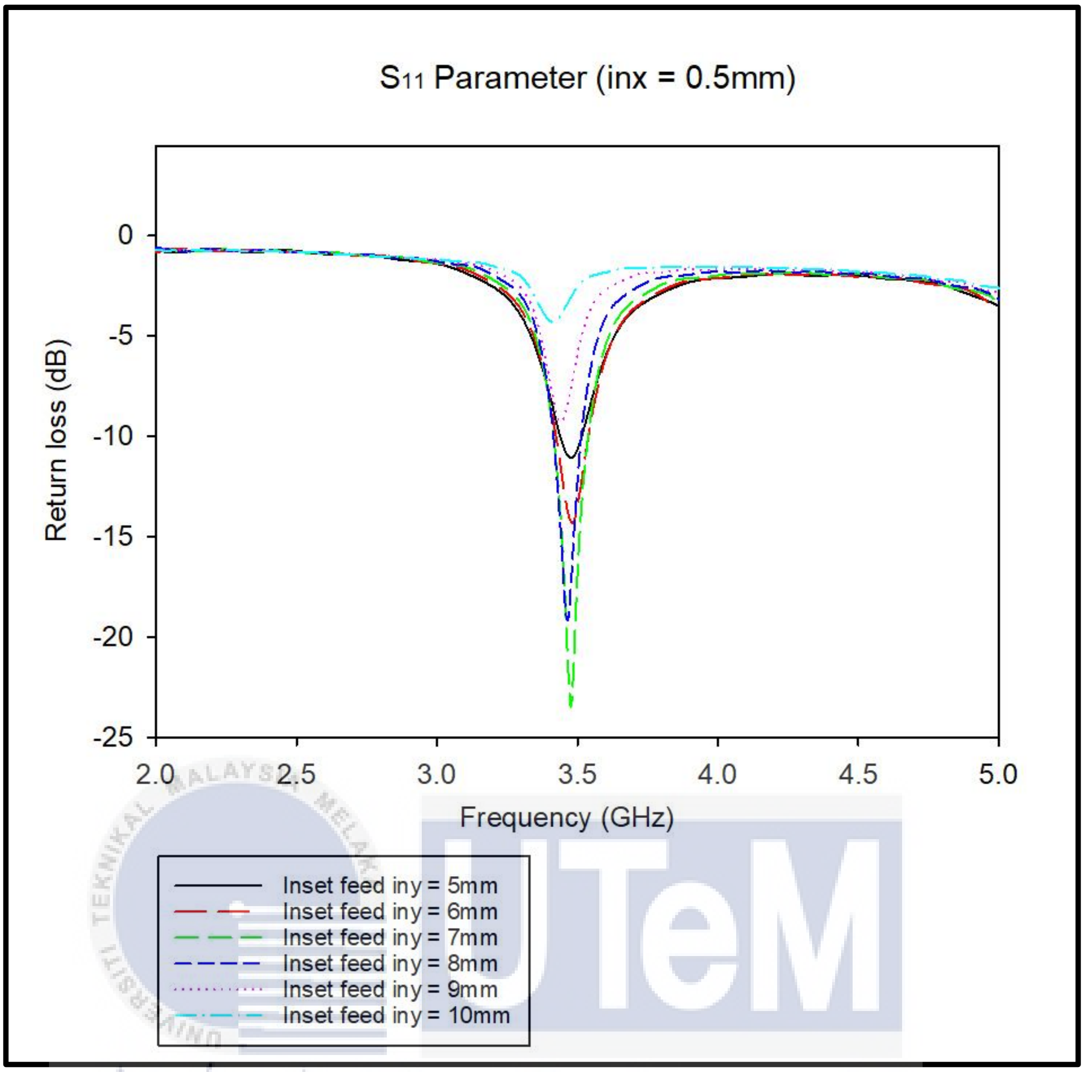


**Figure 3.5: S11 of inset feed length from 5mm to 10mm meanwhile inset feed width is 0.5mm**



| Frequency (GHz) | Return loss (dB) | | | | | |
|---|---|---|---|---|---|---|
| | iny = 5mm | iny = 6mm | iny = 7mm | iny = 8mm | iny = 9mm | iny = 10mm |
| 3.5 | -10.51 | -13.25 | -15.98 | -11.61 | -5.68 | -2.48 |

**Table 3.4: S11 of inset feed length parametric study**

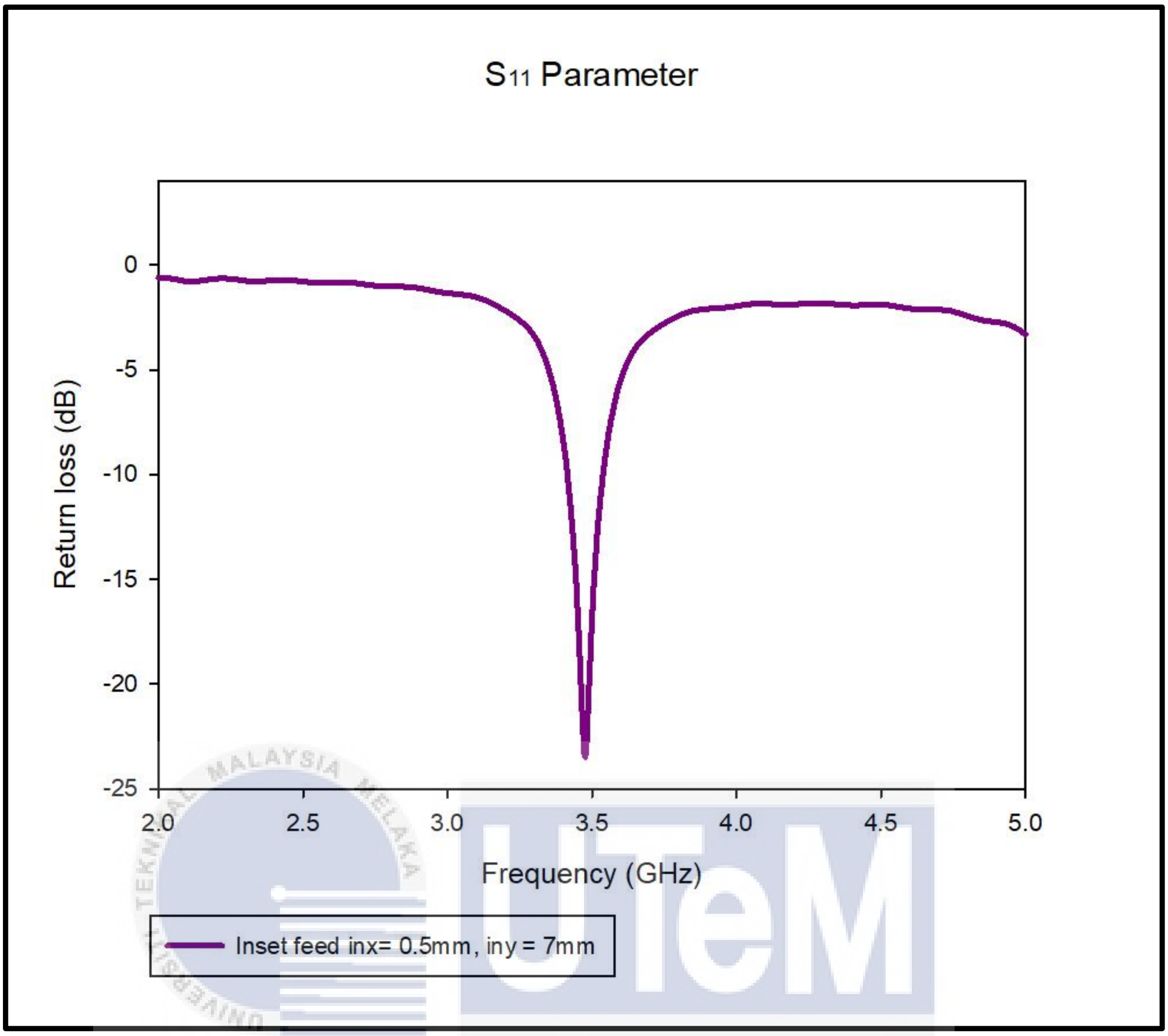


**Figure 3.6: S11 parameters for single rectangular microstrip patch antenna with inset feed**



The outcome of S-Parameters or return loss of the single rectangular microstrip patch with inset feed antenna is displayed in this portion, as illustrated in Figure 3.6. The resonance frequency of the simulated antenna is 3.5 GHz, with a return loss of -16.91dB. The results of the radiation pattern in polar view at phi = 90° are presented in Figure 3.9, and figure 3.7 display the radiation pattern with gain value at phi = 90° which is mentioned as 3.836 dBi and figure 3.8 display the directivity value which is 7.858 dBi.

The radiation pattern of the single patch antenna after simulation in 3-D perspective is depicted in Figures 3.7 and 3.8. In this 3-D radiation pattern, H-field (phi = 0°) and E-field (phi = 90°) are the two sides of the pattern that is studied for this condition. Both fields are necessary for determining the antenna's gain and return loss.

