INVESTIGATION OF THE PERFORMANCE OF CIRCULAR POLARIZATION ANTENNA AT 2.45 GHZ OPERATING FREQUENCY

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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In the loving memory of my father and to my beloved family.

ABSTRACT

This project purpose is to investigate and design the circular polarization patch antenna at 2.45 GHz. The development is based on circular polarization for microstrip patch antenna. Microstrip patch antenna is used because it provides light in weight and low cost suitable with the small antenna types other than the use of this technology in several decades. Then, the antenna is design using the CST software and fabricated at FR-4 board with dielectric substrate of 4.3 with the height of 1.6 mm. The antenna consists of square patch, truncated at corner and notch. The performances of the antenna will be measure regarding the parameter characteristics suitable with the performances of the design. Regarding the polarization, circular polarization is obtained when two orthogonal modes are equally excited with 90° phase difference between them. This is due to the resulting wave having an angular variation. Here, the projects have been done by simulation and measurement. The design was start by done the simulation in order to gain resonant frequency at 2.45 GHz with dimension of the patch first, then proceed by fabrication process and finally the measurement test was obtain through the fabricated patch antenna. Lastly the comparison have been made between simulation and measured results.

ABSTRAK

Tujuan projek ini adalah untuk menyiasat dan reka bentuk antena patch polarisasi pekeliling pada 2.45 GHz. Perkembangan ini berdasarkan pada polarisasi pekeliling untuk antena patch microstrip. Antena patch microstrip digunakan kerana ia memberikan cahaya berat dan kos rendah sesuai dengan jenis antena kecil selain penggunaan teknologi ini dalam beberapa dekad. Kemudian, antena ini direka menggunakan perisian CST dan direka di papan FR-4 dengan substrat dielektrik 4.3 dengan ketinggian 1.6 mm. Antena terdiri daripada patch persegi, dipotong di sudut dan takik. Persembahan antena akan mengukur mengenai ciri-ciri parameter yang sesuai dengan prestasi reka bentuk. Mengenai polarisasi, polarisasi pekeliling diperoleh apabila dua mod ortogonal sama-sama teruja dengan perbezaan fasa 90 ° di antara mereka. Ini disebabkan gelombang yang dihasilkan mempunyai variasi sudut. Di sini, projek-projek telah dilakukan oleh simulasi dan pengukuran. Reka bentuk bermula dengan melakukan simulasi untuk mendapatkan kekerapan resonan pada 2.45 GHz dengan dimensi patch pertama, kemudian meneruskan proses fabrikasi dan akhirnya ujian pengukuran diperoleh melalui antena patch palsu. Akhirnya perbandingan telah dibuat antara simulasi dan hasil yang diukur.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Beneficent and Most Merciful, Who has created the mankind with knowledge, wisdom and power. First and foremost, I would like to express my gratitude to my supervisor, Madam Maizatul Alice Binti Meor Said, for encouragement, guidance and critics. Without her continued support and interest, this thesis would not have been the same as presented here.

I also would like to extend my sincere appreciation to all my friends, who have helped me and gave generous support throughout this semester, their views and tips are useful indeed for this project.

Finally, I would like to thank my loving mother and siblings. Their loves, supports and prayers have given me strength to finish what I have started. Last but not least, to my late father, who unable to witness this, you will always be in my mind and heart.

May Allah SWT bless all of you.

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LIST OF SYMBOLS AND ABBREVIATIONS

CP	:	Circular Polarized
CST	:	Computer simulation technology
Ɛr	:	Thickness of substrate
µ0	:	Permittivity

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CHAPTER 1

INTRODUCTION

Microstrip antenna technology started out its rapid improvement in the late 1970s. By the early 1980s fundamental microstrip antenna factors and arrays have been fairly properly establish in term of graph and modeling [1]. In the most recent a long time printed antenna have been to a fantastic extent examined because of their beneficial instances over different emanating frameworks. For example, mild weight, decreased size, low cost, conformability and opportunity of integration with active devices. Accordingly, this mission is supposed to design a circularly polarized antenna at 2.45 GHz. The predominant benefit of using circular polarization is that regardless of receiver orientation, it will constantly get hold of an issue of the signal. This is due to the ensuing wave having an angular variation [2].

1.1 Project Background

The patch antenna is one type of radio antenna that mounted on the flat surface with low profile. The flat surface consists a sheet of metal or normally known as patch is mounted over the larger sheet metal called ground plane. The patch antenna normally easy to fabricate, modify and also easy to customize. Other than that, it also small in size compare with other larger antenna and light weight so easy to carry everywhere depends on application. The patch antenna is one of the microsrtip antenna with the wavelength is one-half of the radio wave. The patch antenna normally needed the presence of dielectric substrate on the same board in order to enhance the radiation mechanism during transmission and reception process. The technology of mircostrip antenna is developing start on the late 1970s and in the early 1980s, the basic microstrip antenna element in term of design and molding is established.

Therefore, this project was aim to investigate the design and develop a circular polarization patch antenna at frequency of 2.45 GHz. The development is then needed to observe and analyse about the antenna. This project used the truncated corner patch antenna in order to enhance the circular polarization effect. Other than that, the antenna is simulated and tested using CST software and then fabricated on FR-4 board based on the dimension resulting from simulation. After that, the results of antenna are measured at the network analyzer and other antenna test equipment to compare simulation and measured findings.

1.2 Problem Statement

The main reason to design this type of antenna is because using circular polarization for the patch antenna it can better in detects the signal in the different angular variations. Circular polarization has less effect to multi-path issue that cause by reflection. Linear polarization is more likely become out of phase due to it linear type of radio signal rather than circular polarization. Secondly the reason is to improve the gain of the antenna. The gain of the antenna is the ratio of power radiated in the direction of interest with respect to the power in the same direction. So, negative gain will be effect antenna efficiency and antenna directivity.

1.3 Objectives

The objectives of this project were to:

1. Design and investigate microstrip patch antenna at 2.45 GHZ.
2. Fabricate the antenna with the specified characteristics based on the simulation results.
3. Perform measurement regarding the appropriate characteristic in order to compare simulation and measurement results.

1.4 Project Scope

This project requires the use of hardware and software related to the antenna design in order to gain the centre frequency at 2.45 GHz. The software used is Computer Simulation Technology (CST) software. The related software should be understood to improve the knowledge before start the project. The project started with designing the microstrip antenna. Then, the microstrip antenna is simulated using the CST software. After the simulation, the microstrip antenna is fabricated using FR4, with dielectric constant (ε_r) 4.3 and height of 1.6 mm. Finally the microstrip antenna is measured using the network analyzer and the measured values are compared with the simulated values.

1.5 Summary

This chapter provides the introduction of the project, followed by explanation of the problem statement. This chapter also covers the objectives and scope of work that involved while doing this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Antennas generally work in the transmission and reception of radio waves and are necessary part of all radio waves equipment and communication [1]. Antennas are used in several systems such as radio and television broadcasting which both of this contributed most antenna application. Other than that, antenna also used in point-to-point radio communication, wireless LAN, cell phones, and radar applications. The antenna physically is an arrangement of one or more conductors called as elements. In transmission system, the voltage applied at antenna terminals causing the element to radiated n electromagnetic field. In the receiver or reception part, the electromagnetic field that produce from the transmission part is induced the alternating current in the element and the next communicate the voltage for the antenna terminals. However, for some receive antenna such as parabolic and horn antenna is integrated shaped reflective surface in order to collect the radio waves. Both types of antenna are focus and strike onto the actual conductive elements.

2.2 Small Size Antenna

The antenna is equipment that function to transmit o receives the electromagnetic waves. In other words, antenna converts electromagnetic radiation into electric current. From Webster's Dictionary, the antenna is a metallic device that functions for radiating and receiving radio waves and by the description of IEEE Standard, it is means for radiating or receiving radio waves. So, the antenna is the transitional structure free-space and guiding device [1].

Based on the design specification for this project, the researchers is focus on the small types of antenna. The small antenna means the small in size of antenna compare with the other huge antenna out there in market. When deal with the small antenna types, the key point to consider is when it was a small antenna, there is no magic cure to make it act like a large antenna types. The small antenna types is required higher ability to care in order to obtain higher-efficiency same as the large one. This kind antenna can work more efficient when the current is considered as uniform as possible over the length of the antenna using as much as capacitance at the ends of antenna. The other things should be considered is loss which is the size, length and diameter for the small size antenna contributed low loss so that it can work like the large type of antenna.

2.2.1 Microstrip Antenna

The microstrip antenna is one of the small type antennas. Because this project focused on the small types, the microstrip type is the one of the choices can be consider for the project design. The microstrip antenna also known as printed antenna and the most popular types is microstrip patch antenna or patch antenna [4]. A patch antenna normally is a flat sheet of metal that mounted over larger sheet metal named as ground plane. The patch antenna is radiated perpendicular to the ground. The common shapes for the microstrip patch are square, rectangular, circular, truncated corner and elliptical.

Microstrip patch antenna is more interested because of the compact size, light weight and low cost for manufacturing by the used of printed circuit technology [5]. The microstrip technique is used to produce lines that contributed signals for the transmission waves. The patch element that formed on the top surface of a thin dielectric substrate them from the conductive layer at the bottom of substrate and the top bottom layer is the ground plan thus constitutes a line of transmission and radiation of the antenna. For the patch antenna, the dimension and shapes is most important for the antenna features. Figure 2.1 show patch antenna in basic form.

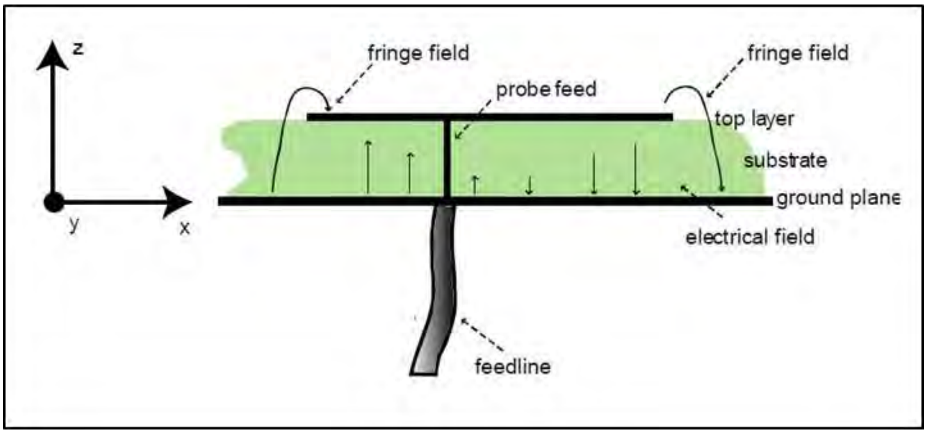


Figure 2.1: Side view of Microstrip Patch

At the centre of the patch, the electric field is zero, maximum at the one side and the minimum at the opposite side [3]. The maximum and minimum side usually change side based on the instantaneous phase of the applied signal. The fringing fields which are the field extension cause the patch to radiate. The microstrip patch antenna also used in array antenna where it may use for high directivity application. Other than that, the microstrip antenna also suitable for active antenna which is having a feeding circuits, active devices, monolithic integral and thus produce compact, low cost and multi-function antenna.

Microstrip antennas usually employed at the Ultra High Frequency (UHF) and higher frequencies because the antenna having the size or dimension which tied directly to the wavelength of the frequency resonance.