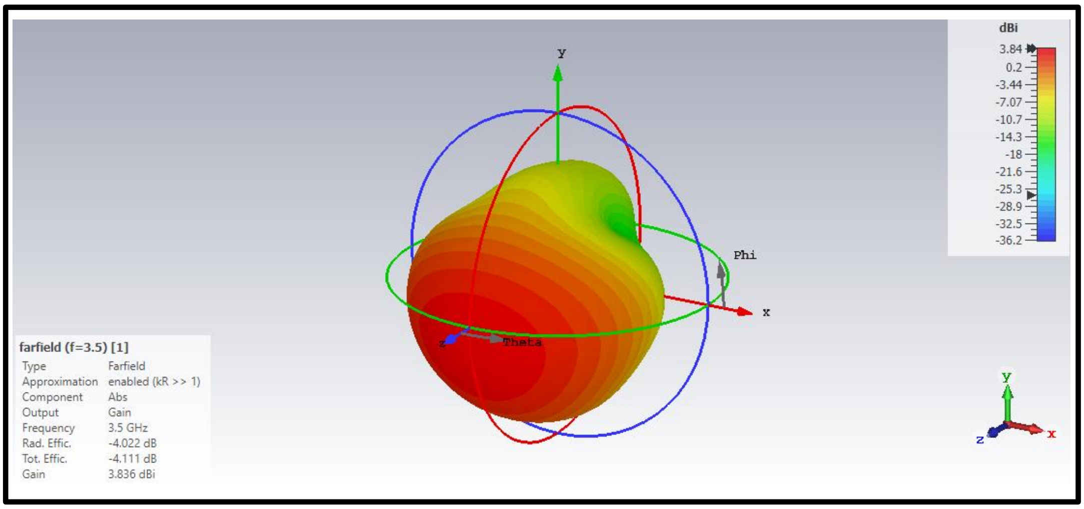


**Figure 3.7: Radiation pattern with gain value at *phi* = 90°**

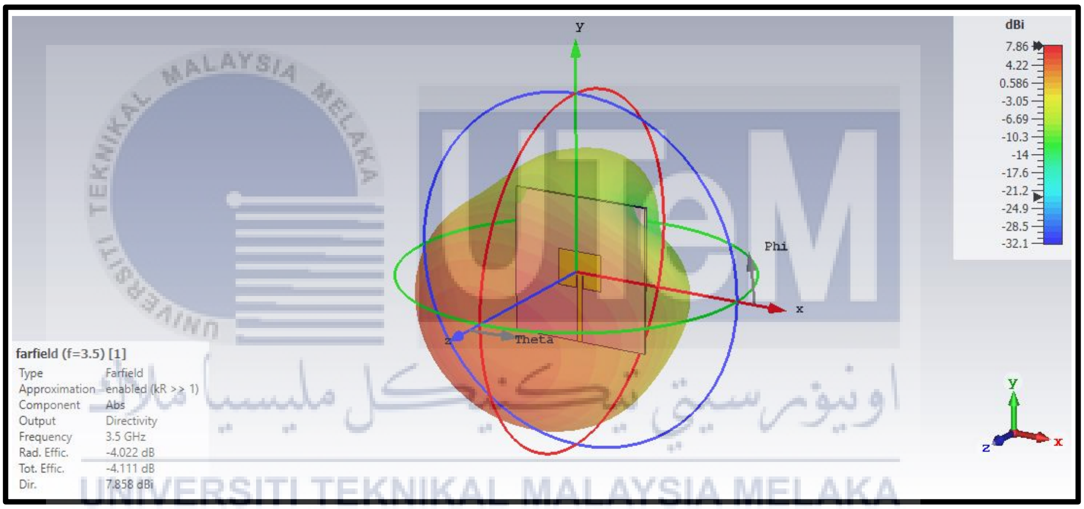



**Figure 3.8: Antenna structure in radiation pattern with directivity value at *phi* = 90°**

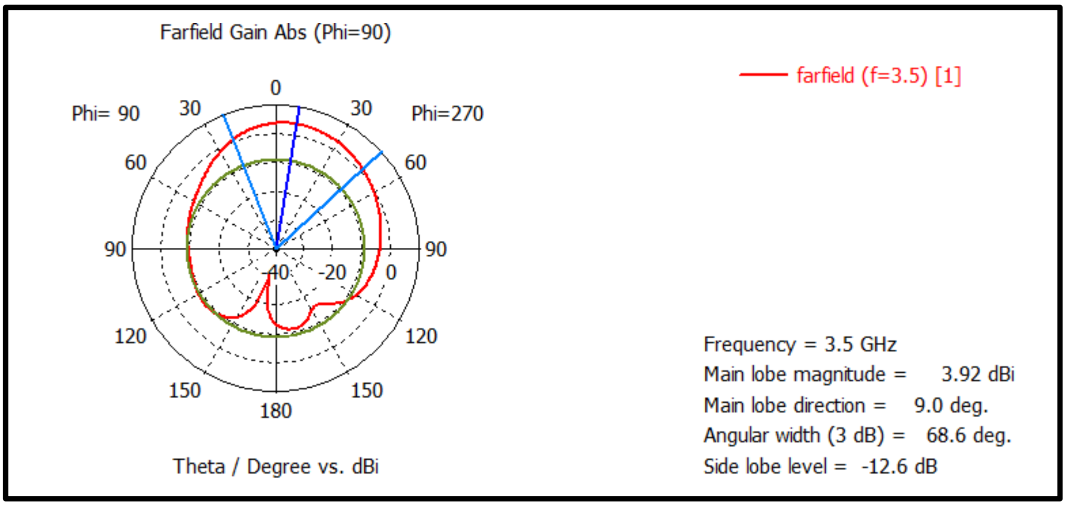


**Figure 3.9: Polar view of antenna at *phi* = 90°**

### 3.9 Design of 1x4 Rectangular Shaped Inset Feed Microstrip Patch Antenna

In the early investigation and debate, a 1 x 4 array of rectangular shaped inset feed antenna was chosen. The concept was executed by placing two 1 x 2 array antennas side by side with a 42.46 mm separation. When designing a 1 x 4 array antenna, the substrate and ground parameters, are changed to meet the overall antenna design. Using impedance transformers of 50Ω and 70Ω ohms, the patch components are grouped into a corporate feeding network. The design of the 1 x 4 array patch antenna in CST simulation software utilizing setup parameter in Table 3.4 is shown in Figure 4.0.

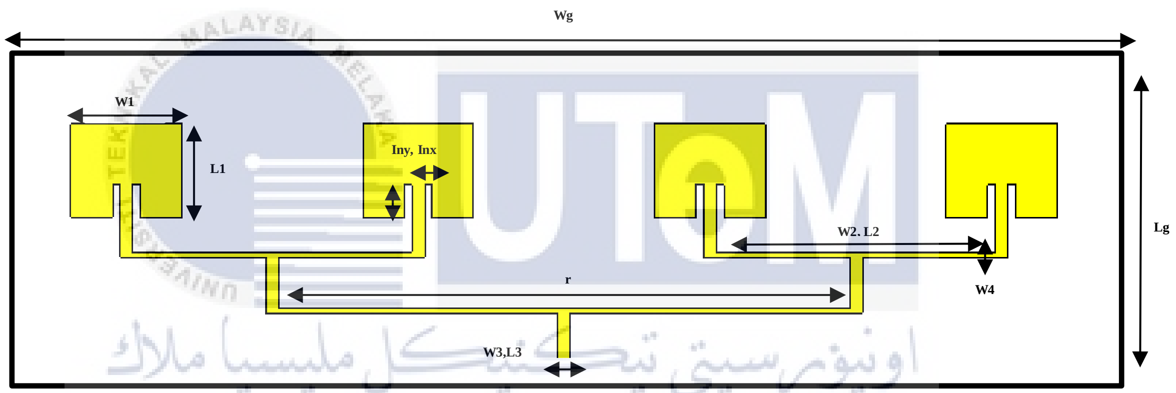




**Figure 3.10: Array antenna 1 x 4 arrangement**

| Symbol | Parameter | Value (mm) |
|---|---|---|
| W1 | Width of patch | 26.08 |
| L1 | Length of Patch | 20.00 |
| Wg | Width of ground plane | 257.70 |
| Lg | Length of ground plane | 61.71 |
| W2 | Matching line width | 12 |
| L2 | Matching line length | 3 |
| W3 | Feedline width | 3 |
| L3 | Feedline distance | 15.50 |
| Inx | Inset feed x | 1.75 |
| Iny | Inset feed y | 7 |
| r | Distance from patch to patch | 140.05 |

| | | |
|---|---|---|
| W4 | Network line width | 1 |

**Table 3.5: Parameter Setup for 1 x 4 Array Antenna Design**

After modelling the aforesaid design, the results for S11 parameters of return loss, gain, directivity, and radiation pattern were gathered. During an antenna test, return loss is a crucial parameter. It has to do with impedance and maximum power transfer theory. It's also a metric for how well an antenna transfers energy from the source to the antenna. S-calculations for rectangular shaped inset feed microstrip 1x4 antennas have been completed successfully. To acquire a higher S11 parameter value, a parametric sweep analysis was performed in a 1 x 4 array antenna. As shown in Figure 4.1, parametric sweep research was undertaken from 0.35mm to 1.75mm to find the best patch feed spacing that provides adequate S11 characteristics.

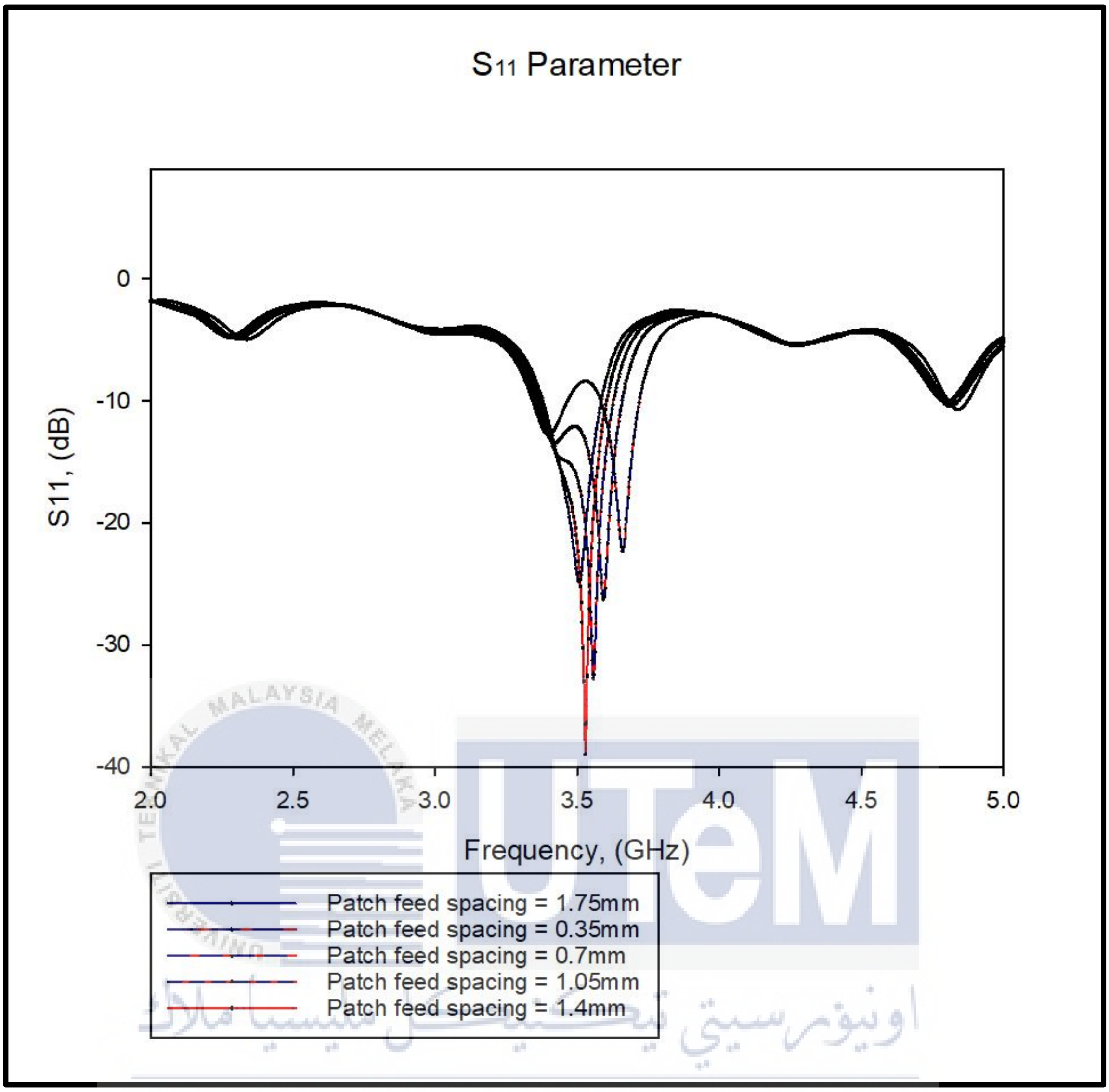



**Figure 3.11: S11 of patch feed spacing from 0.35mm to 1.75mm**

| Frequency (GHz) | Return loss (dB) | | | | |
|---|---|---|---|---|---|
| | Patch feed spacing =0.35mm | Patch feed spacing =0.7mm | Patch feed spacing =1.05mm | Patch feed spacing =1.4mm | Patch feed spacing =1.4mm |
| 3.5 | -8.78 | -12.14 | -16.27 | -21.60 | -24.26 |

**Table 3.6: S11 of patch feed spacing parametric study**

Figures 4.2 show a strong linear curve of S11 characteristics that fell at 3.5 GHz with a return loss of -24.26 dB and 1.75mm patch feed spacing. With a return loss of less than -10 dB, this satisfies one of the study's aims.

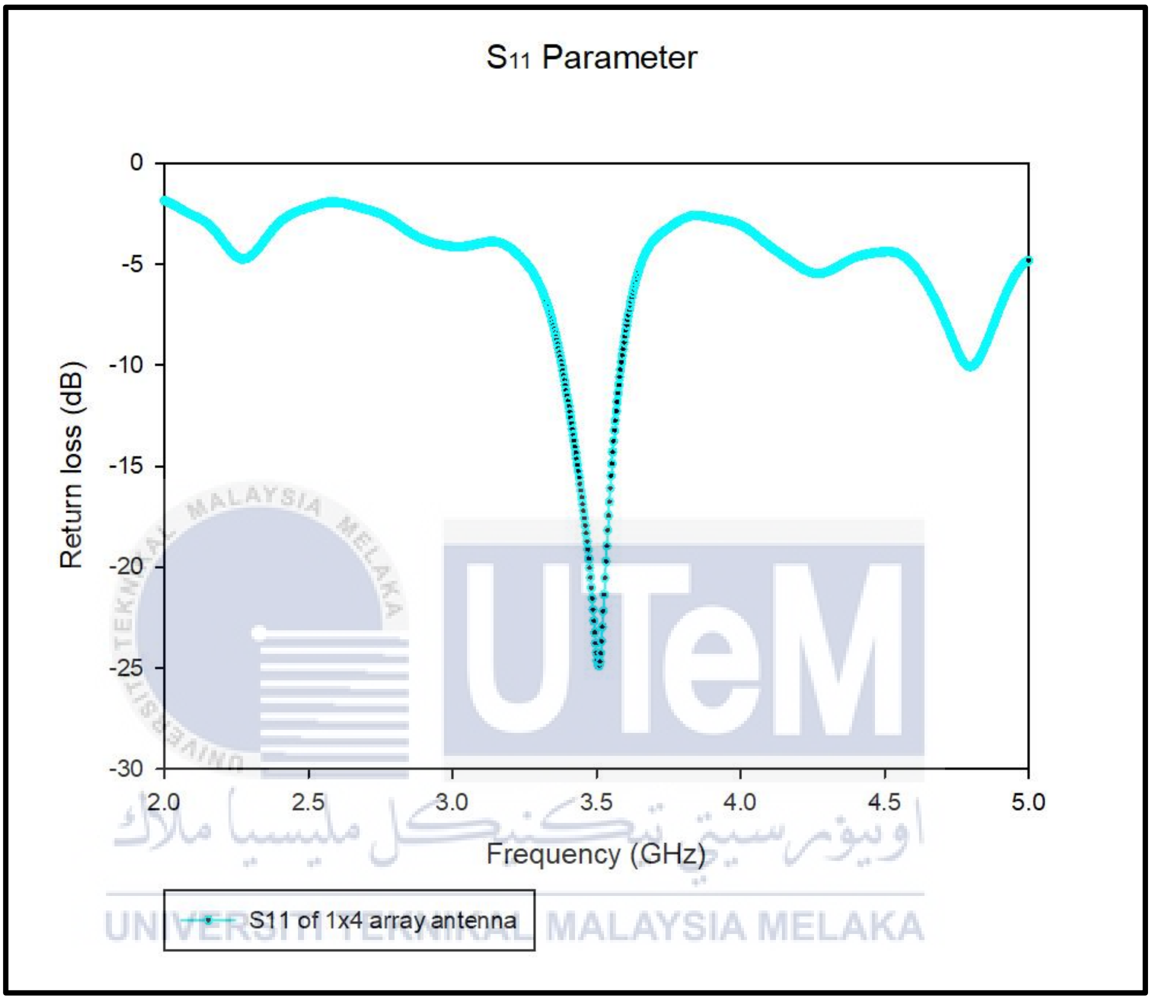


**Figure 3.12: S11 parameters of 1 x 4 array rectangular microstrip patch antenna with inset feed**

The antenna's main essential attribute in this project is gain. It is ineffective to have an excellent matching antenna that does not emit. Antenna gain is a measurement that shows how well an antenna radiates or reacts to power. The 3-D view with structure 1 x 4 rectangle microstrip patch array antenna with inset feed is shown in Figures 4.3 and 4.4. Because the gain was 7.56 dBi, it was closer to the expected outcome of larger than 10 dB. Meanwhile, the 1 x 4 array antenna has a directivity of 12.88dBi.

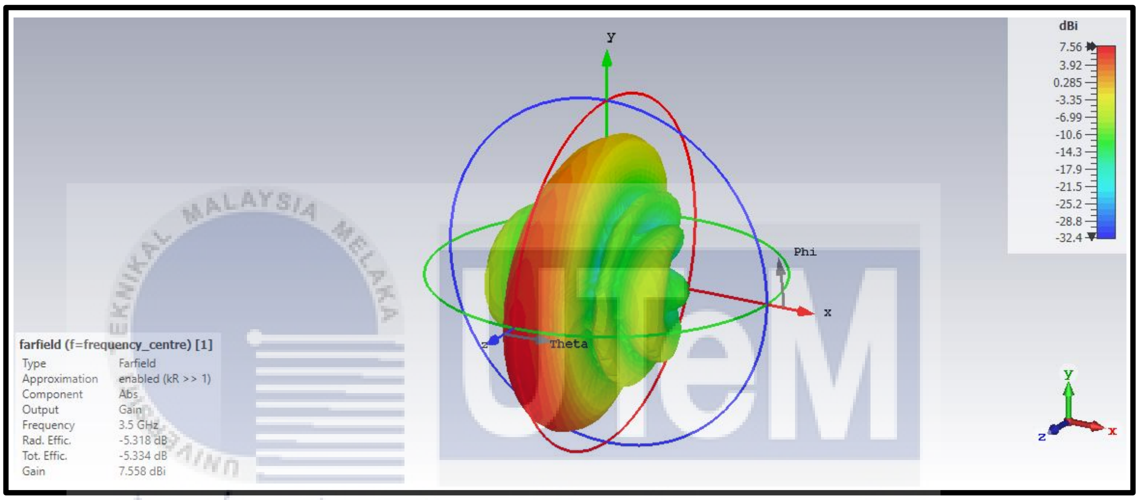


**Figure 3.13: Radiation pattern with gain value at $phi$ = 90°**



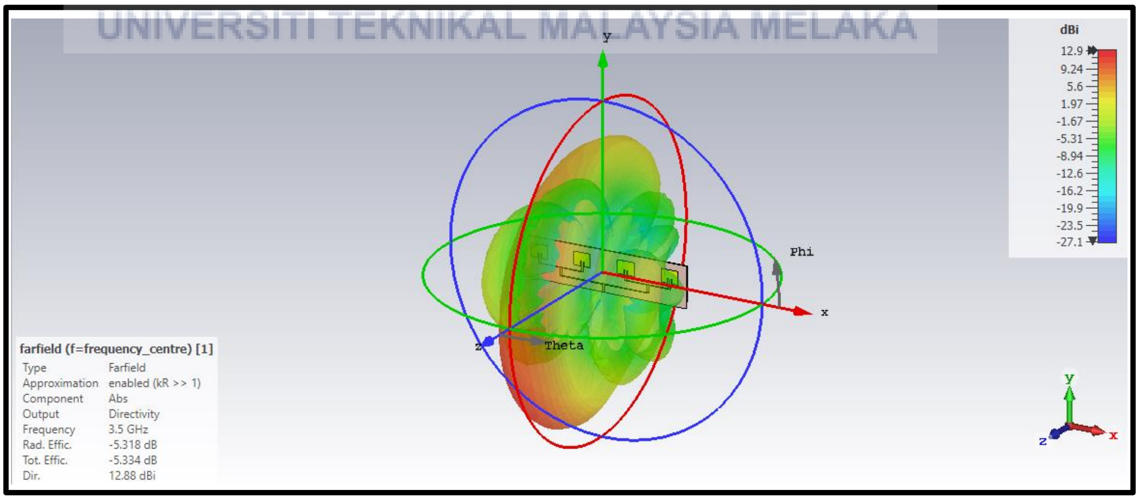


**Figure 3.14: 3-D view with directivity value of structure 1 x 4 rectangle microstrip patch array antenna with inset feed**

The polar view of the radiation pattern at phi = 90° is shown in Figure 4.5, whereas the polar view at phi = 0° is shown in Figure 4.6. The angular breadth of a 1x4 array antenna is determined to be 84.4° when it is in the (XZ) plane and 16.2° when it is in the (YZ) plane. The peak main beam of the radiation pattern (blue color) is near to 0° in the picture below, suggesting that it has a powerful array as well as good radiating properties at their working bands, making it appropriate for 5G applications.