There are many advantages of using microstrip antenna. However, the microstrip antenna likewise experiences a few disadvantages. Table 2.1 shows the advantages and disadvantages of microstrip patch antenna.

Table 2.1: Advantages and Disadvantages of Microstrip Patch Antenna

Advantages	Disadvantages
Light weight and low volume	Narrow bandwidth
Low profile planar configuration	Low efficiency
Low cost of fabrication	
Can support linear and circular polarization	
Capable of dual and triple frequency operations	
Can be easily integrated with microwave integrated circuits (MIC)	

Even though the microstrip patch antenna suffer from several disadvantages, but it suitable to be used in the several application in telecommunications field. This type of antenna can be adjusted so that it can be used in high speed broadband of WLAN system and other applications.

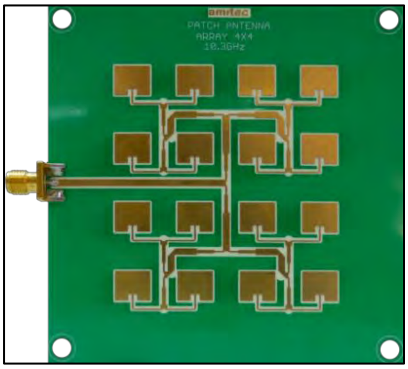


Figure 2.2: Microstrip Patch Antenna

2.2.2 Planar Antenna

Planar antenna is other types of small antenna that contains a ground plane having a ground point. The main radiating element has the feed point those positions nearest the ground point. The position of main radiating element such the space is formed between it is nearest to a contact side of the ground plane. The parasitic element is place between the contact size and the ground plan which is this parasitic element is far from main radiating element that connects with the ground point. The parasitic element usually has at least one slit formed within it [6].

Planar antenna is the new generation of antenna where it boast such striking features such as low profile, light weight, low cost and else [6]. These advantages make the planar antenna being an ideal component of modern communications system mostly for wireless communication. The planar antenna can be design by the form of microstrip patch antenna. The patch antenna is planar antenna used in wireless and microwave applications. Other than that, the microstrip technique is the planar technique function to produce lines that convey signals. Many novel of planar antenna design become more popular in the last five to six years before.

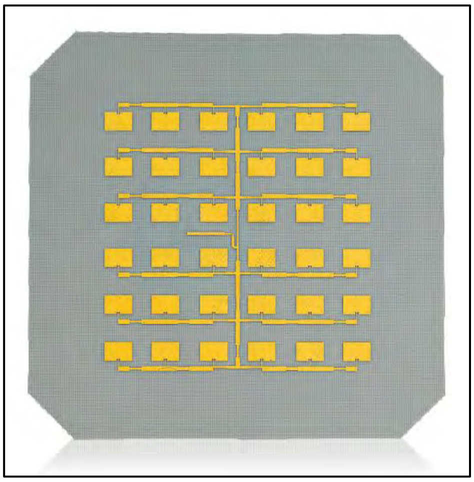


Figure 2.3: Planar Antenna

2.2.3 Aperture Antenna

Aperture antenna also the type of small antenna contains of some kind opening at which the electromagnetic waves s transmitted or received. The application used the aperture antenna is in aircraft applications for example. The aperture can be flatten mounted with the surface of vehicles with the cover of opening can be covered with dielectric that allows electromagnetic energy to pass through it [1].

As a receiver, the aperture imagine as the area of broadside circle constructed to the incoming radiation where all radiation passing within the circle is delivered to match the load. The transmission and reception part are reciprocal which means that the aperture is same for both. The power density income (unit: watts per square meter) times with the aperture (unit: square meter) will be equal to power available from antenna (unit: watts). In general, the directing of radiation in a single radiation will increase the gain [1]. Thus, when the aperture is larger, it will capable to produce higher gain and narrow bandwidth.

2.3 Applications

2.3.1 Energy Harvesting

Energy harvesting is the seize and conversion of small quantities of easily accessible strength in the surroundings into usable electrical energy. The electrical power is conditioned for either direct use or accumulated and saved for later use. This presents an choice supply of power for applications in locations the place there is no grid strength and it is inefficient to set up wind mills or photo voltaic panels.

Other than outdoor solar, no small energy sources provide a great deal of energy. However, the power captured is adequate for most wi-fi applications, far flung sensing, physique implants, RFID, and other functions at the decrease segments of the energy spectrum. And even if the harvested electricity is low and incapable of powering a device, it can nonetheless be used to prolong the lifestyles of a battery. Energy harvesting is beneficial due to the fact it provides an ability of powering electronics the place there are no traditional power sources, removing the want for widely wide-spread battery replacements and going for walks wires to cease applications. By this equal token, it opens up new purposes in far flung locations, underwater, and other difficult-to-access areas where batteries and traditional energy are now not realistic.

2.3.2 Wi-Fi

Wi-Fi s stand for wireless Fidelity which is the name is certified by Wi-Fi Alliance or formerly known as WECA that stands for Wireless Ethernet Compatibility Alliance. WECA is function to ensure compatibility between hardware devices in the standard of 802.11. Nowadays, in order to avoid misused of the certification name, Wi-Fi in reality is a network that complies with the 802.11 standard. By using Wi-Fi, the high-speed wireless local networks are possibly created and thus, the computer is connected not too far from the access point.

The Wi-Fi conducts the OSI model which is the physical layer and data link layer. The physical layer is function to define the modulation radio wave and signalling the characteristics for data transmission. The data link layer act to define the interface between machine bus and the physical layer [10].

2.4 Circular Polarization

This project required to design the circular polarize patch antenna at frequency of 2.45 GHz. The circular polarization only can be achieved when the magnitudes of two components are the same and the time phase difference between them is odd multiple of π/2 [1]. The circular polarization is considered if the field vector possesses must have two orthogonal linear components. The focusing to build up this antenna is based on the reader application only in order to gain the circular polarization at 2.45 GHz.

2.5 UHF Frequency Range around The World

Table 2.2 shows the UHF frequency in several countries. So, UHF frequency used in Malaysia is 919-923 MHz, however, after the improvement the improvement of the frequency is change to 2.45 GHz which is suite with the most of application already in market such as the RFID system that already in market which used frequency of 2.4 GHz.

Table 2.2: UHF Range around the World

Country	Frequency Range (MHz)
North America	902-928
South America	902-928
Europe	865.6-867.6
Turkey	865.6-867.6
Iran	86-868
Brazil	902-907.5 & 86.6-867.6
South Africa	915.4-919 & 865.6-867.6
UAE	865.6-867.6
India	865-867
China	920.5-924.5 & 840.5-867.5
Thailand	920-925
Korea	910-914
Japan	952-955
Taiwan	922-928

Hong Kong	920-925 & 865-868
Malaysia	919-923
Vietnam	920-925 & 866-869
Singapore	920-925 & 866-869
Australia	920-926
New Zealand	864-868

2.6 Frequency Range of Small Size Antenna Applications

Table 2.3 shows the frequency of small size antenna applications that is in the area of 2.45 GHz. So, basically this project is design to meet the frequency of 2.45 GHz and can use for RF energy harvesting and it hopefully can be cover the above frequency applications.

Table 2.3: Frequency Range for Small Size Antenna Application

Small size antenna application	Frequency range (GHz)
RFID	2.446-2.454
WiMAX	2.5-2.7
Wi-Fi	2.4
WLAN	2.4

2.7 Design Parameter

The patch antenna was choose to be the types of antenna that used for design this project because it light weight, low cost, ease of integration into arrays and simple to design. The patch antenna is an ideal component for the communication system because this types of antenna already in the world for several decades. There are some vital parameters should be viewed as that characterize all antenna designs.

There are the polarization, radiation pattern, return loss, gain, bandwidth, and antenna efficiency.

2.7.1 Polarization

The polarization of antenna is important criteria when choosing and installing an antenna. In most communication system, the linear and circular polarizations are used in wider application. Other than that, the vertical and horizontal polarization also used because based on both of this, the circular of linear polarization will be determined. This project is design based on the circular polarization technique. A circular polarized wave radiates energy in both the horizontal and vertical planes where the vertical and horizontal polarization should be same so that, it will be said as circular polarization.

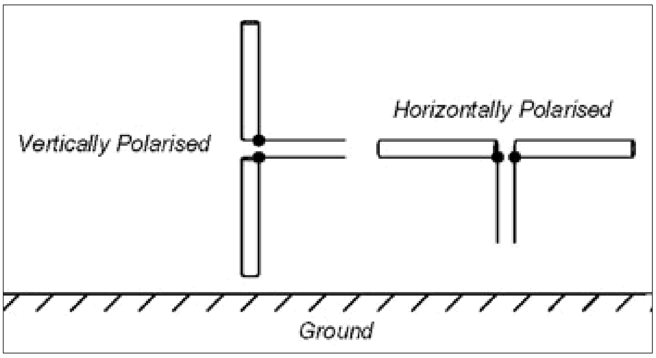


Figure 2.4: Circular polarised wave radiates energy in both the horizontal and vertical planes

2.7.2 Radiation Pattern

The radiation pattern is necessary in designing the antenna whereas via using the radiation pattern, the linear or round polarization can be determined. The radiation pattern is the graphical illustration of the relative area power that transmitted from or acquired by using an antenna. In the simulation results, the radiation pattern can be in 3D, 2D or polar shape with dB scale. However, for the measurement results, the pattern will be measured in polar of dB scale.

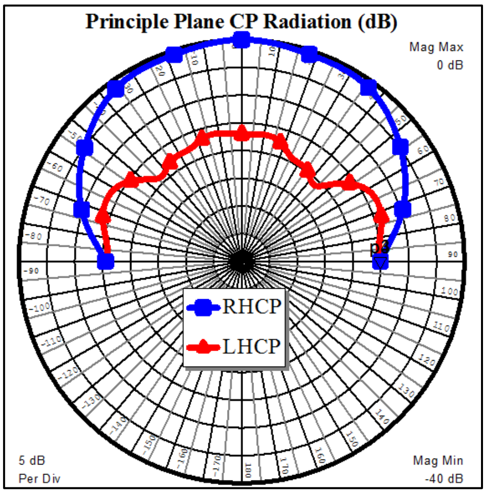


Figure 2.5: Radiation pattern of circular polarization technique

2.7.3 Return Loss

Return loss also known as reflection loss is loss over signalling resulting from reflection where caused at a discontinuity in a transmission line. The discontinuity can be mismatched by terminated the load or with devices inserted in the line. The return loss usually expressed in decibels (dB) as shown below:

$$RL\ (dB) = 10\log_{10}\frac{Pi}{Pr} \tag{2.1}$$

2.7.4 Gain

Gain is suggested of directional antenna gain compared to an isotropic radiator transmitting to or receiving from all direction. Several antennas have greater directional where greater electricity is propagated in sure route than others. If the antenna I no longer directional, the ratio between the quantities of electricity propagated in these instructions in contrast to the strength that would be propagated is no longer similar. For this project, the gain must be in shape to 5 dB.

In order to get the gain and directivity, there are quite a few formulas used to calculate both of this performance parameter. Besides that, the acquired power, Pt must be measured at the spectrum analyser to calculate the gain. The components confirmed the calculation for obtain and directivity.

2.7.5 Bandwidth

The measurement of bandwidth function to show how much the frequency can be varied but it still obtained acceptable VSWR (2:1 or less). It also functions to minimize losses in unwanted direction. For this project, the bandwidth is targeted is more than 100 MHz.