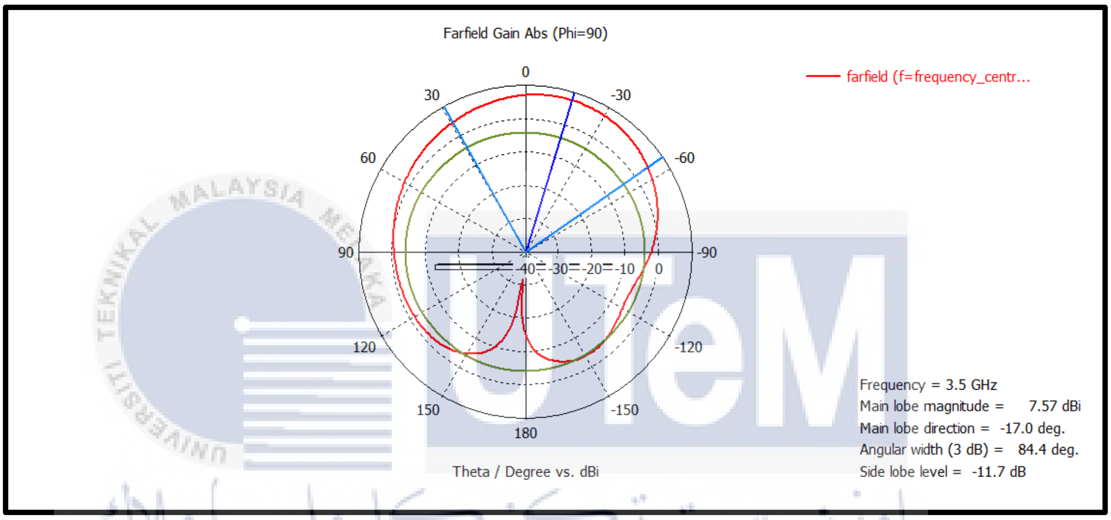


**Figure 3.15: Polar view of the radiation pattern at phi = 90°**



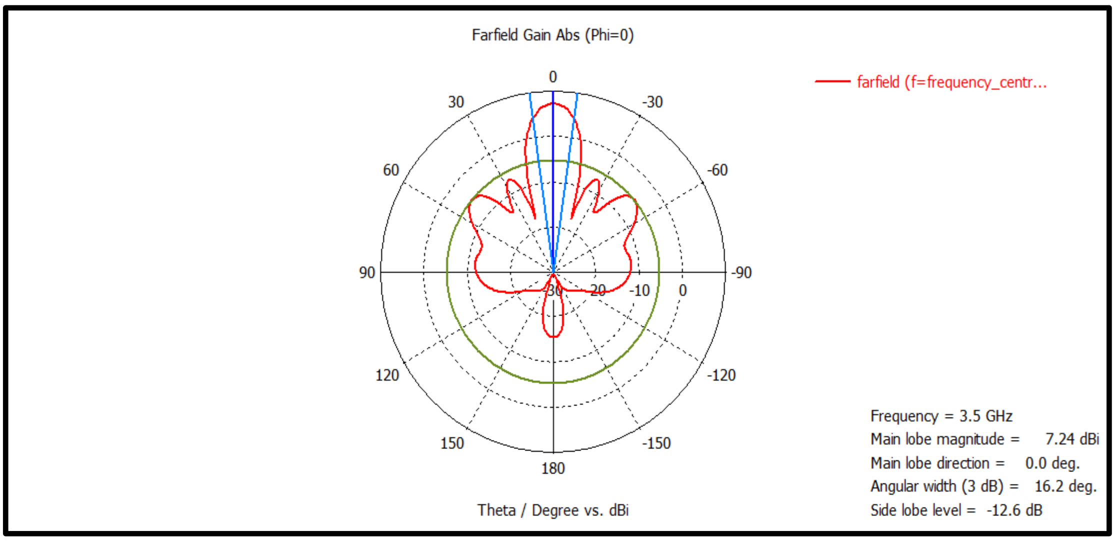


**Figure 3.16: Polar view of the radiation pattern at phi = 0°**

# CHAPTER 4

# RESULTS AND DISCUSSION



## 4.1 Introduction

The results of the antenna design simulation, also known as the analysis portion, are presented, and examined in this chapter. The most ideal array antenna was identified by analysis, which included all the qualities necessary to construct the best 3.5 GHz array antenna. Because the dielectric constant of the substrate is computed to determine antenna width and length, it is critical to pick which material will be utilized when designing and calculating antenna size. The substrates used in the research include FR4, which has a thickness of 1.6 mm ( = 4.4, tan = 0.00009) and is acceptable and effective for the 3.5 GHz submillimeter 5G wave band. A microstrip line is used to supply the patch with input impedances of 50Ω and 70Ω, which must be checked before utilizing the CST antenna assembly programmed.

In this project, there are three crucial processes to designing the antenna. To begin, make a single patch antenna. The array antenna's single patch antenna was upgraded to produce superior results, including a high gain of more than 10dBi, a decreased return loss of -10dBi, and a more accurate radiation pattern. All designs, whether direct or indirect, are predicated on the single and 1x4 array antenna is provided in Chapter 3 being calculated. In addition, the antenna design in this chapter related to the evolution of the array antenna's core design to evaluate all concepts that best met the primary objectives.

### 4.2 Design of 2x4 Rectangular Shaped Inset Feed Microstrip Patch Antenna

In this part, the 2 x 4 array antenna design was chosen to assure a better outcome than the 1 x 4 array antenna. This 2 x 4 array antenna had the same form and shape as the previous one, but several design parameters were measured differently. The true 2x4 array antenna design used in this investigation is shown in Figure 4.6. Table 4.1 shows the parameter measurements for this design.



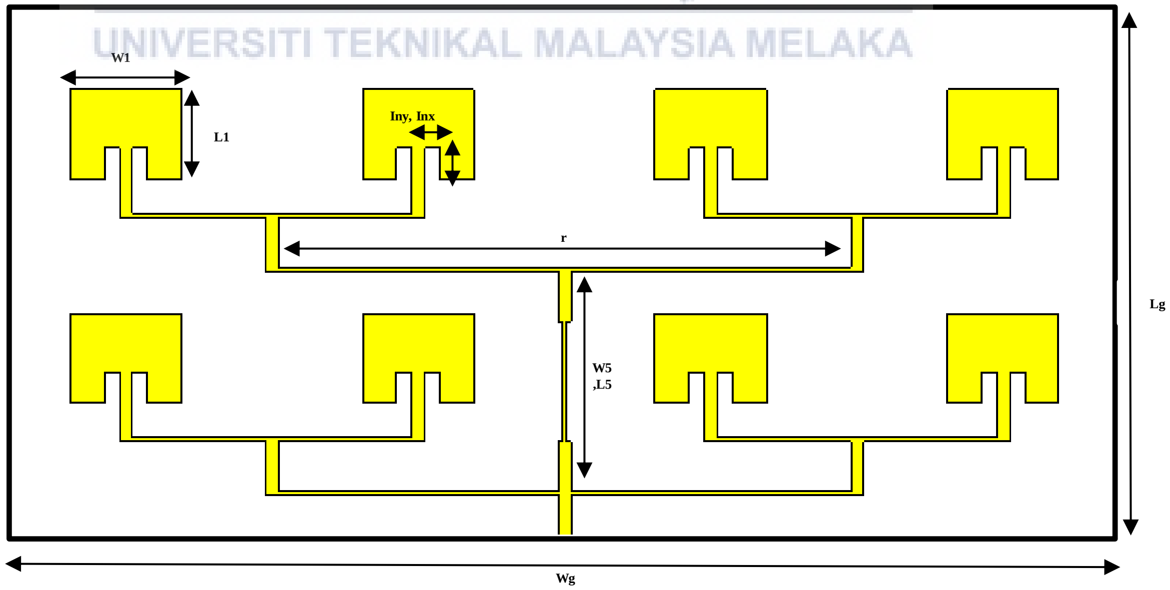


**Figure 4.0: Array antenna 1 x 4 arrangement**

| Symbol | Parameter | Value (mm) |
|---|---|---|
| W1 | Width of patch | 26.08 |
| L1 | Length of Patch | 20.00 |
| Wg | Width of ground plane | 257.70 |
| Lg | Length of ground plane | 120.00 |
| W2 | Matching line width | 12 |
| L2 | Matching line length | 3 |
| W3 | Feedline width | 3 |
| L3 | Feedline distance | 15.50 |
| Inx | Inset feed x | 3 |
| Iny | Inset feed y | 7 |
| r | Distance from patch to patch | 140.05 |
| W4 | Network line width | 1 |
| W5 | Matching line width | 26.75 |
| L5 | Matching line length | 1 |

**Table 4.1: Parameter Setup for 2 x 4 Array Antenna Design**



The S11 waveform, which depicts return loss for 2 X 4 array antenna setups, is seen in figure 4.2. The return loss is smaller than -10dB at 3.5 GHz, or -26.68 dB. At 3.5 GHz, this shows that the antenna has a minimal return loss. As a result, a significant portion of the signal is sent by the antenna.

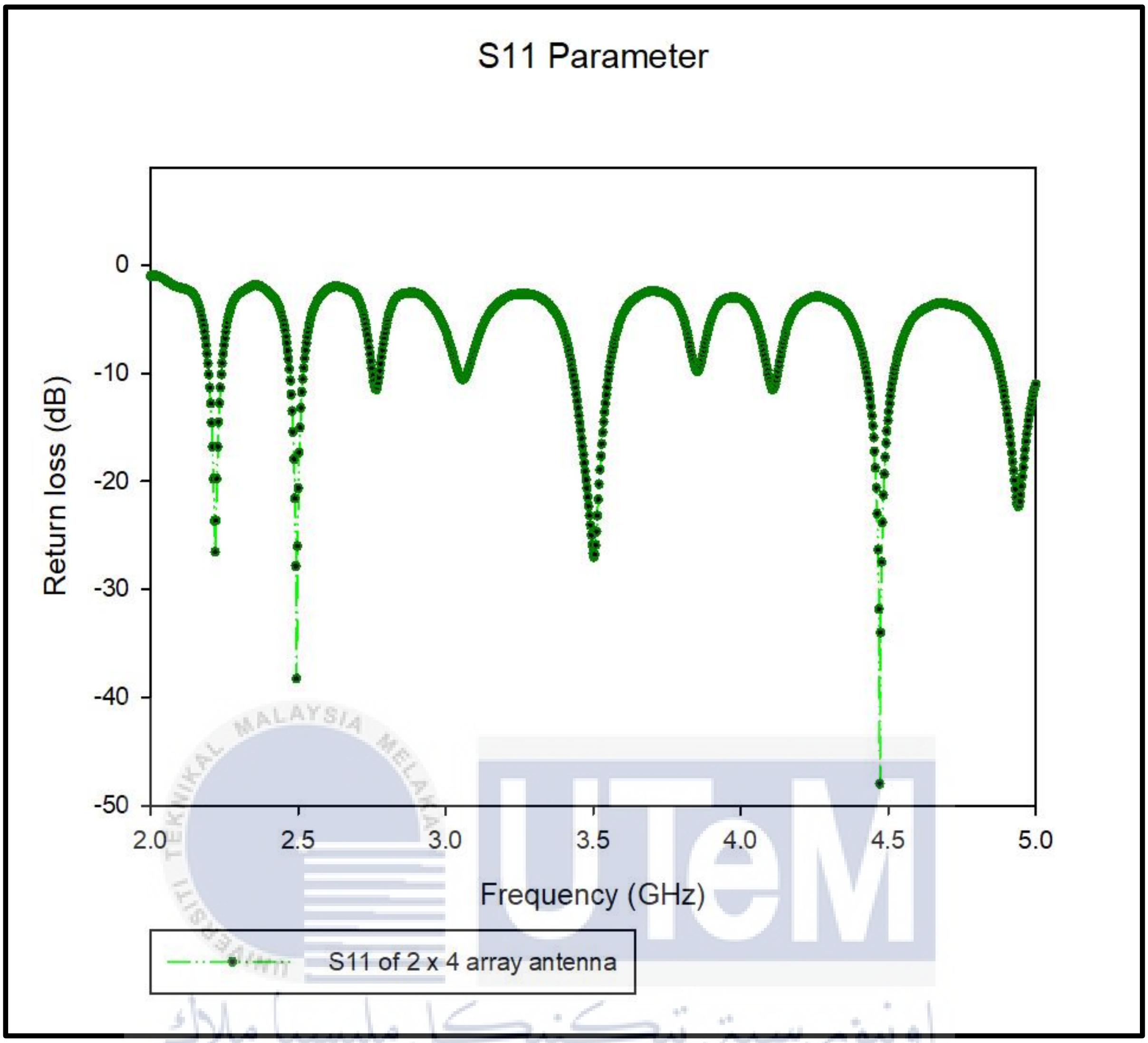


**Figure 4.1: S11 parameters of 2 x 4 rectangular microstrip patch array antenna with inset feed**



The polar view of the radiation pattern at phi = 90° is shown in Figure 4.2, whereas the polar view at phi = 0° is shown in Figure 4.3. The main lobe directivity of a 2 x 4 array antenna is determined to be 10.4 dBi at 2 degrees in theta direction. Meanwhile, at phi = 90° (XZ) plane, the side lobe is -17.1 dB. The result produced 10.3 dBi at 0 degree for phi = 0° (YZ) plane, while the side lobe is − 10.8 dB. Side lobes and rear lobes are smaller than the main lobe. The major lobe emits more energy than the other lobes. The greater the radiation, the smaller the lobe.

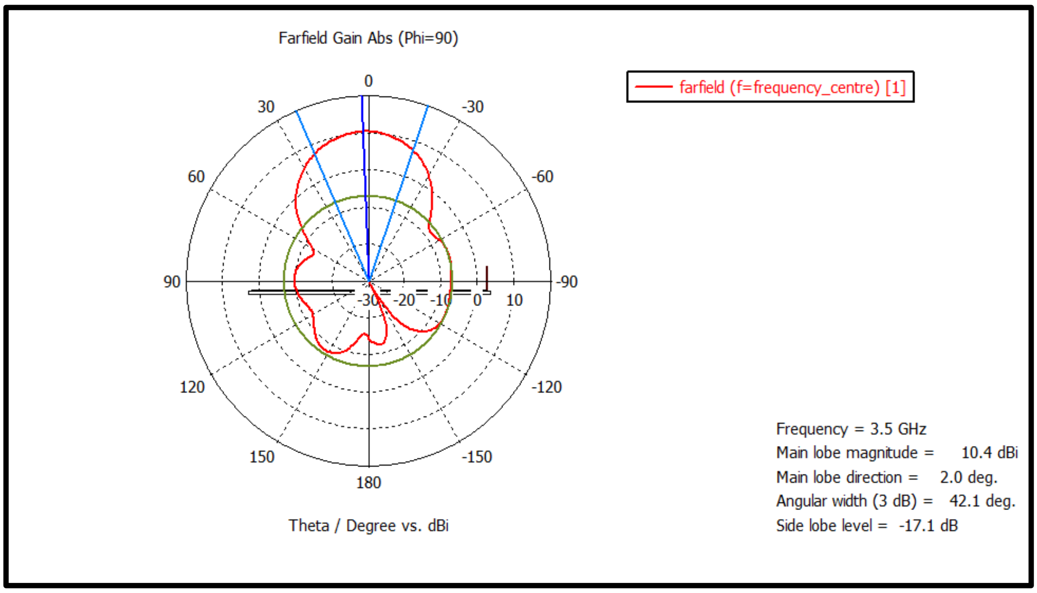


**Figure 4.2: Polar view of the radiation pattern at phi = 90°**

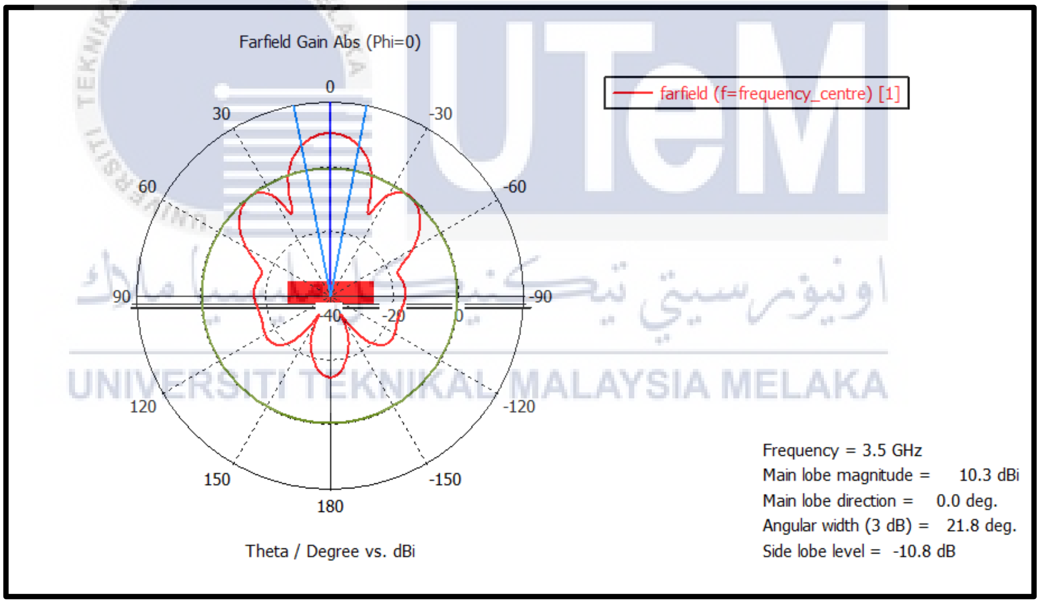




**Figure 4.3: Polar view of the radiation pattern at phi = 0°**

The antenna gain is the next component to consider in this project. Because the goal is to construct a high gain array antenna suitable of 5G applications, gain is one of the most important aspects to consider. The 2 x 4 array antenna with a gain of 10.33 dBi, as illustrated in Figure 4.4, demonstrates that the antenna can reach a greater distance in 5G applications.