2.7.6 Beamwidth

Beamwidth is carried the measurement of directivity and the range of angular pattern in which at least half of the maximum power was still emitted. The beamwidth consist of half power beamwidth (HPBW) and first-null beamwidth (FNBW). The targeted beamwidth for this project is 60°. The figures shows are the examples of radiation pattern for several degree of beamwidth.

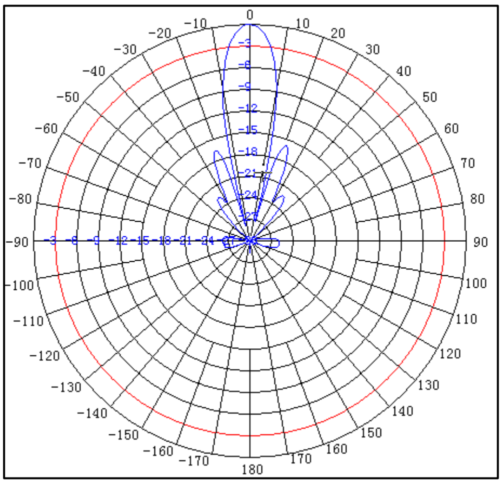


Figure 2.6: Radiation pattern of 120° horizontal beamwidth

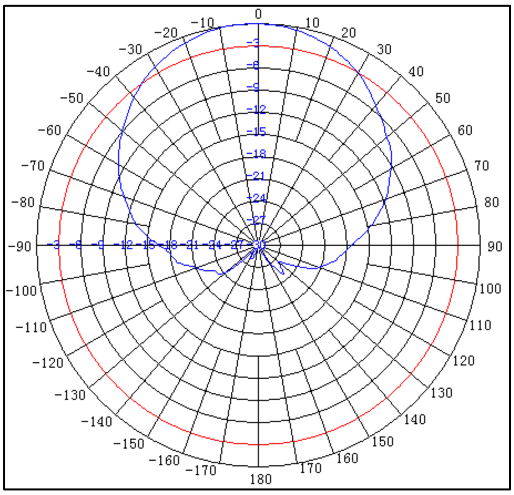


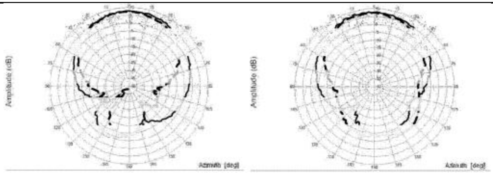
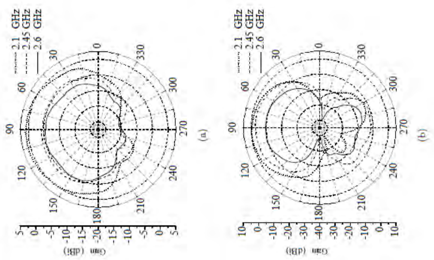
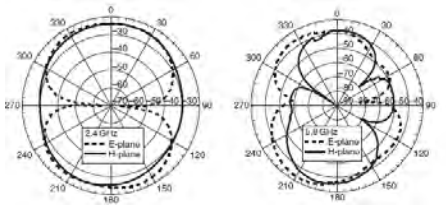
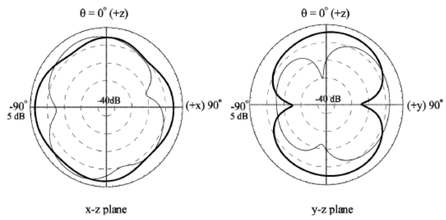
Figure 2.7: Radiation pattern of 60° horizontal beamwidth

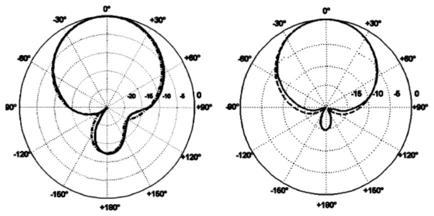
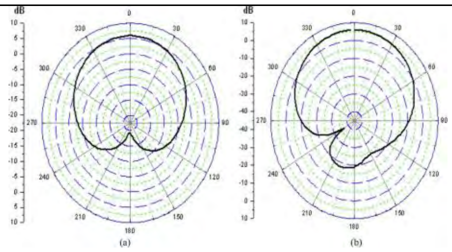
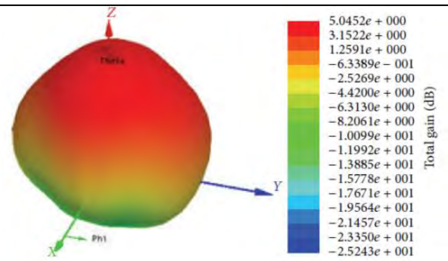
2.7.7 Axial Ratio

This parameter is majorly used to describe the polarization nature of circularly polarized antennas. The Axial Ratio (AR) is defined as the ratio between the minor and major axis of the polarization ellipse. Recall that if the ellipse has an equal minor and major axis it transforms into a circle, and we say that the antenna is circularly polarized. In that case the axial ratio is equal to unity (or 0 dB). The axial ratio of a linearly polarized antenna is infinitely big since one of the ellipse axis is equal to zero. For a circularly polarized antenna, the closer the axial ratio is to 0 dB, the better.

2.8 Literature Review from Other Researchers

Table 2.4: 2.45 GHz Antenna Designs of Several Researchers

No.	Year	Researcher(s)	Gain	Return Loss	Radiation Pattern	Axial Ratio
1.	2004	Xianming Qing, Ning Yang	10.0 dB	-13.0 dB		0.09 dB
2.	2006	A. Tronquo, H. Rogier, C. Hertleer and L. Van Langenhove	6.5 dB	< 11.5 dB		
3.	2007	Z. G. Fan, S. Qiao, J. T. Huangfu, and L. X. Ran	7.0 dB	-37.5 dB		
4.	2007	L. Liu, S. Zhu and R. Langley	2.0 dB	-18.0 dB		
5.	2011	Chih-Yu Huang and En-Zo Yu	1.4 – 1.9 dB	17 dB		

6.	2011	Zied Harouni, Laurent Cirio, Lotfi Osman, Ali Gharsallah, and Odile Picon,	5.7 dB	10 dB		3 dB
7.	2013	Tingqiang Wu, Hua Su, Liyun Gan, Huizhu Chen, Jingyao Huang, and Huaiwu Zhang	6.32 dB	-10.0 dB		5.00 dB
8.	2015	A. Bakkali, J. Pelegri-Sebastia, T. Sogorb, V. Llario, and A. Bou-Escriva	4 dBi	<14 dB		

2.8.1 Circularly Polarized RFID Reader Antenna

The authors are reserved to add aperture to the microstrip antenna that is circulated to the exhibited performances for RFID applications. Good impedance has been shown and radiation characteristics more than 2.35 GHz so 2.5 GHz gets more gain than 9.0dBic and the return loss is less than -13dB. The prototype produced using the board is very conservative, lightweight, easy and minimum. This prototype is best suited for RFID as a reader antenna. Microstrip antennas typically use two orthogonal patch modes in the square phase to achieve the polarization of the perimeter [6].

Most polarization patch antenna patches are on either side adjacent to square patch patches with simultaneous signal magnitude and there is a phase difference using the power dividing circuit. As example is a control splitter or half and half coupler. The truncated patch fed can be used as circular polarization patch antenna given by single path or coaxial line.

2.8.2 Robust Planar Textile Antenna for Wireless Body LANs Operating in 2.45 GHz ISM band

This journal has proposed a single rectangular ring texture antenna for use on a wireless body area network operating on ISM 2.45 GHz [7]. Flectron1 is used in the conductive parts of this planar antenna, including fur texture also used as a non-conductive substrate antenna. In this study, this type of antenna is very suitable for use as it is very productive, flexible and capable of being put into a coat of clothing. The bending level of this antenna has been proven effective.

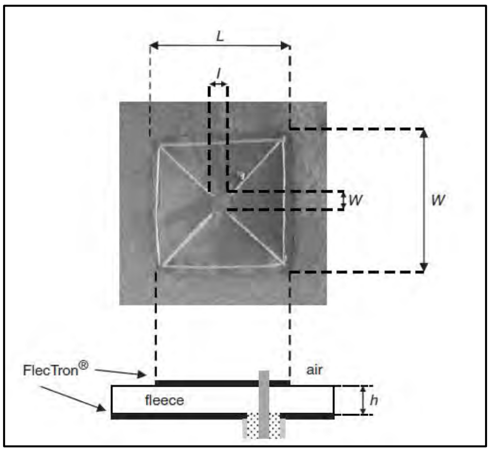


Figure 2.8: Geometry of rectangular-ring microstrip textile antenna

Table 2.5: Dimension of rectangular-ring textile antenna

Patch (Flectron®) (mm)		Substrate (fleece)	
L	49	h	2.56
W	2	ε_r	1.25
Feed point	(7;9)	tan δ	0
Slot			
l	8		
w	7		

2.8.3 A Miniature Printed Dipole Antenna with V-shaped Ground for 2.45 GHz RFID Reader

However in this journal, the author presented a miniature printed dipole antenna with a V-shaped ground used for radio frequency identification readers (RFID). This antenna works on frequency of 2.45 GHz [8]. The level of micro balun and dipole is disconnected and the contemporary outline has been designed. To reduce the coupling between the balloon and the dipole, the ground should be stretched and formed, the antenna bandwidth impedance need to be expanded and the antenna radiation design is moved forward.

To evaluate antenna performance, the 3D finite-time domain electromagnetic (FDTD) simulation must be completed. The advantages of widening and ground position should be checked for good parameters. Antenna must be designed and measured in anechoic microwave room. The findings suggest that broader impedance bandwidth capacity is generated, future radiation profits will increase and the more reasonably concealed concealer will be able to reflect the noisy rays.

2.8.4 Dual-band Triangular Patch Antenna with Modified Ground Plane

In this journal, the components of the parasitic top of the modified small plane at the triangular patch antenna [9] were introduced. This antenna operates on two frequency bands at transfer speeds exceeding 20% on lines 2.45 and 5 GHz. By cutting wide open rectangles inside it can alter the soil that allows the frequency band and the change of partition division.

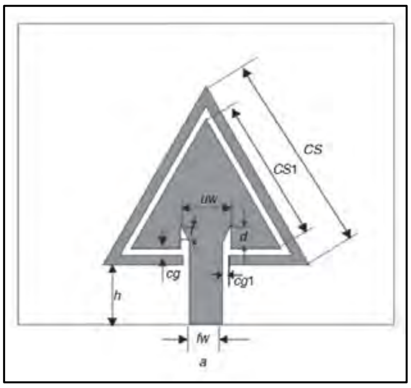


Figure 2.9: Dimensions of triangular patch antenna with parasitic wire

2.8.5 A Slot-monopole Antenna for Dual-band WLAN Applications

Next, this journal proposed the coplanar transient antenna (CPW) consists of a space and a monopole antenna for the proposed dual band composite. This antenna can provide two impedance bandwidths of 124 MHz (about 5.1% focused on 2.45 GHz) and 1124 MHz (about 22.4% focused on 5.5 GHz). This makes the antenna easy to accommodate WLAN operations in 2.45-GHz band (about 3.4% of bandwidth required) and band 5.2 / 5.8-GHz (about 13% required capacity for data transfer). Additionally, this proposed antenna has a security position of 3.mm, capable of making it reasonable for the setting of a remote grip.

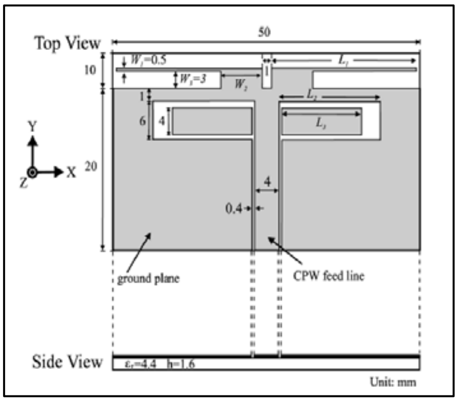


Figure 2.10: Geometry of the CPW-fed slot-monopole antenna

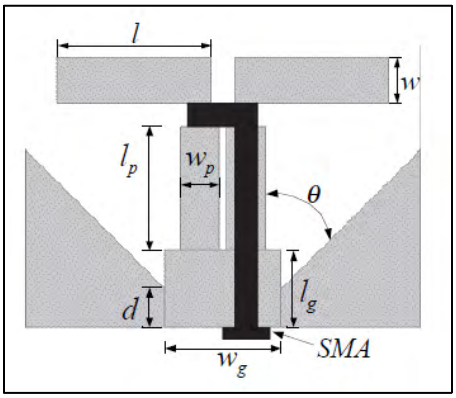


Figure 2.11: Printed dipole antenna structure with a V-shaped land

2.8.6 A Dual Circularly Polarized 2.45 GHz Rectenna for Wireless Power Transmission

The dual-round polarization patch antenna (DCP) is used for minimal 2.4 GHz rectifier antenna (rectanna) at the RF-dc power conversion section has been displayed. This DCP antenna has been combined with a microstrip line in the next ground plane combined with a bandpass filter for consonant discharge. Intended 2100MHz bandwidth has been shown (loss of 10 dB) and CP 705 MHz bandwidth (3 dB axis ratio). Maximum efficiency is 63% and dc voltage is 2.82 V opposite to the resistive load is 1600Ω for the density of 0.525 mW / cm2. The plan of the proposed antenna and its parameters are delineated in Figure 2.13. The parameters of the antenna were gotten utilizing limited component using finite element commercial software [11].

Square mm patch antenna has been printed on the Duroid substrate 5880 where the thickness is 3175mm. The single microstrip buffer has been printed on the subtraction of the 25N Arlon where the line is 1.524 mm and placed on the back of the antenna. On the plane of the ground there is a horizontal opening where it is precisely focused on the transmitter component. Between the patch antenna and the microstrip bowling line were focused on four coupling points which were then obtained (the circle in Figure 2.13) and were carefully promoted by the microtrip bolt line. There are 90 different phases that have emerged as a quarter of the wavelength exits between the coupling points.

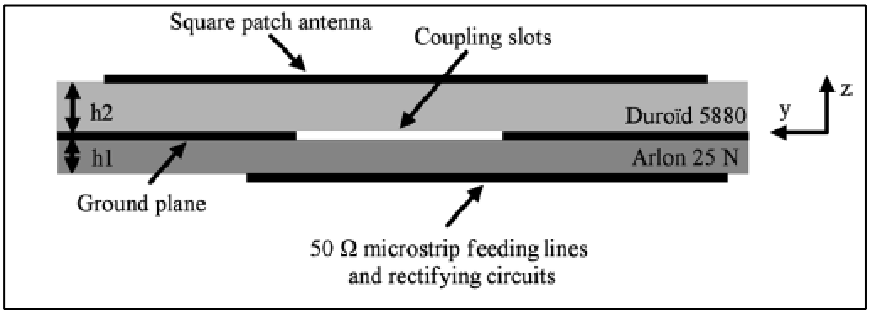


Figure 2.12: Side view of DCP rectenna

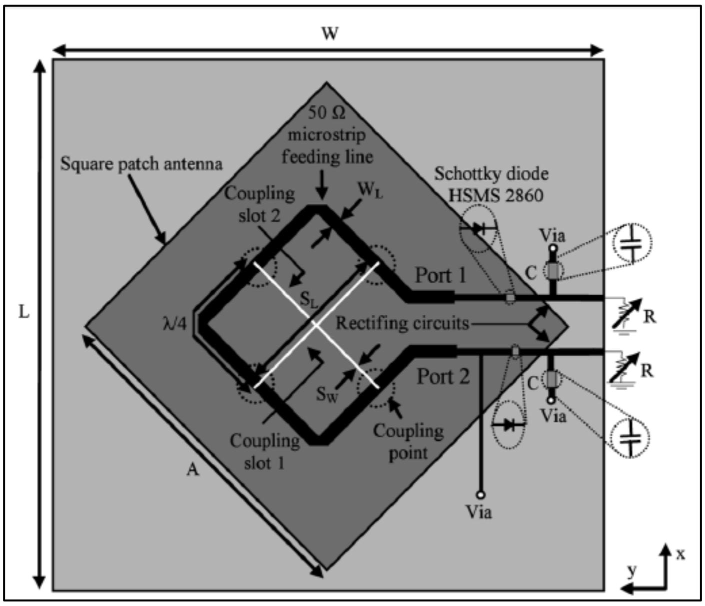


Figure 2.13: Layout of the DCP rectenna (dimensions in millimeters)

2.8.7 A Compact and Broadband Microstrip Stacked Patch Antenna with Circular Polarization for 2.45 GHz Mobile RFID Reader

In this journal, solid and broadband microstrips were assembled in a patch polarized antenna (CP) for readers by the introduction of 2.45 GHz portable passive radio frequency recognition (RFID). Two patch antennas are consists between the antenna that has been backed up. This antenna is designed to promote matching S-shaped impedance matching network (IMN) with related test. With the recommended IMN support, many large impedance examples and broadside symmetry can be obtained.

The basis of this CP operation can be achieved with the top parasite setting successively turning 90 increments but since the repairs will be lower. Conservative operation can be obtained with the opening of four symmetric- L limit on patch antenna. The proposed antenna is fixed by forming a S. shape. The results of this experiment indicate that the antenna reader size has a 3-dB beam width greater than 9.1 dB. The frequency range from 2.31 to 2.56 GHz is greater than 6 dBi and it is able to reach 6.32 dBi at the centre frequency of 2.45 GHz after the peak gain is adjusted. Voltage standing wave ratio (VSWR) bandwidth impedance is greater than 15.1%. The proposed antenna is capable of having the broad impedance transmission capacity and the high performance as shown in Figure 2.14.

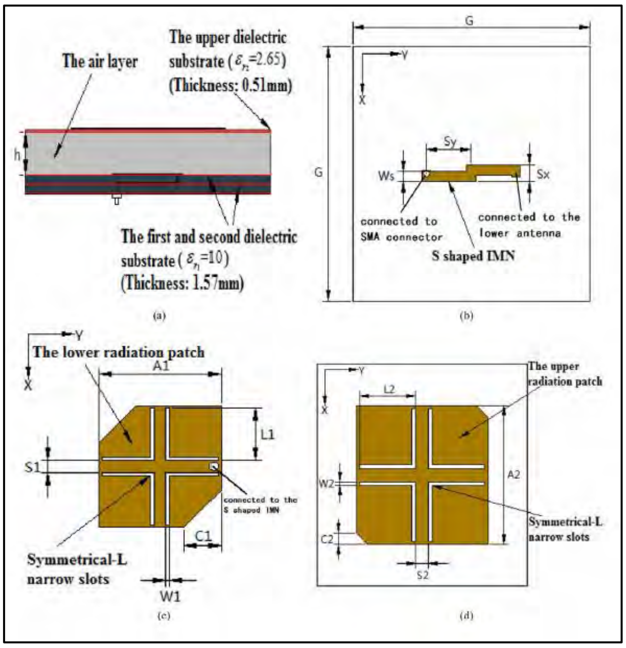


Figure 2.14: Geometry of the proposed compact antenna with circular polarization

2.8.8 A Dual-Band Antenna for RF Energy Harvesting Systems in Wireless Sensor Networks

And lastly in this paper, the authors concentrate on surrounding radio recurrence vitality accessible from business broadcasting stations with a specific end goal to give a framework in light of RF vitality gathering utilizing another plan of getting receiving antenna. Some antenna designs have been proposed for the use of the RF energy harvesting system. Configuring the wires that receives wire configuration is indispensable because the collected energy measurements are subjected to the radio wire highlights [12].

It promises to provide an energy source of choice as the ultimate goal of controlling sensors that are in extreme conditions or isolated places, where other sources of energy cannot work. Dual-band antennas can be combined with the RF energy harvesting system on the same circuit board. Simulations and measurements have been done to assess the antenna condition and see the various effects on the line performance of the antenna parameter. Receiver antennas can meet the desired broadband specification and provide higher than 4dBi working band.

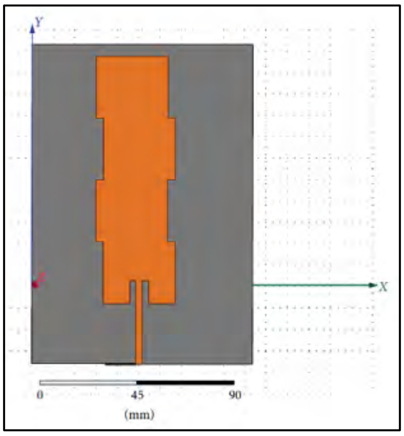


Figure 2.15: Geometry of the proposed dual-band antenna

2.9 Summary

This chapter discussed the properties of the antenna. It explains the basic information of the antenna. Then, this chapter also covers the parameters that important to antenna. For example, polarization, radiation pattern, returns loss, gain, bandwidth, beamwidth and axial ratio. Next, this chapter also discussed about literature review from other researchers.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter it will shows the planning activities for develop this project to guide the students work due to the timeline. The project is discussed first with the supervisor. For the first meeting, the project is design for microstrip patch antenna. Next the project must be design the circular polarization patch antenna at the frequency 2.45 GHz. This project is registered and researches about this project have been done through the literature review. The research is done based on circular polarization technique. After that, the software that commonly used for this design study is CST software. Next, the project is start by design the antenna using the CST software and simulate. Based on the simulation results, the antenna is then will be printed in the transparency paper and the fabrication process will be done. Finally, the patch antenna is measured using the network analyser, spectrum analyser and other antenna test equipment to gain result.

3.2 Flow of Project

Based on the flow chart in Figure 3.1 , the project development was start by identifying the project needs and objectives. Then, the process is finding the references material related to the project requirement such as references book and journal by the other researcher that is related to this project. After that, the literature review was done based on the references material. The processes followed by design the antenna and simulate using the CST software. If the simulate using CST software. If the simulation success, the design can be fabricates using FR-4 board but if the simulation failed, the project should be designed again. After the fabrication process, the antenna was test on the spectrum analyser, network analyser and other antenna test equipment to get the results. The results are analysed and wrote the report.