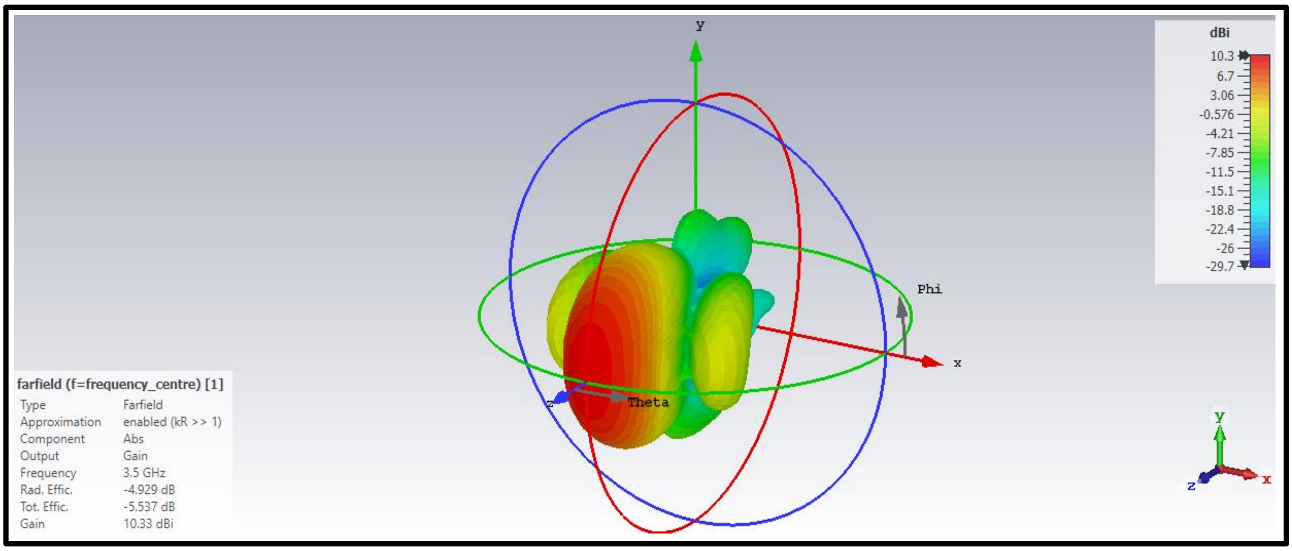


**Figure 4.4: Radiation pattern with gain value at $phi$ = 90°**

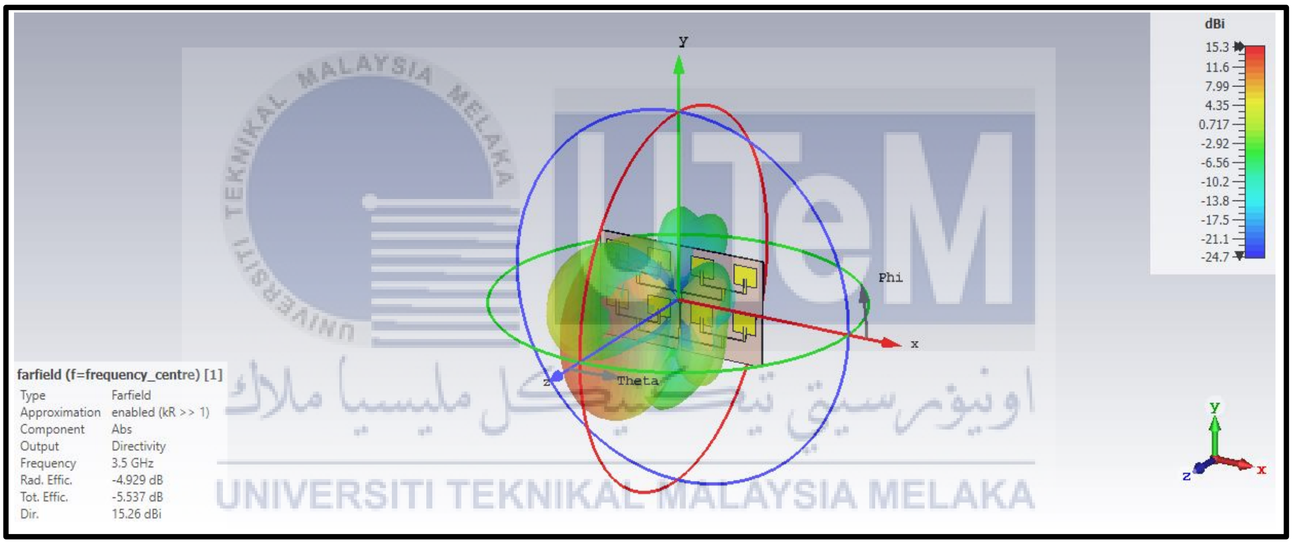



**Figure 4.5: 3-D view with directivity value of structure 2 x 4 rectangle microstrip patch array antenna with inset feed**

## 4.3 Measurement results of the antenna

After the antenna's simulation results were found to be good, the design was exported from the CST and manufactured on a FR-4 substrate, as illustrated in Figure 4.6. The antenna was then linked to a Vector Network Analyzer to determine the S11 parameter of the microstrip patch antenna, which was found to be -27.35dB at 3.57GHz, as shown in Figure 4.8. Then, to evaluate the gain, the microstrip patch antenna was set up as illustrated in Figure 4.7. The antenna gain was computed as

10.03dB by taking into consideration elements such as power transmitted, power received, distance between the antennas, cable loss, and gain transmitted. The manufactured antenna's measured parameters were then summarized in Table 4.3, as shown below. The contrast between simulated and measured gain is displayed in Figure 4.7, with a 0.3dB difference between the two gains. Table 4.3 shows the comparison between the simulated parameters and the measurement results.

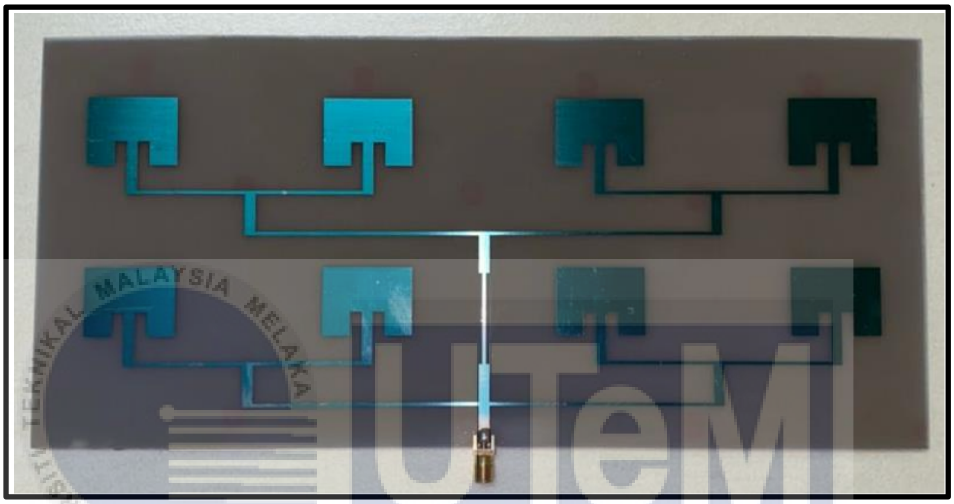

**Figure 4.6: Fabricated 2 x 4 rectangle microstrip patch array antenna with inset feed**



**Figure 4.7: Gain measurement**

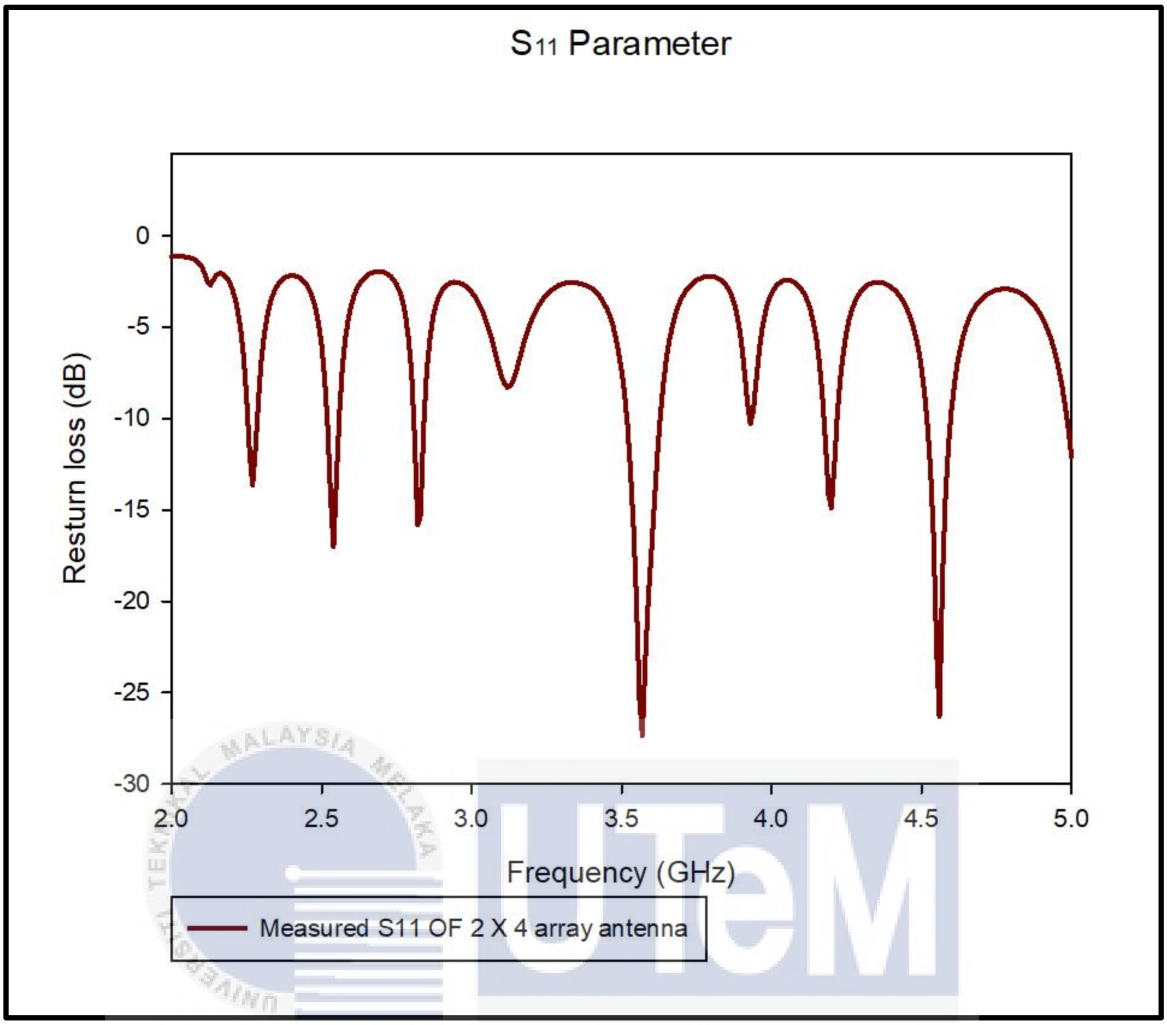


**Figure 4.8: Measured S11 parameter of 2 x 4 array rectangular microstrip patch antenna with inset feed**

### 4.4 Analysis on Various Design of Antenna

The goal of this analysis is to find the best design for this study. All antenna designs were separated and compared in this study, with each feature appropriate for analysis being gain, return loss, and radiation pattern. Table 4.2 summarizes the results of this chapter's antenna design comparisons. A comparison of the measured and simulated results of the proposed 2 x 4 array antenna in terms of gain, directivity, and return loss has been performed and provided in table 4.3. It clearly indicates a virtually perfect agreement between the suggested antenna's simulated increased 10dB gain and the simulated outcome as a higher characteristic above others described here [1], [3] and [6].

| Antenna Type | Gain(dB) | Return loss(dB) | Directivity(dB) |
|---|---|---|---|
| Single Rectangular Shaped Inset Feed Microstrip Antenna | 3.836 | -16.91 | 7.858 |
| 1x4 Rectangular Shaped Inset Feed Microstrip Patch Antenna | 7.56 | -24.26 | 12.88 |
| 2x4 Rectangular Shaped Inset Feed Microstrip Patch Antenna | 10.33 | -26.68 | 15.26 |

**Table 4.2: Analysis on Various Design of Antenna at 3.5 GHz in Simulation**

| Antenna Parameter | Desired Specification | Simulation | Measured |
|---|---|---|---|
| Working Frequency | 2GHz – 5GHz | 2GHz – 5GHz | 2GHz – 5GHz |
| Center Frequency | 3.5GHz | 3.5GHz | 3.57GHz |
| Gain | ≥ 10dBi | 10.33dBi | 10.03dBi |
| Return Loss | ≤ -10dB | -26.68dB | -27.35dB |
| Radiation Pattern | Unidirectional | Unidirectional | Unidirectional |

**Table 4.3: Comparison between Simulation and Fabricated Antenna**

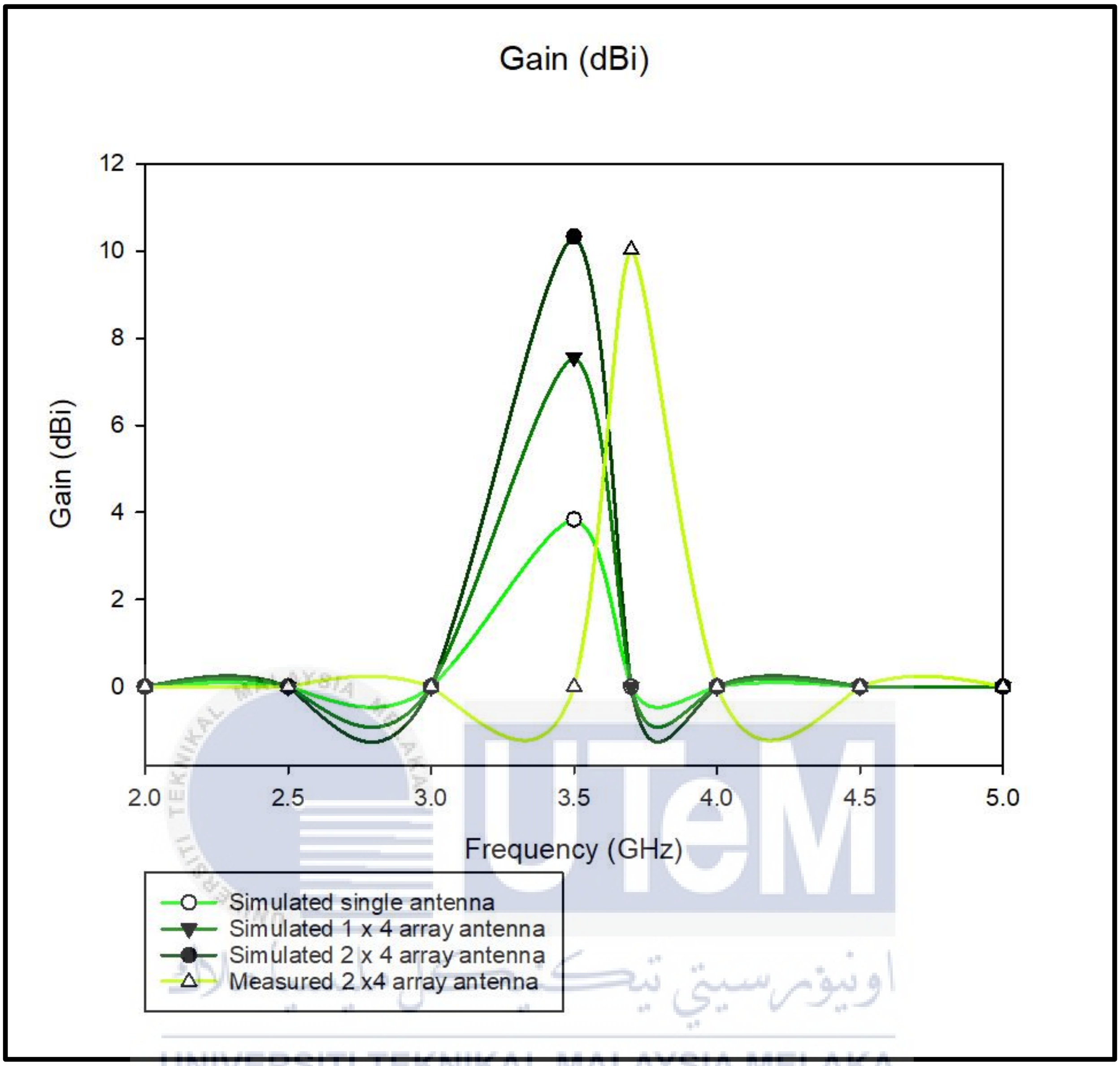




**Figure 4.9: Comparison of the antenna's simulated and measured gain values**

The antenna gain is the parameter being assessed in the graph above. Because the primary goal of this study is to build a high-gain antenna, the focus of this study was on finding an antenna capable of generating high gain. According to Tables 4.2 and 4.3, the 2 x 4 array antenna had the maximum gain of 10.33 dB, whereas the 1x4 array antenna had a gain of 7.56 dB. A high-gain antenna allows a considerable amount of radiated power to be transferred to the receiver, increasing the signal intensity received. A high-gain antenna also gathers more of the signal when it is delivered, resulting in increased signal strength.

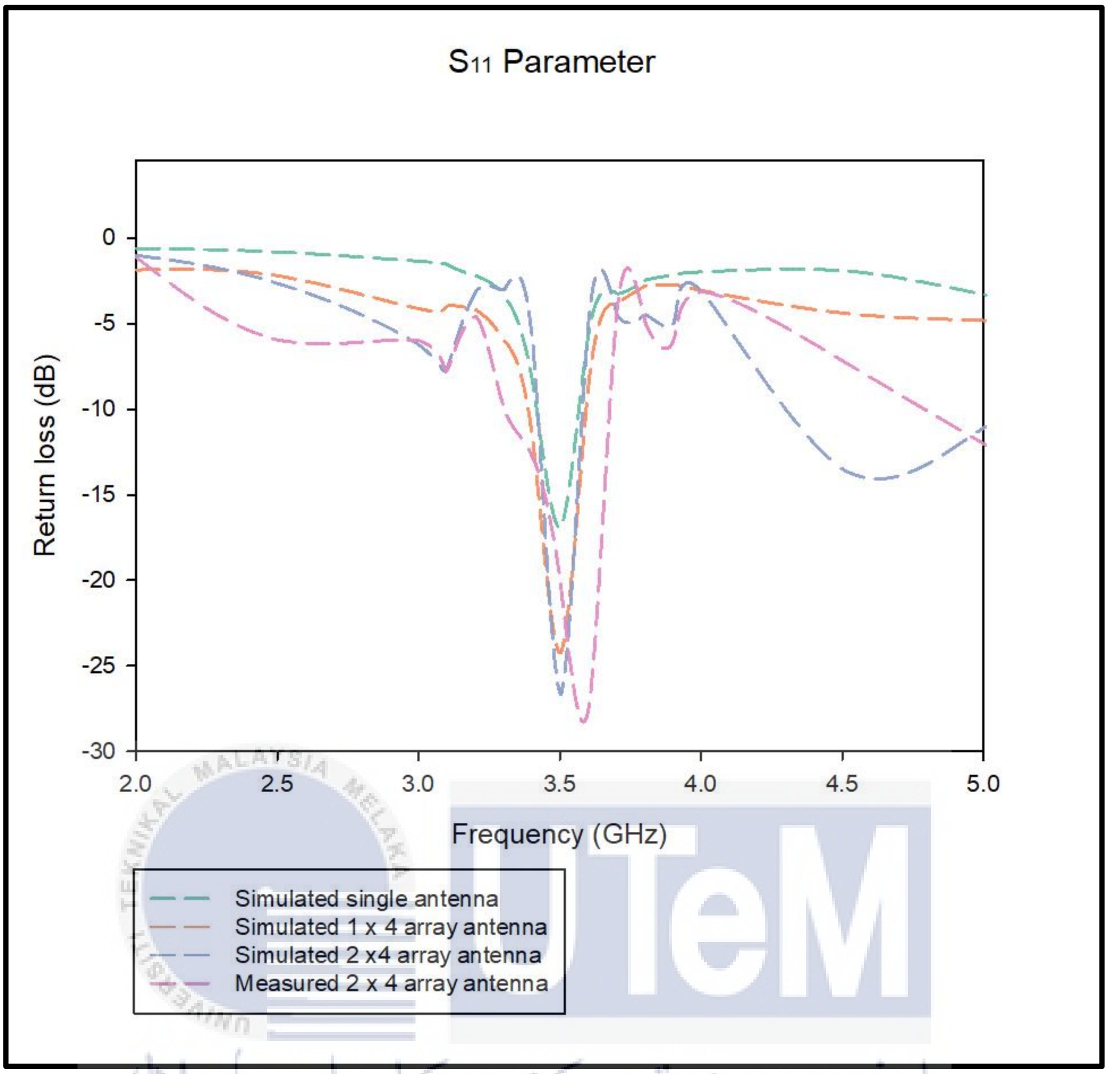




**Figure 4.10: Comparison of the antenna's simulated and measured return loss values**

The first point of discussion was the return loss of each antenna. The lowest return loss is -16.91 dB for a single rectangular microstrip patch antenna with inset feed, followed by a return loss of -24.26 dB for a 1 x 4 array antenna. Finally, the 2 x 4 rectangular microstrip patch array antenna with inset feed has a superior return loss value of -26.68 dB, which matches the project's target specifications. Because the goal of this project is to produce a return loss of at least -10 dB, the outcome indicated a small return loss for the antenna. This parameter determines how much power was reflected at the input port. There should be no reflected power and the base station should transmit 100 percent power. Return loss of less than -10 dB indicates that the device or receiver receives at least 90% of the input power and less than 10% of the reflected power [23].