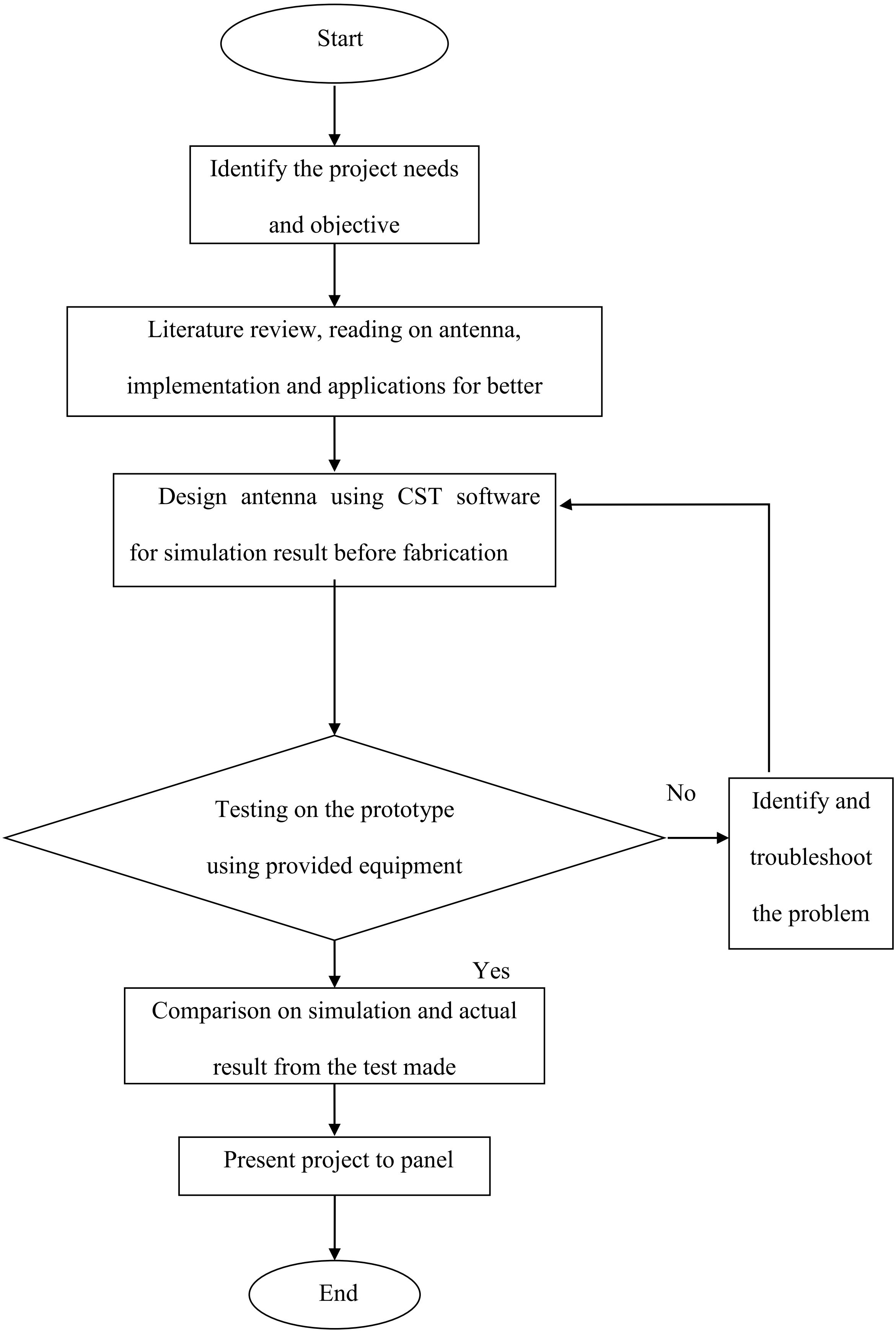


Figure 3.1: Flow Chart of the Project

3.3 Design of Antenna

Design of the antenna was the main part for this project. The following process was show the design process before simulation. The square patch is chosen because it simplifies analysis and performance prediction. The circularly polarized antenna is designed to operate at 2.45 GHz with input impedance of 50Ω, using FR4 (εr = 4.3) and height (h) of 1.6mm.

The equation (3.1) is used to calculate the length of patch.

$$Length\ (L) = \frac{C}{2f\sqrt{\frac{\mathcal{E}r+1}{2}}} - 2\Delta L \tag{3.1}$$

To find $\mathcal{E}reff$,

$$effective\ dielectric\ constant, \mathcal{E}reff = \frac{\mathcal{E}r+1}{2} + \frac{\mathcal{E}r-1}{2}\left(1+12\frac{h}{W}\right)^{\frac{-1}{2}} \tag{3.2}$$

$$effective\ length, Leff = \frac{C}{2f\sqrt{\mathcal{E}reff}} \tag{3.3}$$

Then, find (ΔL)

$$fringing\ length\ (\Delta L) = \frac{0.412h(\mathcal{E}reff + 0.3)(\frac{W}{h} + 0.264)}{(\mathcal{E}reff - 0.258)(\frac{W}{h} - 0.8)} \tag{3.4}$$

$$actual\ length, L = Leff - 2\Delta L$$

$$length\ of\ the\ ground, Lg = 2L$$

$$width\ of\ the\ ground. Wg = 2W$$

By using the above formulas, the patch length is 29.14mm.

The width is basic as far as power efficiency, antenna impedance and bandwidth. It is to a great extent reliant on the operating frequency and the substrate dielectric constant. The equation (3.5) is used to find the width of the patch.

$$W = \frac{1}{2fr\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon r + 1}} \tag{3.5}$$

Therefore, the width of the patch is 37.58mm. However, since this project uses square patch, the width and length chosen is 29.14mm.

After we have all the parameters, we can start with the first step it is calculate the impedance. Firstly our target is to get the 50Ω of impedance. So, after fill all the information of data, check first the value of the impedance in the simulation. If the value of impedance is not 50Ω then we have to find it with change the Wf. In this case, we have to try and error until we get perfect impedance.

Or by using the formula for (3.6),

$$Zo = \frac{120\pi h}{W\sqrt{\varepsilon reff}}$$

Where,

H = height of the dielectric substrate

W = width

εeff = effective dielectric constant

Table 3.1: Dimension of the Antenna

Dimension	Size/Length (mm)
Patch width, W	29.14
Patch length, L	29.14
Substrate and ground length	58
Substrate and ground width	58
Impedance length, L50	10
Impedance width, W50	3.07
Length of feed line, Lqw	5
Width of feed line, Wqw	3.07
Length of truncated corner, Lcc	10
Gap between patch and insert fed, Gpf	4
Height of conductor, Ht	0.035
Height of dielectric substrate, Hs	1.6
FR-4 Dielectric constant	4.3
Feeding method	feedline

3.4 Fabrication Process

The fabrication started by UV exposure using UV exposure machine in order to patch the design layout from transparency into FR-4 board. UV exposure is used to switch the photo of the circuit pattern with a movie (transparency) in an UV exposure machine onto to the photo face up to laminated board. This process was typically taken 2 minutes. After the UV process, the FR-4 board took into growing technique which is a picture withstand developer entails washing away the exposed withstand so that the pattern will be entirely developed. It is dissolved into the chemical for various seconds till it truly dissolved and the patch antenna at the FR-4 board is washed using clean water and dried it using the dryer as shown in **Figure 3.3**. Some precaution should be taken during conducted the fabrication process especially etching process is needed to wear an apron and want to avoid the chemical hit the human body. We need to wear personal precaution equipment as shown in Figure 3.2. After that, the FR-4 went to the next step which is the etching process to remove the unwanted part of copper only. Ferric chloride is needed for the etching process. The etching process was conduct several times until unwanted part is cleaned as shown in Figure 3.4. Then the FR-4 board is washed in the clean water and dried it. Finally the feeding line for the patch was soldier. After the port is soldered, the antenna was done in term of fabrication and ready to be measured. Flow chat on **Figure 3.5** was showed the flow process for etching.

.

Figure 3.2: Personal Precaution Equipment

Figure 3.3: Developing process

Figure 3.4: Etching process

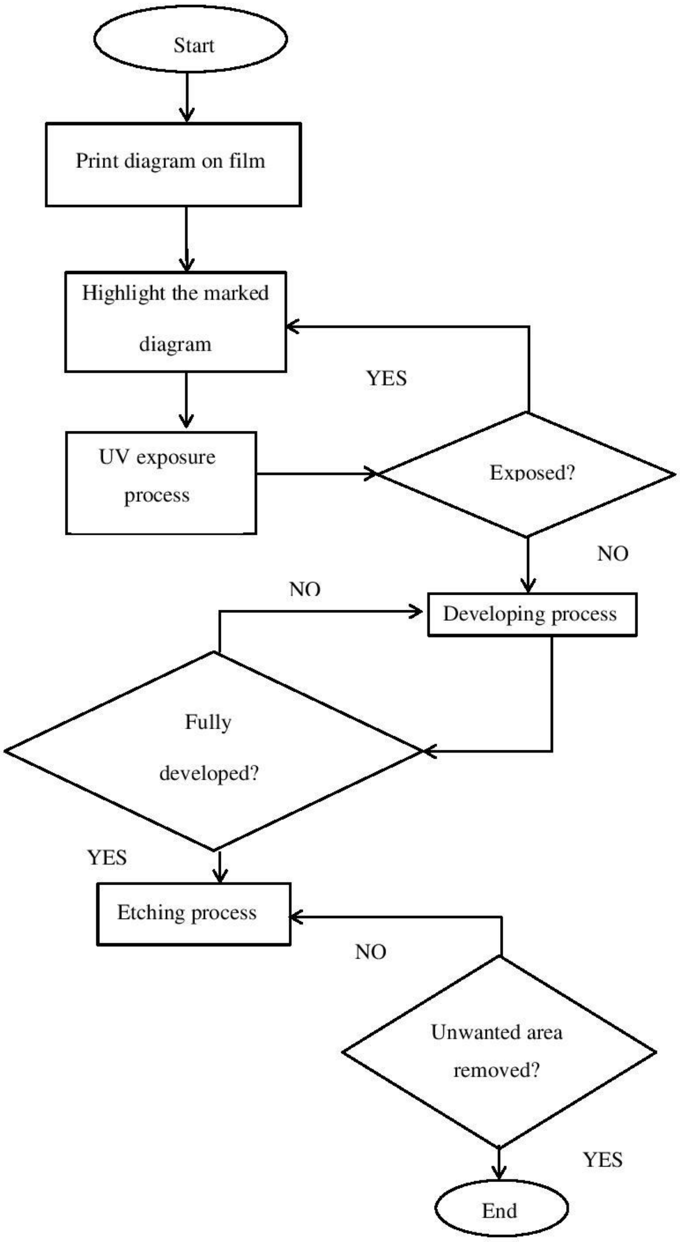


Figure 3.5: The flow process for etching

3.5 Measurement Process

The measurement process will include the calibration using network analyser as shown in Figure 3.6. The calibration is start by connecting cable to the port at network analyser. Because of the antenna only have one port; the calibration process is done for on port only. Next, the calibration is done using the open, short, and load calibration where each of this is calibrated, the button at the network analyser that show the calibration of open, short and load was push and finish with clicked the finis calibration button. Then the measurement is started to gain the result for return loss, measured frequency and the bandwidth.