Finally, the directivity refers to the section of the signal where the strongest emission occurs, and the largest gain is processed. The directivity of the single antenna simulation was 7.858 dB. Meanwhile, for a 1 x 4 array antenna, the simulation is 12.88 dB, while for a 2 x 2 array antenna, the simulation is 15.26 dB. The directivity always correlates to the gain. As the gain rises, the directivity rises with it. The stronger the signal sent across the aperture of the array antenna, the higher the directivity [24].

# CHAPTER 5

# CONCLUSION AND FUTURE WORK



## 5.1 Conclusion

This chapter summarizes and describes all the pertinent work that has been completed. Potential research and recommendations for improving this project will be considered as well. With a 3.5 GHz operating frequency, the rectangular microstrip patch antenna with inset feed was designed in single, 1 x 4 array, and 2 x 4 array configurations. This antenna was modelled using Computer Simulation Technology (CST) Microwave Studio Software

Antenna characteristics like as gain, return loss, radiation pattern, and directivity are investigated during this phase. Evidence reveals that the ratio of rejected to accepted radio waves arriving at the antenna's input is less than -10dB, implying that the antenna configuration for the systems employed has significant gains and return losses. Often, the radiation pattern is aimed towards a high gain. These antenna properties will aid in making antennas a prevalent element of future 5G applications.

## 5.2 Future Works

The design of a 2 x 4 rectangular microstrip patch array antenna with inset feed is adequate for operation at 3.5 GHz, according to simulation findings. All parameters examined had virtually obtained the exceptional performance at 3.5 GHz throughout the simulated design phase. For 5G mobile communications, this research focuses on resonance frequency at 3.5GHz. In the future, the antenna might be adapted to function in the millimeter wave band (24.25GHz – 52.6GHz), where it could be employed in industrial applications for short-range wireless networks. Instead of being manufactured only, three types rectangular microstrip patch array antennas with inset feed designs also were compared in this study.



The focus of this project was on raising the antenna's gain and making it a good antenna that can transfer more power to the receiver, hence enhancing the strength of the signal it receives. As a result, the design may be tweaked to raise the gain for various applications while also increasing the return loss. Additional work, such as the use of other dielectric materials, might be done to enhance the antenna's return loss. The performance of antenna parameters may also be determined by utilizing various types of dielectric materials. To compare the results, it is also necessary to adapt and invent the structural design of the rectangle created inset feed array antenna. To increase the average antenna, gain with the return loss, further research should be done. Finally, a material alteration as well as an antenna diameter have been noticed to improve the antenna's efficiency in the 5G application.

# REFERENCES


[1] P. Imperatore, E. Salvadori, and I. Chlamtac, “Path loss measurements at 3.5 GHz: A trial test WiMAX based in rural environment,” Proc. 3rd Int. Conf. Testbeds Res. Infrastructures Dev. Networks Communities, TridentCom 2007, 2007, doi: 10.1109/TRIDENTCOM.2007.4444709.

[2] A. Bria, F. Gessler, O. Queseth, R. Stridth, M. Unbehaun, J. Wu, J. Zendler, "4-the Generation Wireless Infrastructures: Scenarios and Research Challenges", IEEE Personal Communications, Vol. 8, No.6, December 2001.

[3] S. F. Jilani and A. Alomainy, "A Multiband Millimeter-Wave 2-D Array Based on Enhanced Franklin Antenna for 5G Wireless Systems," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2983-2986, 2017.

[4] D. M. Pozar, Microwave engineering, New York Wiley NY USA, pp. 655–695, 1998.

[5] S. F. Jilani and A. Alomainy, "A Multiband Millimeter-Wave 2-D Array Based on Enhanced Franklin Antenna for 5G Wireless Systems," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2983-2986, 2017.

[6] N. M. Nor, M. H. Jamaluddin, M. R. Kamarudin, and M. Khalily, "Rectangular Dielectric Resonator Antenna Array for 28 GHz Applications," Progress in Electromagnetics Research C, Vol. 63, 53-61, 2016.

[7] N. A. Wahab, Z. Bin Maslan, W. N. W. Muhamad, and N. Hamzah, “Microstrip rectangular 4×1 patch array antenna at 2.5GHz for WiMax application,” Proc. - 2nd Int. Conf. Comput. Intell. Commun. Syst. Networks, CICSyN 2010, pp. 164–168, 2010, doi: 10.1109/CICSyN.2010.73.

[8] K.G. Tan, S.Ahmed, Abdelsalam Hamdi, C. X.Ming, K. Abdulwasie, Ferdous Hossain, Choo-Peng, H. Basarudin, Mohd Khairil Rahmat and Vinesh Thiruchelvam “FR-4 Substrate Based Modified Ultrawideband Antenna with Gain Enhancement for Wireless Applications” Received 17 December 2018; Accepted 27 August 2019, doi: 10.25103/jestr.124.13.

[9] Sidra Farhat, Farzana Arshad, Ashfaq Ahmad, Ameer Taimour Khan “High Gain Patch Antenna Array with Defected Ground Structure for 5G Applications” December 2020, doi:10.1109/ICOSST51357.2020.9333068. 14th IEEE International Conference on OpenSource Systems and Technologies (ICOSST 2020) At: UET Lahore.



[10] N. Ferdous, G. Chin Hock, H. A. S. Hamid, M. N. A. Raman, T. Sieh Kiong, and M. Ismail, “DESIGN of A SMALL PATCH ANTENNA at 3.5 GHZ for 5G APPLICATION,” IOP Conf. Ser. Earth Environ. Sci., vol. 268, no. 1, 2019, doi: 10.1088/1755-1315/268/1/012152.

[11] S. Sahithi and S. A. Kumar, “A U-slot Microstrip Patch Antenna for Wi-Max Applications,” no. Iccs, pp. 109–111, 2018.

[12] Priyanka R. Sonkar, Prof A.B.Thatere: “E Shape Patch Antenna Array,” ISO 9001:2008 Certified Journal.

[13] A. Srivastava and N. Pradhan, "Analysis of Different Substrate Material & Frequency on Microstrip Patch Antenna," Nandita Pradhan Int. J. Electron. Electr. Comput. Syst. IJEECS, no. February, pp. 58–64, 2017.

[14] K. J. K. Gupta, "Different Substrates Use in Microstrip Patch Antenna-A Survey," Int. J. Sci. Res., vol. 3, no. 5, pp. 1802–1803, 2014, [Online]. Available: https://www.ijsr.net/archive/v3i5/MDIwMTMyMTQw.pdf.

[15] Brajlata Chauhan Sandeep vijay S C Gupta(2013) Comparative analysis of Microstrip Patch Antenna using different substrate and observe effect of changing parameter at 5.4 GHz, Conference on Advances in Communication and Control Systems .

[16] N. Kaur, N. Sharma, and N. Singh, "A Study of Different Feeding Mechanisms in Microstrip Patch Antenna," Int. J. Microwaves Appl., vol. 6, no. 1, pp. 5–9, 2017.

[17] S. R. Behera, "Dual Band and Dual Polarized Microstrip Patch Antenna Bachelor of Technology," Master Thesis, no. May 2010.

[18] M. Ayyappan, B. Manoj, and S. Rodrigues, "Low return loss circular microstrip patch antenna at 5.8GHz for wide-band applications," International Conference on Electrical, Electronics, and Optimization Techniques, ICEEOT 2016, pp. 3023–3026, 2016, doi: 10.1109/ICEEOT.2016.7755255.

[19] D. PARAGYA and H. SISWONO, "3.5 GHz Rectangular Patch Microstrip Antenna with Defected Ground Structure for 5G," ELKOMIKA: Jurnal Teknik Energi

Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, vol. 8, no. 1, p. 31, 2020, doi: 10.26760/elkomika.v8i1.31.

[20] Elisma, Neng Putri and, Hanny Madiawati: “Realization of Rectangular Patch 2x4 Microstrip Array Antennas at Frequency 2.7 GHZ- 2.9 GHZ for Weather Radar Applications” DOI: 10.9790/2834-1602010826.

[21] Mohammad Aneesh, Mohd GulmanSiddiqui, J.A Ansari, Ashish Singh, Kamakshi : “Inset Feed Toppled H-Shaped Microstrip Patch Antenna for PCS/WiMAX Application” DOI: 10.11591/ijeecs.vl.i2.pp365-370.

[22] J. Singh, “International Journal of Computer Science and Mobile Computing Inset Feed Microstrip Patch Antenna,” 2016.

[23] Ȧ H. K. V., Ȧ M. K., A. K. Ȧ Jaiswal, Ȧ R. S., and Ȧ K. J., “A survey on different feeding techniques of rectangular microstrip patch antenna,” International Journal of Current Engineering and Technology, vol. 4, no. 3, pp. 1418–1423, 2014.

[24] M.K.Abdulhameed, M.S.Mohamad Isa, I.M. Ibrahim, Mowafak.K.Mohsen, S.R.Hashim,Mothana L. Attiah: “Improvement of Microstrip Antenna Performance on Thick and High Permittivity Substrate with Electromagnetic Band Gap,” DOI: 10(4):661-669.