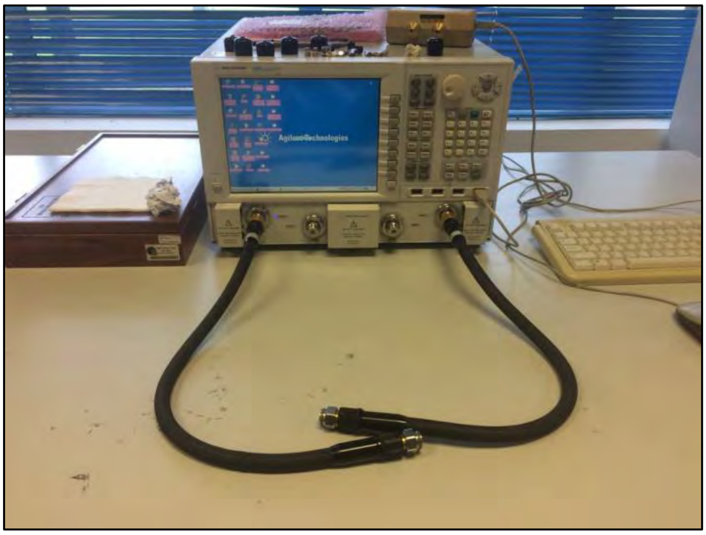


Figure 3.6: Example of Network Analyser

Then, it will show the figure of the measurement process of the radiation pattern. The radiation pattern was conduct by put the patch antenna at the receiver part while the transmitter part is horn antenna. The measurement data was directly saved at computer with the results of radiation pattern. After that, the received power is measure using spectrum analyser in order to calculate the gain.

Figure 3.7: Example of Spectrum Analyser

3.6 Summary

This chapter explains the methods used in this project. It is started with calculation to find the width and length of the antenna. Then, the design is simulated using CST software. This chapter also briefly explains the fabrication process of the antenna. Finally, measurement method and equipment that are used in this project are been explained.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The microstrip antenna is design guided by the flow chart that mention early in chapter 3 which is in the methodology part. The design was split into several tasks in order to achieved short-term goals for every task. This will help the researcher to obtain the result on time. The microstrip patch antenna is designed with guiding to the specification parameters as shown in the Table 4.1. Figure 4.1 shows the proposed antenna layout with dimension using CST software.

Table 4.1: Parameters of Microstrip Patch Antenna

Parameters	Targeted value
Frequency	2.45 GHz
Return loss	<-10 dB
Gain	=> 5 dB
Bandwidth	=> 100 MHz
Polarization	Circular

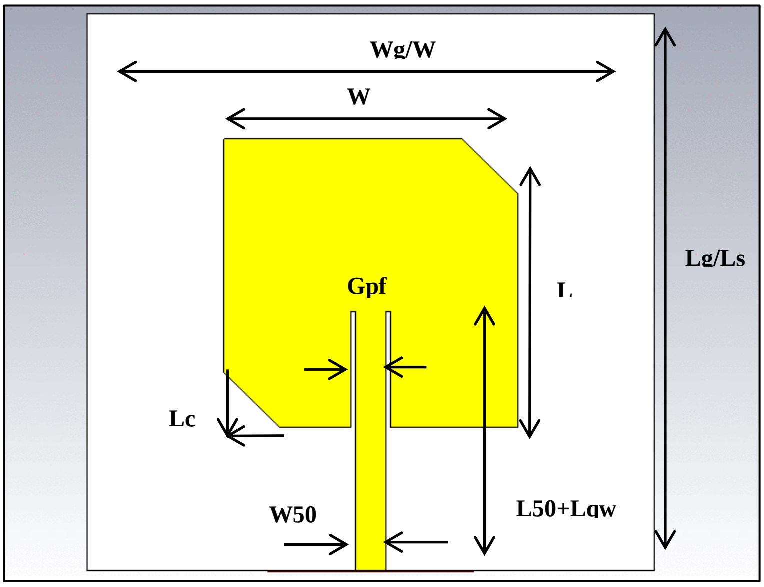


Figure 4.1: Antenna Layout with Design Dimension using CST software

4.2 Analysis on Parameters Optimization

Optimization of the antenna structure is crucial in order to obtain much better outcomes in terms of return loss and even the directivity of the antenna. This optimization process can be done by conducting the parametric analysis on certain parameter of the antenna.

Table 4.2: Parametric Study on the Length of Ground, Lg

Parameter W (mm)	26	28	29	29.5	29.75	30
Resonant frequency, fr (GHz)	2.834	2.6284	2.5364	02.4906	2.4615	2.4425
Return Loss (dB)	-12.058	-31.607	-26.306	-21.525	-18.653	-21.64

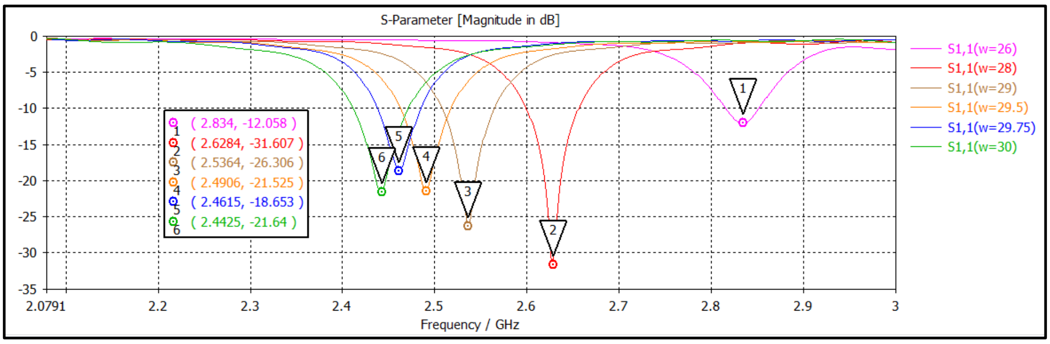


Figure 4.2: Parametric Study on the Width of the Patch, W

Figure 4.2 are the outcomes of the parametric analysis on the width of the patch, W. Based on the graph, there are hugely different frequency shifting can be observed. The resonant frequency seems to be shifting to the lower frequency as the length increases. For this parameter, the value W = 30 mm is chosen as the optimized value.

Table 4.3: Parametric Study on the Length of feed line, Lqw

Parameter Lqw (mm)	2	4	5	6	8	10
Resonant frequency, fr (GHz)	-	2.5416	2.5234	2.5007	2.4581	2.4301
Return Loss (dB)	-	-15.116	-13.209	-15.159	-15.769	-17.11

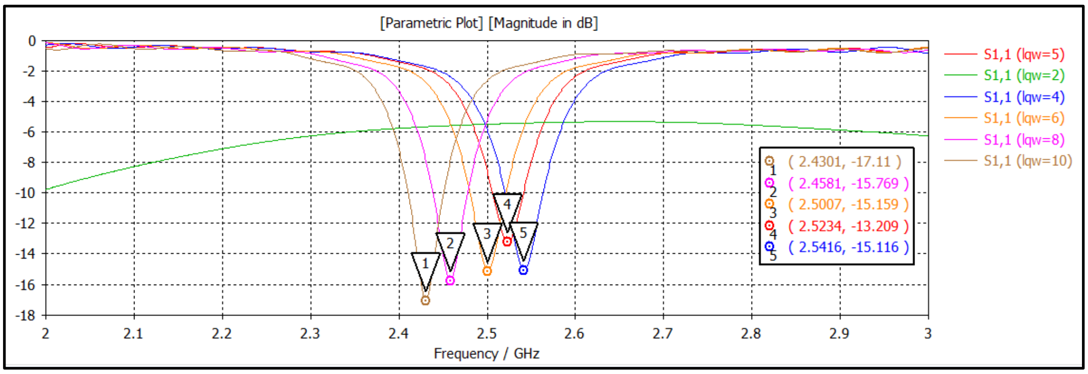


Figure 4.3: Parametric Study on the Length of feed line, Lqw

Figure 4.3 above is outcomes of the parametric analysis on the length of feed line, Lqw. Based on the graph in Figure 4.3, there are constantly shifting interval can be observed, where resonant frequency seems to be shifting more to the higher frequency as the length decreases. For this parametric study, the value of Lqw = 10.00 mm is chosen as the optimized value.

Table 4.4: Parametric Study on the Length of Impedance, L50

Parameter L50 (mm)	5	7	9	11	10	13
Resonant frequency, fr (GHz)	2.5941	2.5744	2.5418	2.5009	2.5228	2.4585
Return Loss (dB)	-17.95	-16.313	-15.278	-15.077	-13.201	-15.376

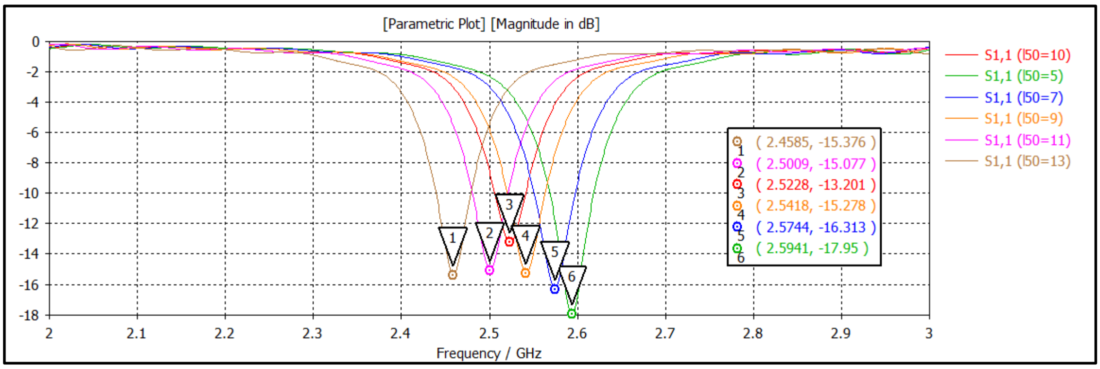


Figure 4.4: Parametric Study on the Length of Impedance, L50

Figure 4.4 indicates the outcomes of parametric analysis on the length of impedance, L50. Based on the graph in Figure 4.4, there is slightly frequency sifting can be observed, where the resonant frequency seems to be shifting more to the higher frequency as the decreases. For this parametric study, the value L50 = 10 mm is chosen as the optimized value.

Table 4.5: Parametric Study on the Width of feed line, Wqw

Parameter Wqw (mm)	3	3.2	3.4	3.6	3.8	4
Resonant frequency, fr (GHz)	2.5238	2.5265	2.5286	2.5321	2.544	2.5496
Return Loss (dB)	-13.211	-15.118	-17.303	-21.355	-24.174	-17.055

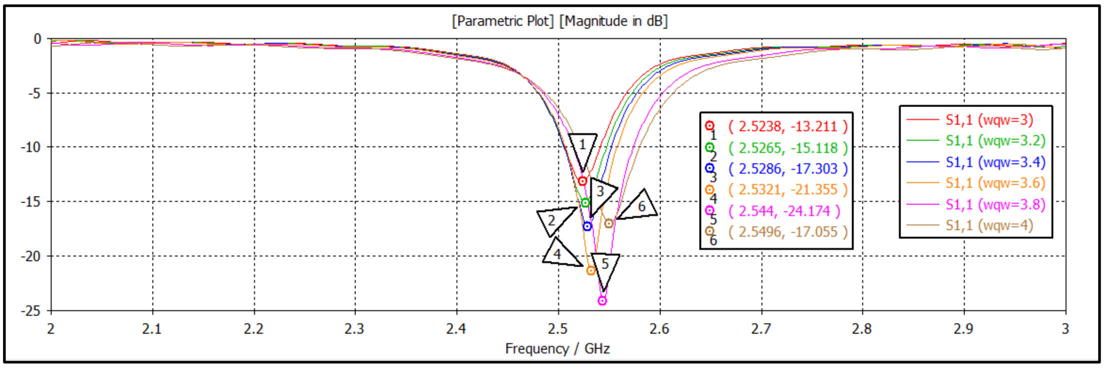


Figure 4.5: Parametric Study on the Width of feed line, Wqw

Figure 4.5 indicates the outcomes of the parametric analysis on the width of the feedline. Wqw. Based on the graph in Figure 4.5, there are slightly frequencies shifting but the return loss is getting lower as the length increases. Unlike the first and second parameter analysis, the changes of the return loss are much more visible. For this parameter, the value Wqw = 4 mm is chosen as the optimized value.

Table 4.6: Parametric Study on the Gap between patch and insert fed, Gpf

Parameter Gpf (mm)	4	5	6	7
Resonant frequency, fr (GHz)	2.5344	2.524	2.5229	2.5192
Return Loss (dB)	-32.223	-13.211	-9.0848	-6.7889

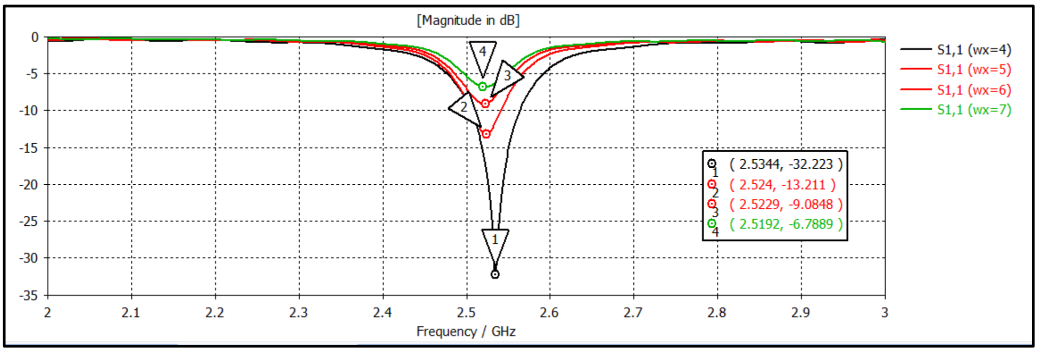


Figure 4.6: Parametric Study on the Gap between patch and insert fed, Gpf

Figure 4.6 above indicates the outcomes of the parametric analysis on the gap between patch and insert fed. Based on this graph on this Figure 4.6, there are not so visible frequency shifting but we can observed that the return loss is getting lower as the length of the gap between the patch and insert gap increases. For this parameter, the value Gpf = 4 mm is chosen as the optimized value because the return loss is very lower compared to the other value.

4.3 Antenna Result

The antenna designed is to operate for any application which at the frequency of 2.45 GHz. The antenna dimensions are determined using the equation as stated in the subsection 3.3 in chapter 3. But to get the good return loss and frequency needed, try and error process have been done based on the analysis of parametric study above. The antenna structure has been constructed using the CST software and therefore, the simulation is to be tested and the pre-fabrication analysis can be further analyzed. The dimension of the patch antenna is shown in the Table 4.7 below. Then, the fabricated microstrip patch antenna is measured using the Microwave Test Set, which is available at MRG lab. Microwave Test Set only can measure the return loss of the antenna.

Table 4.7: Dimension of proposed patch antenna

Dimension	Size/Length (mm)
Patch width, W	30
Patch length, L	30
Substrate and ground length	58
Substrate and ground width	58
Impedance length, L50	10
Impedance width, W50	3.07
Length of feed line, Lqw	5
Width of feed line, Wqw	3.07
Length of truncated corner, Lcc	8
Gap between patch and insert fed, Gpf	4
Height of conductor, Ht	0.035

Height of dielectric substrate, Hs	1.6
FR-4 Dielectric constant	4.3
Feeding method	feedline

4.3.1 Return Loss

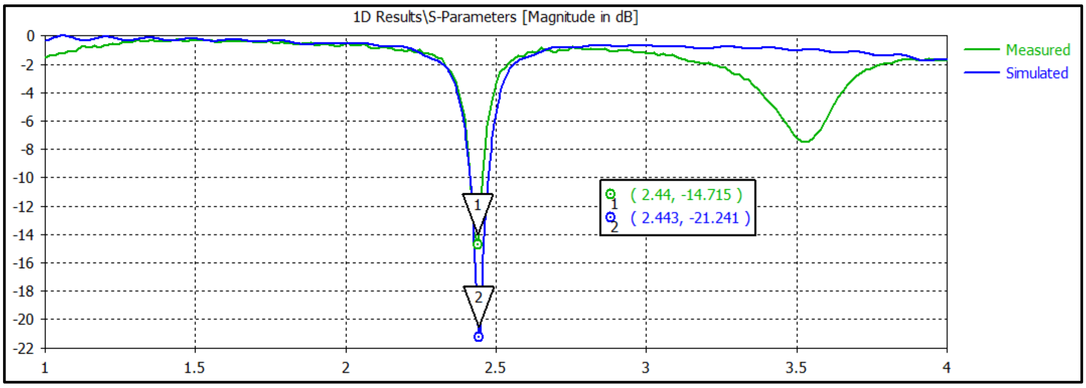


Figure 4.7: The Simulation and Measurement Result on Return Loss

Based on Figure 4.7, the simulation parameter of return loss (S1,1) is analyzed and the graphical illustration indicates the resonant frequency and its return loss. The simulation result shows there is one resonant frequency dropped at 2.443 with return loss of -21.241 dB. The measurement results shown the frequency dropped at 2.44 with return loss of -14.715 dB.

4.3.2 Radiation Pattern

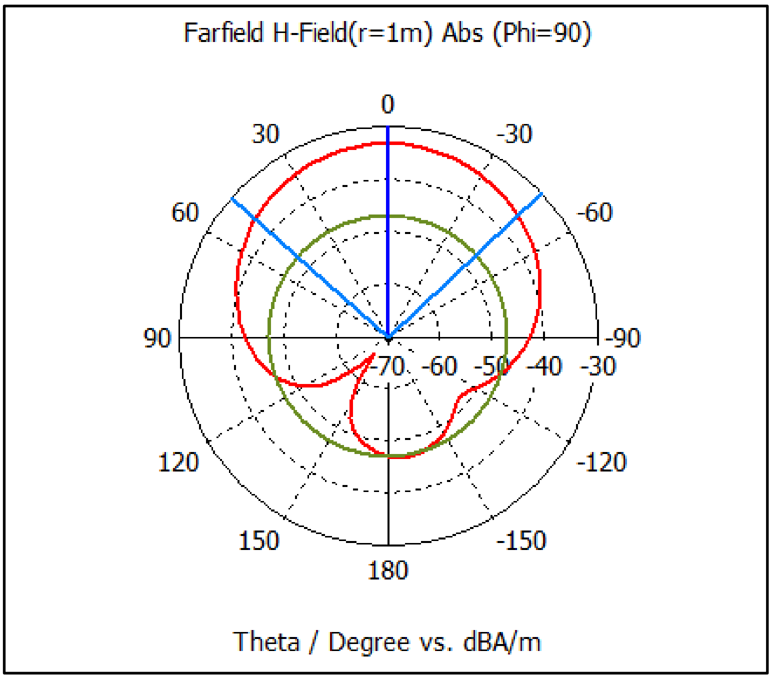


Figure 4.8: The Polar View of Simulation Antenna (E-plane Cross-Polarization)

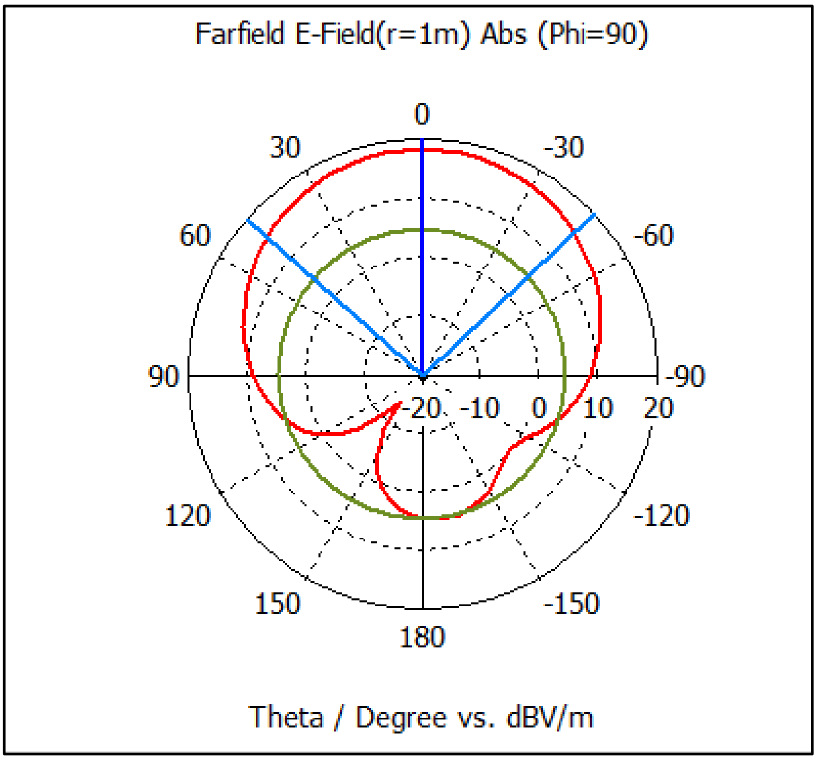


Figure 4.9: The Polar View of Simulation Antenna (H-plane Cross-Polarization)

Based on Figure 4.8, the simulation shows the radiation pattern of the antenna at E plane polarization. Figure 4.9, the simulation shows the radiation pattern of the antenna at H plane polarization.

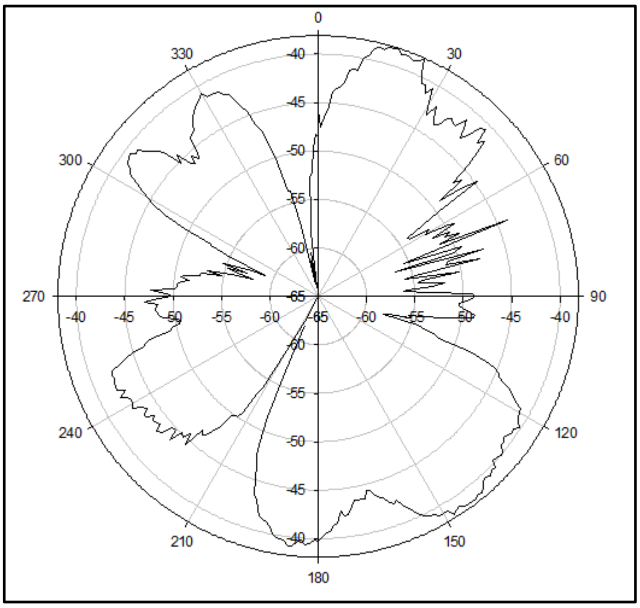


Figure 4.10: The Polar View of Antenna (H-plane Co-Polarization)

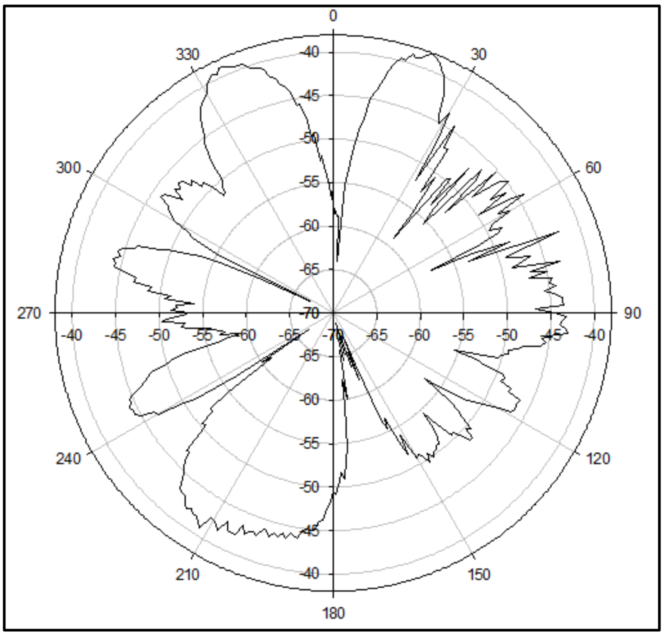


Figure 4.11: The Polar View of Antenna (E-plane Co-Polarization)

Figure 4.10 show the polar view of the antenna radiation pattern on the H-plane polarization. Figure 4.11 show the polar view of the antenna radiation pattern on the E-plane polarization. Both of the radiation patterns are observed to have almost to the unidirectional pattern.

4.3.3 Gain and Directivity

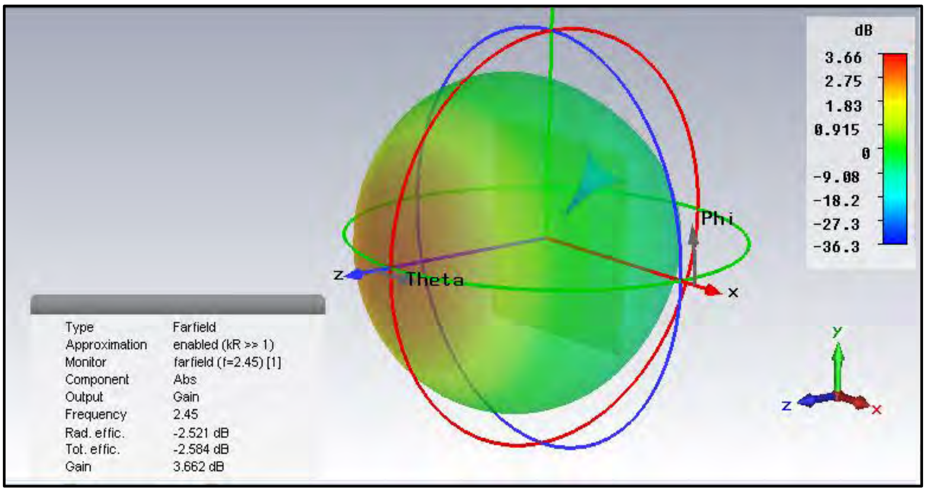


Figure 4.12: The 3D Polar View of Antenna Gain at 2.45 GHz

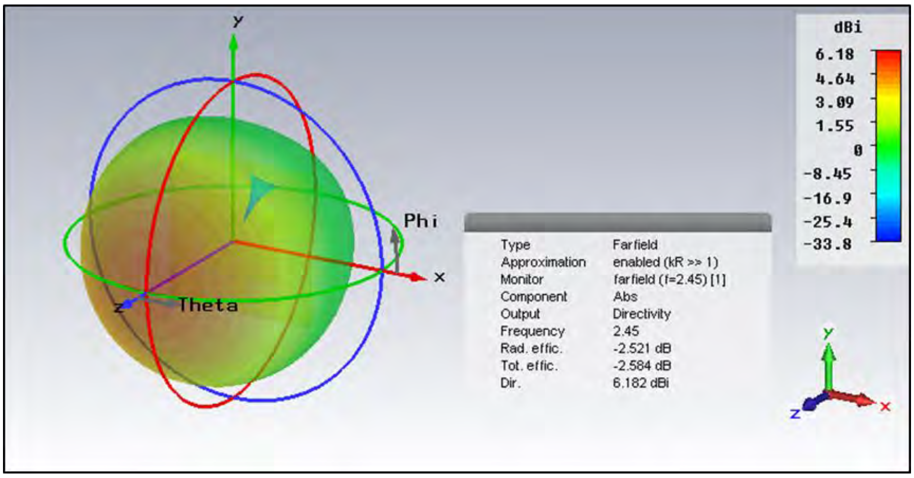


Figure 4.13: The 3D Polar View of Antenna Directivity at 2.4 GHz

Based on Figure 4.12, the simulation of the radiation pattern of the antenna at 2.45 GHz shows that the gain is 3.66 dB with efficiency of -2.521 dB. Based on Figure 4.13, the simulation of radiation pattern of the antenna shows that the directivity is 6.18 dBi with same efficiency same as gain.

For measurement of the gain of the antenna, we need to calculate manually the value of gain measured. Below shows the formula to calculate the gain for antenna (AUT) by using Horn antenna as transmitter:

$$P_{loss} = 34.21 + 20\log f + 20 \log d \qquad (4.1)$$

$$G_r = P_r - P_t - G_t + P_{loss} + P_{cable\ loss} \qquad (4.2)$$

The gain value that has been calculated is 16.195 dB

.

4.3.4 Axial Ratio

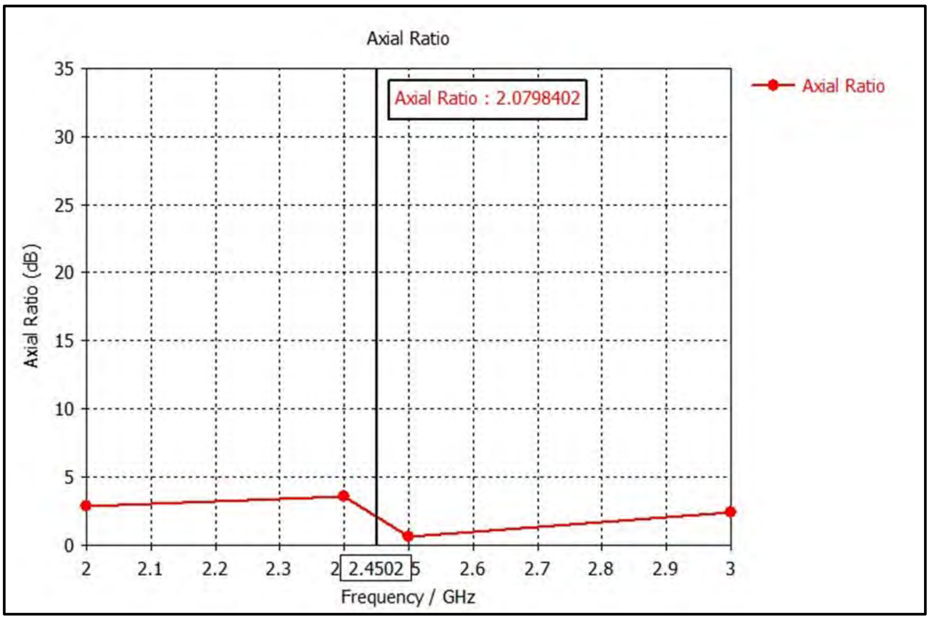


Figure 4.14: The Simulation Result on Axial Ratio of the Antenna

Figure 4.14 show the simulation of the axial ratio of the antenna at 2.45 GHz. The value of axial ratio is 2.0798 dB. Axial ratio can used to determine the quality of the circular polarization and linear polarization. The axial ratio for circular polarization is less than 3dB for ratio accuracy; meanwhile linear polarization is more than 3dB.

4.4 Summary

The design and development of this project using the technique microstrip patch is achieved. Comparisons on the result produced by CST simulation and the measurement using ANA equipment have been done. The differences in value are slightly visible and can be observed from the comparison between simulated and measured result.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Introduction

This chapter presents and concludes the overall data and information observed and obtained in regards to this project. By the end of this chapter, the suggested on improvement methods and techniques are also presented as for the purpose of future research with higher quality of designs and greater performances of antenna.

5.2 Conclusion

The purpose of this project is to design and analyze a circular polarization antenna at 2.45 GHz. The result indicates the performances of the antenna thus this project focuses on the improvement of the antenna by changing the structure of the patch antenna. The parameter analyzed included the return loss of the antenna. The analysis of the parametric study also contributes to the antenna performances thus may be the additional optimization technique to improve certain antenna parameters.

This project has successfully developed an antenna which operated in circularly polarization while maintaining lower return loss and positive gain. Then, the literature review and case study regarding the development of microstrip patch antenna was done in chapter 2. The procedural process from the design of antenna from mathematical equation to antenna fabrication and measurement were mentioned in details in chapter 3, also covered the determination of desired resonant frequency and material selection. In chapter 4, the results obtained both simulated and measured were compared.

5.3 Commercialization

This project which offers circular polarization antenna characteristic will be the driving force in the race of producing high-end technologies that is not only focuses on the functionality but also introduces powerful compact antenna as competitive as the conventional antenna, which then also will reduce the manufacturing and installation cost of antenna. As conclusion, this project objectives and completion are followed and achieved thoroughly to the project scheduling and by taking this into recommendation.

5.4 Improvements and suggestions

Improvement are to be made and recommended as for the study of future works in producing better and higher-quality in term of performances and functionality of current antenna design. Therefore, the following areas are to be explored and studied:

1. Antenna structure of array technique and using metamaterial in order to achieve higher radiation efficiency and antenna directivity.
2. Design microstrip antenna patch using the fractal geometry structure in order to cater the multi-band characteristics while at the same time, introducing miniaturized antenna physical.
3. The radiation pattern of circularly-polarized antenna with enhanced percentage achieves in order to cater larger user capacity.

5.5 Summary

There are many various type of antenna that can excite circular polarization. In this chapter, all data are be presented and concluded from what have been observed and obtained in regards to this project. Then, in term of commercialization, this project objectives and completion are followed and achieved thoroughly to the project scheduling and by taking this into recommendation. Next the suggested on improvement methods and techniques are also presented as for the purpose of future research with higher quality of designs and greater performances of antenna

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APPENDICES

APPENDIX A

This following appendix refers to the FR-4 data sheet:

FR4 Data Sheet :-

Test/Specification	FR4 Laminate Typical Values
Thermal Stress, Solder bath 288 deg. C	>60
Dimensional Stability, E-2/150	<0.04% Warp/fill
	<1.00% Bow/Twist
Flammability, Classification UL94	V0
Water Absorption E-1/105	0.10%
Peel Strength After Thermal Stress	11 lb./in After 10s/288 Deg. C
Flexural Strength	100,000 lbf/in^2 Lengthwise
	75,000 lbf/in^2 Crosswise
Resistivity After Damp Heat Volume	10 ^8 M ohms cm
Resistivity After Damp Heat Surface	10 ^8 M ohms
Dielectric Breakdown. Parallel to laminate	>60KV
Dielectric Constant @ 1MHz	4.7
Dissipation Factor @ 1MHz	0.014
Q-Resonance @ 1 MHz	>75
Q-Resonance @ 50 MHz	>95
Arc Resistance	125 s
Glass Transition Temperature	135 Deg. C
Temperature Index	130 Deg. C
A Few Other Relevant Facts from other Sources	
Specific Gravity	1.8-1.9
Rockwell Hardness (M scale)	110
Coefficient of Thermal Expansion	11 microns/m/Deg.C Lengthwise
	15 microns/m/Deg.C Crosswise
Thermal Conductivity	2.2-2.5 cal/h. cm Deg C

APPENDIX B

This following appendix refers Gantt chart: