DESIGN OF ULTRA-WIDEBAND ANTENNA FOR FUTURE 5G

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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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Universiti Teknikal Malaysia Melaka

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DECLARATION

I declare that this report entitled "Design of Ultra-wideband Antenna for Future 5G" is the result of my own work except for quotes as cited in the references.

Signature	:	…………………………………
Author	:	TANG ZAN HOU
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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 : …………………………………

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Date : 21/8/2020

DEDICATION

This project is dedicated to my parents and friends.

ABSTRACT

After the release by the Federal Communications Commission of frequency range from 3.10 GHz to 10.6 GHz in 2002 for Ultra-wideband (UWB) wireless communication applications, UWB technology has become a hot research field. One of the challenges is designing an antenna of smaller size for wider frequency range applications. The objective of this thesis is to design UWB antennas for future 5G that able to operate from frequency range 2.0 to 12 GHz. Microstrip patch antenna design is chosen for designing UWB antenna due to its low budget and can be fabricate easily. In this thesis, microstrip patch antennas are designed for two different shapes of patch by using flame retardant 4 (FR4) as substrate. Techniques such as etching slots and defected ground structure is presented for both antennas and effect on both antennas is compared and discussed. The design of the UWB antenna is conducted via a simulation with CST Studio Suite 2019 software. The parameters of the antenna such as return loss, gain, radiation pattern and Voltage Standing Wave Ratio have been investigated.

ABSTRAK

Suruhanjaya Komunikasi Persekutuan membenarkan frekuensi dari 3.10 GHz hingga 10.6 GHz diguna pada tahun 2002 untuk komunikasi tanpa wayar Ultra-wideband (UWB), telah menjadi teknologi UWB sebagai bidang penyelidikan yang hangat. Salah satu cabarannya ialah merancang antena dengan ukuran yang lebih kecil untuk aplikasi rentang frekuensi yang lebih luas. Objektif tesis ini adalah untuk merancang antena UWB untuk 5G masa depan yang dapat beroperasi dari julat frekuensi 2.0 hingga 12 GHz. Reka bentuk antena patch microstrip dipilih untuk merancang antena UWB kerana harganya yang rendah dan mudah fabrikasi. Dalam tesis ini, antena patch mikrostrip dirancang untuk dua bentuk tampalan yang berbeza dengan menggunakan FR 4 sebagai substrat. Teknik seperti defected ground structure ditunjukkan untuk kedua-dua antena dan kesan pada kedua antena ini dibandingkan dan dibincangkan. Reka bentuk antena UWB dilakukan melalui simulasi dengan perisian CST Studio Suite 2019. Parameter antena seperti kehilangan pulangan, corak sinaran, keuntungan dan voltage standing wave ratio telah diteliti.

ACKNOWLEDGEMENTS

This project would never been done without the help and guidance of various people at the Universiti Teknikal Malaysia Melaka.

Firstly, I would like to thank Dr. Mohamad Harris Bin Misran for giving me wonderful opportunity to complete my degree thesis under his supervision. Thank you for your guidance throughout the writing and editing of this thesis and giving me the opportunity to grow in this field of research. Your wealth of knowledge in the field of ultra-wideband antenna is inspiring.

I would also like to give special thanks to Mr. Sufian. Thank you for your helping me installing CST Studio Suite 2019 in my laptop. This help me done this simulation results in house.

Lastly, I would like to thank my parents for their support and patience. Their advice was more valuable than I could ever imagine.

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LIST OF SYMBOLS AND ABBREVIATIONS

CST	:	Computer Simulation Technology
FR 4	:	Flame Retardant 4
DGS	:	Defected ground structure
FCC	:	Federal Communication Commission
VSWR	:	Voltage Standing Wave Ratio
PBG	:	Photonic band gap
EBG	:	Electromagnetic band gap
SMA	:	SubMiniature version A
PEC	:	Perfect Electric Conductor

CHAPTER 1

INTRODUCTION

1.1 Project background

An antenna is a hardware that sending or receiving signals. The most common challenges in antenna design is the high rate transition in more covering areas of the communication systems. In 2002, frequency range from 3.10 to 10.6 GHz is allowed as intentional Ultra-wideband emissions by Federal Communication Commission (FCC). Ultra-wideband antennas have been designed and introduced due to commercial applications that achieve accurate location applications and high-speed wireless communications. Operating frequency for the designed antenna is between 2 GHz to 12 GHz. Some techniques such as adding slots to the patch or using partial ground to increase the bandwidth. The material of the substrate is Flame Retardant 4 (FR4) in square or rectangular in shapes while the numbers of the slot will determine the return loss and frequency range of the ultra-wideband antenna. This ultra-wideband also known as microstrip antenna because antenna is fabricated using microstrip techniques on PCB. The simulation results are simulated using Computer Simulation Technology (CST) software tool. The S parameter of the designed antenna get a return loss below than -10 dB and the frequency range between 2 and 12 GHz.

1.2 Problem statement

Ultra-wideband system is facing many challenges and one of these challenges is to develop a suitable antenna that can work over entire ultra-wideband bandwidth. Different application operates in different frequency, therefore each of the application has its specific antenna to receive the frequency. The design of this ultra-wideband antenna is supposed able to transmit at a wide frequency range between 2 and 12 GHz, which enable it can work with any application that within the frequency range. This means the ultra-wideband antenna can be operated on multi-application that not only focus on one type of application only. For devices of a single frequency, it requires many antennas to operate. Using a smartphone as an example, it needs two types of antennas to operate in 2.4 GHz and 5 GHz while ultra-wideband antenna able to reduce the number of antennas needed and functional compare to single frequency antennas since it has a large frequency range from 2 to 12 GHz [1]. Next, there is another difficulty occurs when designing UWB using microstrip patch antenna. The limitation that faced is lower bandwidth of its initial design, therefore techniques such as DGS and length of the microstrip also need to be consider in designing an antenna that has wider bandwidth. For antenna that applied DGS much smaller size compare with antenna that has same operating frequency. The design of antenna in smaller size is very important for portable devices [2] [3]. Another criterion that need to be consider is the effective area of UWB antenna. Based on the radiation pattern, the antenna can be concluded that whether linear or omni directional behavior at certain frequency bandwidth. For 5G applications, omnidirectional antenna is more prefer compare to linear directional or also known as unidirectional antenna because it able radiates and receives radio frequency in all directions [4].

1.3 Objectives

I. To design and optimize a single patch antenna that operates at 19 GHz and a leaf-shaped patch antenna into ultra-wideband frequency from the range 2 to 12 GHz.

II. To design and optimize two ultra-wideband antennas with return loss less than – 10 dB.

III. To fabricate and analyses the performance of ultra-wideband antenna that able use in multi-application.

1.4 Scope of work

Four parts such as literature review, design and simulation, fabrication and lastly is analysis and measurement are divided in this project.

First part is the literature review. After studied journals or articles regrading ultra-wideband, the techniques and characteristics of the UWB antenna especially return loss, Voltage Standing Wave Ratio, gain, directivity and radiation pattern are investigated and analyzed.

Second is the design and simulation of this project. Both UWB antennas are designed at the frequencies range between 2 to 12 GHz and Computer Simulation Technology (CST) software is used to simulate the results.

Third is the fabrication process. Rectangular patch antenna and irregular patch antenna is fabricated on Flame Retardant 4 (FR4) board. By using the photolithography techniques, both antennas design is printed on the FR4 board. After that, a SubMiniature version A (SMA) port that has 50 Ω impedance is soldered on the patch.

Lastly, simulation results of both antennas are plotted using CST software and MATLAB while measurement results such as gain is measured by using Vector Network Analyzers (VNA), radiation pattern is recorded inside anechoic chamber and gain received is calculated by using formula. Parameters of rectangular and irregular patch antenna is compared and discussed.

1.5 Project overview

Initial structure for the first UWB antenna is a planar rectangular and second UWB antenna is designed by using a leaf-shaped patch. Next, techniques such as notching and beveling are applied on the patch to increase the bandwidth ratio. A ground place with slot is optimized to obtain stable radiation patterns. FR4 board is chosen as the substrate for both antennas. There is a comparison and discussion between these both antennas after got the optimized parameter values which are return loss, gain, radiation pattern and VSWR.

1.6 Thesis outline

This thesis has five chapters that cover the whole design, simulation and measurement for both UWB antennas. Chapter one describes the introduction of this project, problem statement, objective, scope of work, project overview and thesis outline.

Chapter two is the literature review which discusses topic on UWB antenna such as gain, return loss, radiation pattern and bandwidth. There are also included information on the shapes of patch, types of substrate and feeding techniques that help to achieve better results for the antenna.

Chapter three is the project methodology which explained the flow of process in designing of two different antennas. Different simulation results is compared and the best results will be chosen before next techniques is applied.

Chapter four is the results and discussion where includes calculation, simulation results of two different type of UWB antenna. Parameters such as return loss, gain, radiation pattern and VSWR is compared between both antennas.

Chapter five is the conclusion and future work. This chapter concludes the results for both antennas design and recommendations for the future development for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter proposed to review and compare theories and methods to build up a UWB antenna that able to receive frequencies between 2 and 12 GHz. This review will only focus on three major themes which are different structures of antenna, suitable sizes for portable device and improvement parameters of antenna which are return loss, gain, radiation pattern, bandwidth and VSWR.

2.2 History and Background for UWB Antenna

Devices that can send and receive signals are known as antennas. Ultra-Wide Band (UWB) is a high-speed data transmission but short distance wireless communication technology. Federal Communication Commission (FCC) allow access frequency between 3.10 and 10.6 GHz is available for the wireless system in February 2002.

Since different frequencies require different antennas, so it will cause more numbers of antenna and increases the size of wireless portable device, therefore UWB antenna was designed to replace multi narrow-band antennas [5]. Based on the need for the communication applications, different types if UWB such as wide-band microstrip, wide-slot UWB antenna and elliptical monopole UWB antenna is designed according different antenna parameters in terms of gain, bandwidth and circular polarization. Usually wide-band microstrip antenna is popular selection for the researcher due to its low price, light and simple to fabricate after applying different types of techniques on it [6].

2.3 Antenna Parameters

For designing of the UWB antenna, the important purposes are increasing the gain with return loss that below – 10 dB at frequencies range between 2.0 GHz and 12 GHz. To achieve all these goals, different parameters are considered such as gain, return loss, bandwidth, radiation pattern and VSWR. The value of these parameters will decide the performance of an antenna.

2.3.1 Gain

Gain explains in an isotropic source contains how many powers are transmitted in a specific direction to the peak radiation. It shows the maximum effectiveness of powers that an antenna can send or receive in a specified direction. Equation to obtain antenna gain is shown in equation 2.1. For a measurement of the power received through the antenna relative to power radiated from the antenna is also known as radiated efficiency. Situations such as impedance mismatch, conduction and dielectric losses will causes power losses and having low efficiency. For theoretical, antenna radiated efficiency is 100 % but in real life, an antenna that radiates 50 – 60 % is considered good enough. Radiation direction is not considered for measuring antenna efficiency, therefore usually used as a measurement for omni-directional antenna. For example, mobile devices need to have good efficiency in any direction. Directivity is a ratio of radiation intensity in a fixed direction to the radiation intensity in any directions from an antenna. For the direction that is not given, direction of the maximum radiation intensity is taken. For antenna with low directivity able to receive signals from any direction while high directivity only can receive signals from certain direction [7].

$$\boldsymbol{G_{RX} = P_{RX} + P_{cable\ loss} + P_{loss} - P_{TX} - G_{TX}} \quad \textbf{2.1}$$

Where,

$G_{RX} = Received\ gain\ of\ antenna$

$P_{RX} = Power\ received$

$P_{cable\ loss} = Cable\ loss$

$P_{loss} = Path\ loss$

$P_{TX} = Power\ transmitted$

$G_{TX} = Transmitted\ gain\ of\ antenna$

2.3.2 Return Loss of S11

The return loss of S11 is the ratio of the reflected power to the transmitted power in decibels. It causes by mismatch from the transmission line. When more energy received by antenna, it means large return loss [8]. For example, 3 dB of the antenna is received by the antenna means that S11 is equal to -10 dB. Therefore, bigger return loss values indicate better return loss

$$\boldsymbol{Return\ Loss} = -\mathbf{10}\ \mathbf{log_{10}} \frac{P_R}{P_I} \quad \mathbf{2.2}$$

Where,

P_R = Reflected Power

P_I = Incident Power

2.3.3 Radiation pattern

Changes of the power radiation by an antenna are represented as radiation patterns. It shows the direction of the relative intensity of the power radiation to the antenna. When this energy is released into one direction, it will also increase the directivity of antenna. We can see the direction of an antenna transmit and receive power by observing its radiation pattern. There are two common patterns used to mention the radiation pattern of an antenna. First, is the omnidirectional antenna where is usually used in cellular telephone and wireless routers due to its ability to radiates and receives equally in all direction. Next, is the directional antenna which able to propagate in specific direction only. Applications such as satellite internet and satellite television installations needed this kind of antenna.

2.3.4 Bandwidth

Bandwidth is the antenna operating frequency range. In wireless communication, operating frequencies bandwidth of an antenna has a return loss of below than −10 dB. Antenna bandwidth also known as fractional bandwidth that used on narrow or wideband antenna and bandwidth ratio that used on UWB antenna. Equation 2.3 shows the formula to calculate the percentage bandwidth.

$$\% \, BW = \frac{f_{max} - f_{min}}{f_{max} + f_{min}} \times 2 \times 100 \qquad \textbf{2.3}$$

Where,

BW = percentage bandwidth

f_{max} = maximum frequency of the operation band

f_{min} = minimum frequency of the operation band

2.3.5 Voltage Standing Wave Ratio (VSWR)

VSWR is another parameter as return loss but only expressed in different scale. Values of VSWR always show positive number and unitless. For ideal situation, there is no power is returned from the antenna where the minimum value of VSWR is 1. Smaller value of VSWR means that greater power is delivered to an antenna which indicate a good antenna match. Table 2.1 shows the relationship between VSWR, reflection coefficient and reflected power in percentage and decibel [9]. Table 2.1 shows that if the value of VSWR is less than 2 is considered as good antenna. This is because a VSWR of 2 has 88.9 % of the power is transmitted to the antenna [10].

Table 2.1: Relationship Between VSWR, Reflection Coefficient and Power

VSWR	Reflection Coefficient, Γ	Reflected Power, %	Reflected Power, dB
1.0	0.00	0.00	- ∞
1.5	0.20	4.00	-14.0
2.0	0.33	11.1	-9.55
2.5	0.43	18.4	-7.36
3.0	0.50	25.0	-6.00

2.4 Shapes of the Patch

The most common shapes in designing microstrip antennas are rectangular, circular. However, there also have other shapes which are square, triangular, circular and elliptical designed as the shapes of the patch [11]. From table 2.2, it can be concluded that different shapes of the patch have different return loss and gain if no other techniques applied on it.

Table 2.2: Return Loss and Gain for Different Antenna Shapes

Antenna shapes	Return loss, dB	Gain, dBi
Square	-15	-0.5
Circular	-10	1.88
Rectangular	-14	0.98

2.5 Feeding Techniques

An antenna able to radiate by direct contact if use a feed line. Antenna bandwidth can be improved if the patch and feed line of the microstrip are well coupled. Four basics feeding techniques are microstrip feed line, aperture couple, proximity couple and coaxial probe line.

2.5.1 Microstrip Feed Line

For this technique, the size of conducting strip is smaller compared to the patch is connected directly at any edge of the microstrip patch. Easily to fabricate is one of the advantages for this technique. The patch and feed line also will have similar impedance by using this technique. Figure 2.1 shows the microstrip line feed [12].

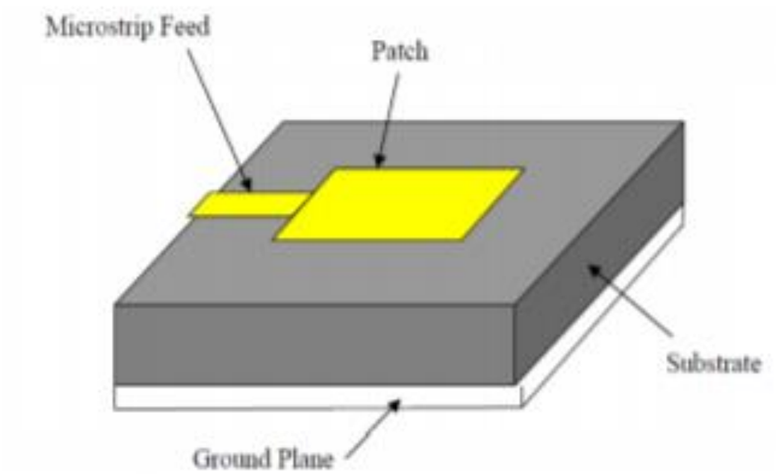


Figure 2.1: Microstrip Feed Line

2.5.2 Aperture Coupled feed

This feed technique, it divided into two layers. Top layer is known as the radiating layer where patch is printed on it and a slot is etched on the ground plane of the top layer while bottom layer is known as feed layer where microstrip feed line is designed on it. Two different frequencies are produced, one is due to the patch and another one by slot. It will increase antenna bandwidth if both resonances coupled properly. Figure 2.2 shows the aperture coupled feed [13].

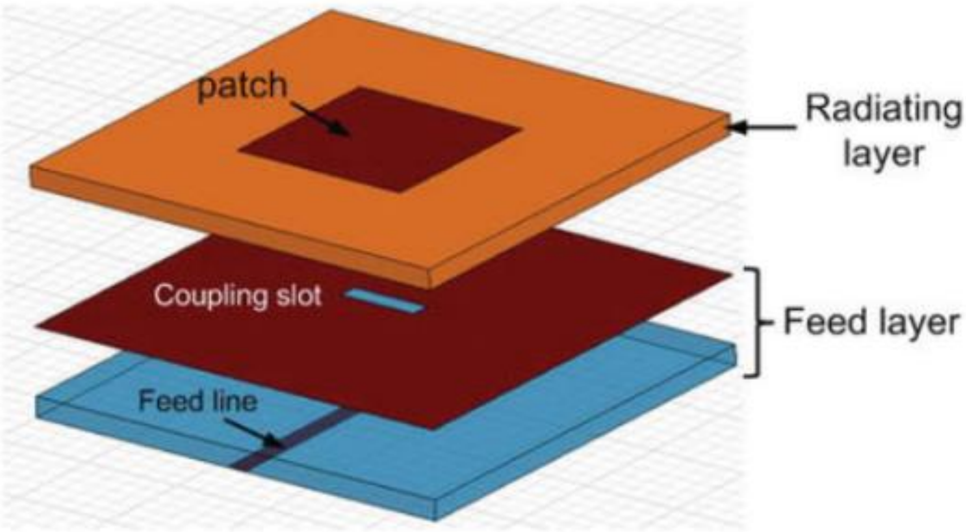


Figure 2.2: Aperture Coupled Feed

2.5.3 Proximity Coupled Feed

For this feed technique, it almost same as the aperture coupled feed which contains two layers. The only difference is there is no ground plane at radiating layer. Therefore, there is no direct connection between the feed line and microstrip patch. This able to improve the antenna bandwidth. Figure 2.3 shows the proximity coupled feed [14].

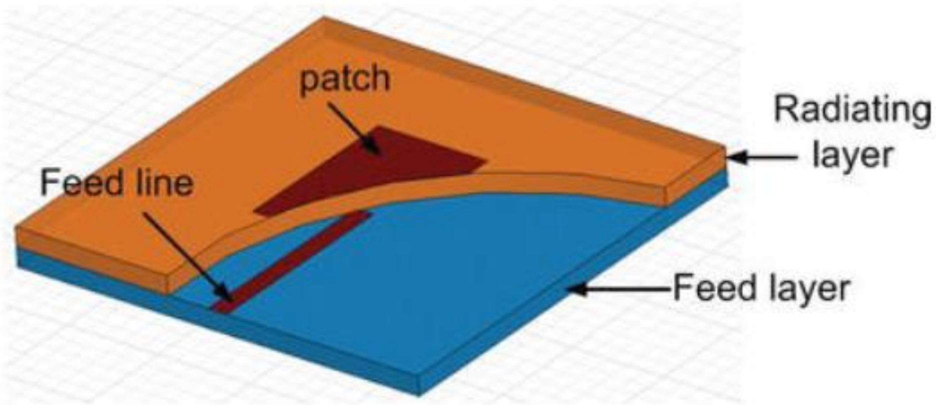


Figure 2.3: Proximity Coupled Feed

2.5.4 Coaxial Probe

For this technique, the ground plane is connected directly to the coaxial cable at the outer conductor and the inner conductor is extended inside the patch antenna. It has low radiation effects. Figure 2.4 shows the coaxial probe [15].

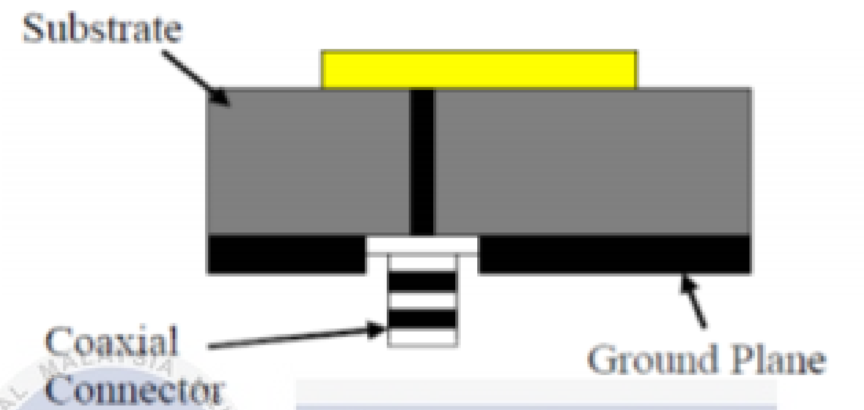


Figure 2.4: Coaxial Probe

2.5.5 Comparison of Different Feeding Techniques

Based on the research regarding feeding method, table 2.3 is listed return loss, resonant frequency, VSWR, ease of fabrication, reliability and bandwidth of these four feeding techniques.

Table 2.3: Characteristic of Different Types of Feeding Techniques

Characteristic	Microstrip feed line	Coaxial probe	Proximity coupled	Aperture coupled
Return loss	Low	High	High	Low
Operating frequency	Wide	Small	Widest	Smallest
VSWR	Less than 1.5	1.4 to 1.8	Less than 1.23	2
Ease of fabrication	Easy	Soldering and drilling	Arrangement required	Arrangement required
Performing	Good	Poor	Good	Good
Bandwidth percentage	2 to 5%	2 to 5%	13%	21%

2.6 Types of Material for Substrate

Omnidirectional radiation frequency bandwidth can be increased due to substrate which has a low dielectric constant. Any changes on the dielectric constant will also affect the values such as gain and bandwidth [16].

Table 2.4: S-parameters for Different Types of Material for Substrate

Material	Dielectric constant	Bandwidth, GHz	Resonating frequency, GHz	Return loss, dB	Price, RM
FR4	4.3	22	2.408	-20.516	Cheap
Rogers (Ro4003)	3.4	25	2.408	-27.994	Expensive
Rogers (RT Duroid 5880)	2.2	30.5	2.406	-19.402	Expensive
GML 1000	3.2	26	2.411	-41.363	Expensive

2.7 Types of Structure Design for UWB Antenna

Four types of structure have been discussed to improve the efficiency, gain and operating bandwidth for the designed antenna.

2.7.1 Electromagnetic Band Gap Structure (EBG)

Periodic arrangement that consists of metallic and dielectric elements that are separated by small gaps and connect the patch with the ground plane in the EBG structures. It can reduce the mutual coupling of the array antenna. Usually, EBG structures are known to operate on a narrow band but not a wideband antenna as it can measure electromagnetic waves at high sensitivity and suppress the surface wave propagation in certain frequency bands [17]. EBG structures can be separated into three groups which are one dimensional, two dimensional and three dimensional. Transmission line is included in one dimensional follow by planar surfaces as two dimensional and three dimensional is volumetric structures. These structures are combines together and achieve higher gain or efficiency antenna. Figure 2.5 shows the EBG structure.

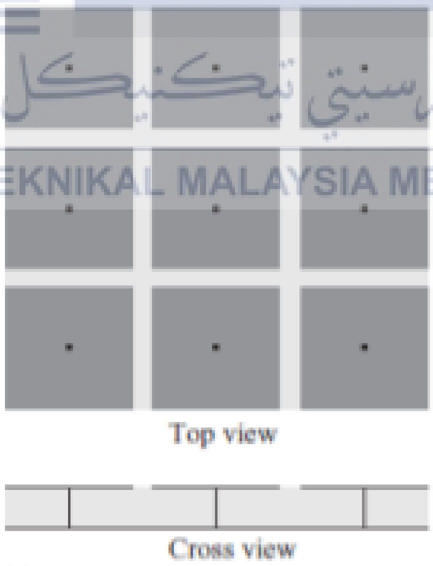


Figure 2.5: EBG Structure

2.7.2 Defected Ground Plane Structure (DGS)

DGS refer to there are compact geometrical slots either in periodic or non-periodic shapes that etched on the ground plane. Any slots on the ground plane will change the direction of surface current. Advantages of implementing this technique can reduce the disturbance to the radiation pattern of an antenna. Figure 2.6 shows the DGS structure [18].

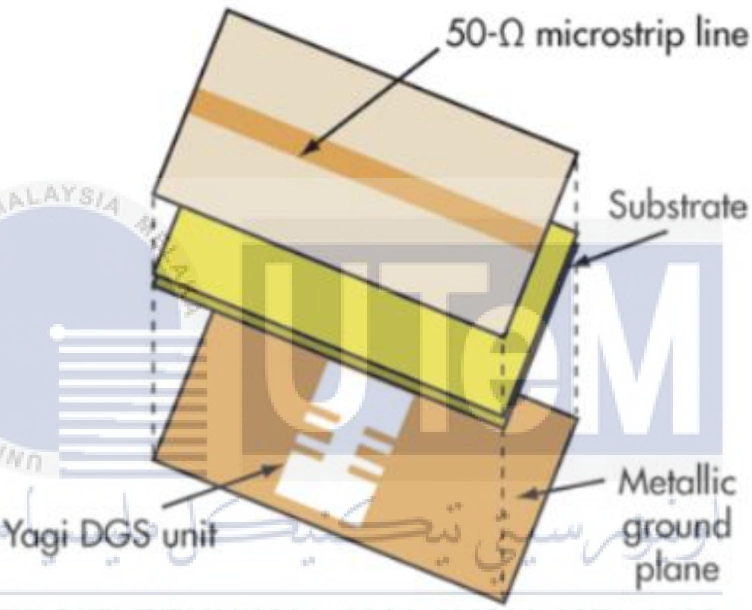


Figure 2.6: DGS Structure

2.7.3 Split Ring Resonator (SRR)

SRR technique can be applied in designing narrow and wideband antennas. The structure has two types of configuration which are edge coupled and broadside couple where both of it is formed by two metallic open rings. Usually, SRR used as a narrow band antenna that able to achieve higher gain or a resonator for measuring microstrip properties. When applying SRR and band notch techniques on UWB antenna, it can improve the band notch characteristic but the disadvantages are the size of antenna become bigger and more complicated [19].

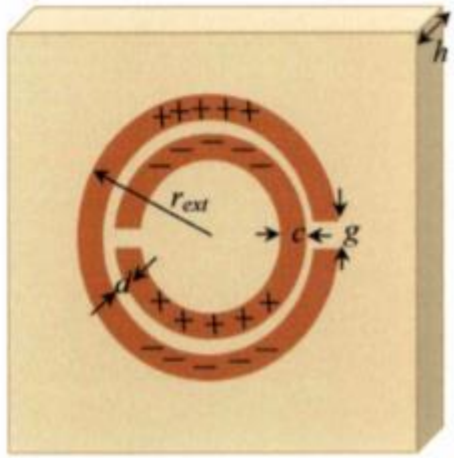


Figure 2.7: Edge Coupled

Figure 2.8: Broadside Coupled

2.7.4 Frequency Selective Surfaces (FSS)

FSS are made by planar and periodic arrangement of patch or aperture with different shapes. Usually, it is designed to propagate electromagnetic waves. Aperture element FSS reflects all the low frequencies while patch element reflects all the high frequencies. To obtain a high directive antenna, a superstrate of FSS is placed on the patch antenna and ground plane is placed below the patch of antenna [20].

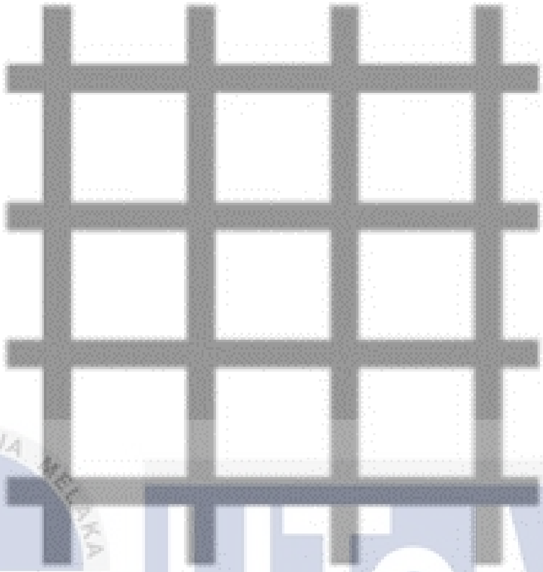


Figure 2.9: Aperture Element

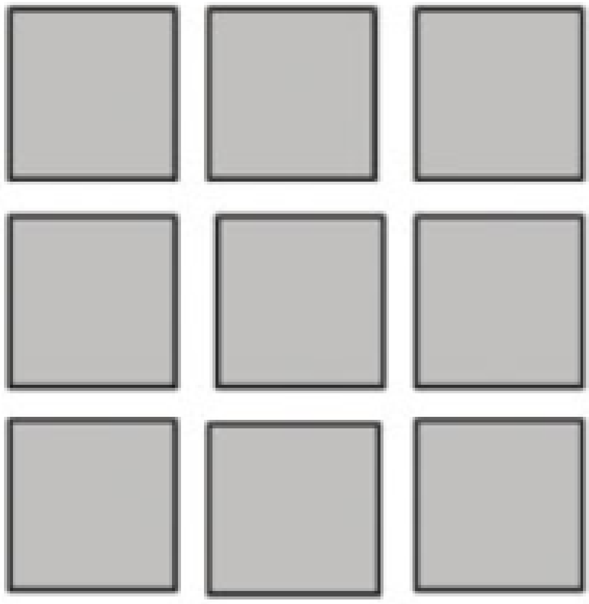


Figure 2.10: Patch Element

2.7.5 Comparison Different Types of Structural Design for UWB Antenna

Table 2.5 shows the geometries, difficulty on parameter extraction, size and ease of fabricate between four types of different structures. Technique by using DGS is the primary choice since it is very simple in hardware fabrication.

Table 2.5: Comparison Between Four Types of Different Structures

Structures	EBG	DGS	SRR	FSS
Geometry	Periodic etched structure	Few etched structures	Periodic etched structure	Periodic etched structure
Parameter extraction	Difficult	Simple	Difficult	Difficult
Size	Large	Small	Small	Large
Fabrication	Difficult	Easy	Difficult	Difficult

2.8 Example of UWB Antenna

Different shapes of radiating patch and different types of structure used in designing UWB antenna will get different parameters. Five different types of designed antennas are listed below.

2.8.1 Antenna with C shape Slot with FSS

The front view patch of the UWB planar antenna is etched with a C shape annular ring slot. The proposed antenna is using FR4 as substrate with size 18.7 mm x 17.6 mm and thickness 1.5 mm. The operating frequency of this antenna is 2.9 until 13.7 GHz but at frequency 5.1 to 5.9 GHz is rejected because return loss obtained more than −10 dB. Maximum gain of this designed antenna is 4.4 dBi. Figure 2.11 shows the geometry for this antenna [21].

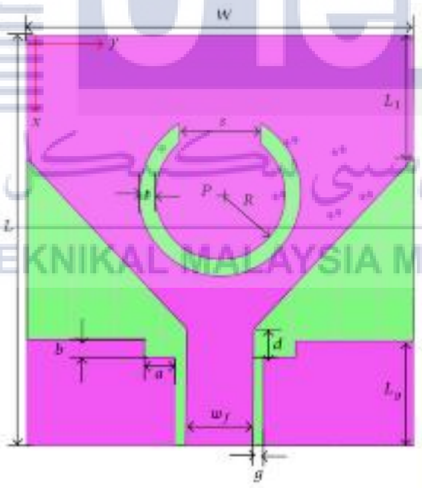


Figure 2.11: Antenna with C Shape Slot with FSS

2.8.2 Circular Patch Antenna with DGS

A circular radiating patch is designed on the layer of FR 4 substrate. The size of the substrate is 84 mm x 86 mm. For improving the wideband operating frequency ranges from 1.17 to 12 GHz, technique such as defected ground structure is used on the ground plane. Gain for this proposed antenna is 2.78 dBi. Figure 2.12 shows the configuration of this antenna [22].

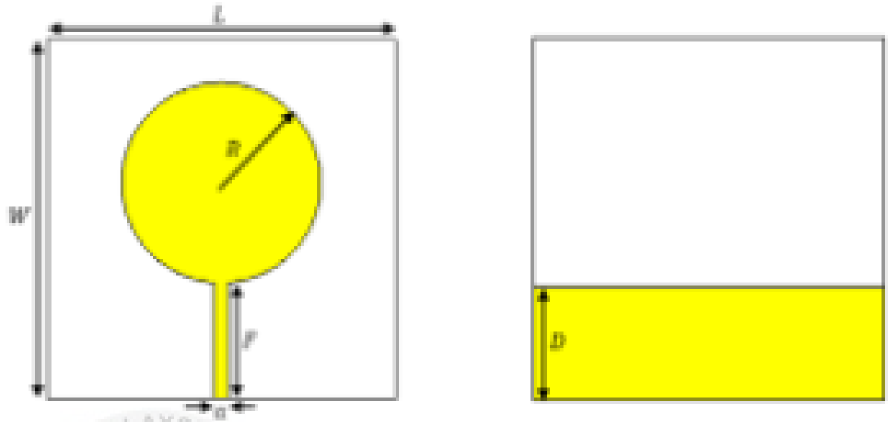


Figure 2.12: Circular Radiating Patch with DGS

2.8.3 Microstrip Rectangular Patch Antenna with DGS

In this journal, different positions of the additional patch in ground plane are located to get wider frequency ranges. Operation frequency of this antenna is from 3.10 until 14.5 GHz due to the defected ground structure technique used on ground plane. By using rectangular radiating patch and FR4 substrate, it obtains gain around 4.9 dBi. Total size for this proposed antenna is 30 mm x 32.6 mm. Figure 2.13 shows the design of this antenna [23].

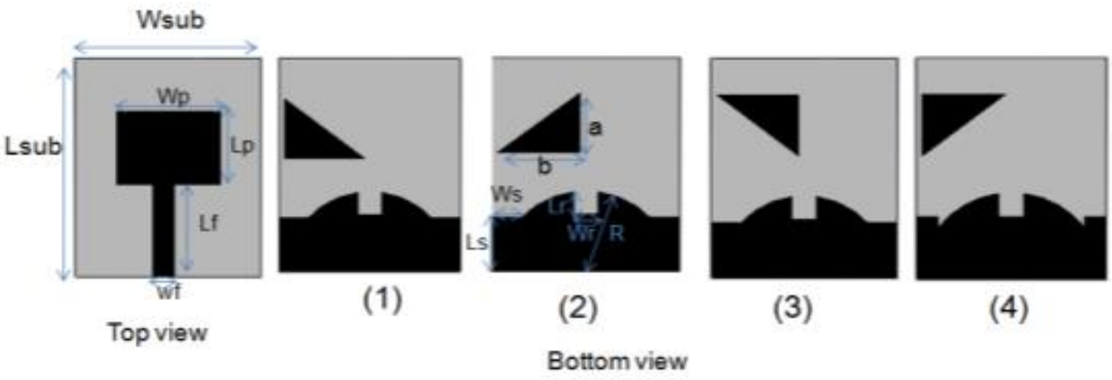


Figure 2.13: Rectangular Radiating Plane with Different Positions of Additional Ground Plane

2.8.4 Dual Half-elliptical Ring Antenna

A UWB antenna with dual notch half-elliptical is printed on FR4 substrates. Size of this substrate is 32 mm x 32.6 mm. The measured bandwidth for this antenna is between 2.6 GHz to 12 GHz with gain 4.8 dBi. Figure 2.14 shows the geometrical structure of this proposed antenna [24].

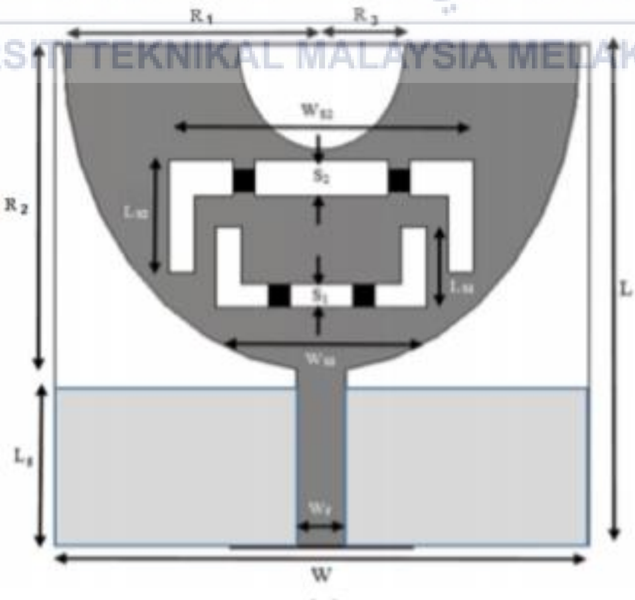


Figure 2.14: Half-elliptical Ring Antenna

2.8.5 Diamond shape Front Patch with Partial Ground Plane and Four Stars-shaped Etched

The design of this antenna has a size of 30 mm x 25 mm. The radiating patch of this antenna is diamond-shaped. For the ground plane, it is applied defected ground structure by using partial ground plane and four stars shape additional patch. The antenna achieves gain with 4 dBi and operating frequency from 2.7 to 10.3 GHz. Figure 2.15 shows the geometry of this antenna [25].

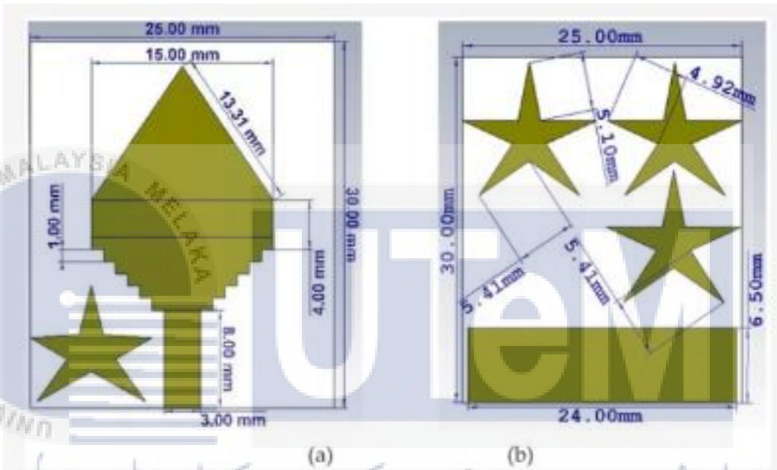


Figure 2.15: Diamond Shape with Partial Ground Plane and Four Stars Shape Patch

Table 2.6: Comparison Between Characteristics and Limitations of Five Types of Different Design of Antenna

Antenna	Material of substrate	Frequency range (GHz)	Size	Gain, dB	Limitations
Antenna with C-shaped slot with FSS	FR4	2.9 to 13.7	18.7 mm x 17.6 mm	4.4	1. Difficult to fabricate
Antenna with circular patch with DGS	FR4	1.17 to 12	84 mm x 86 mm	2.78	1. Size too big 2. Gain too low

Microstrip rectangular patch antenna with DGS	FR4	3.1 to 14.5	30 mm x 26 mm	4.9	1. Difficult to calculate the value of ground plane
Dual half-elliptical ring antenna	FR4	2.6 to 12	32 mm x 32.6 mm	4.8	1. Difficult to fabricate
Diamond shape radiating patch with partial ground plane and four stars shaped etched	FR4	2.7 to 10.3	30 mm x 25 mm	4	1. Difficult to fabricate

The comparison between characteristics and limitations of five types of different design of antenna is shown in Table 2.6. From table 2.5, the best design of the proposed antenna is microstrip rectangular patch antenna with DGS because it able to minimize the size of antenna with the largest frequency bandwidth and highest gain.

CHAPTER 3

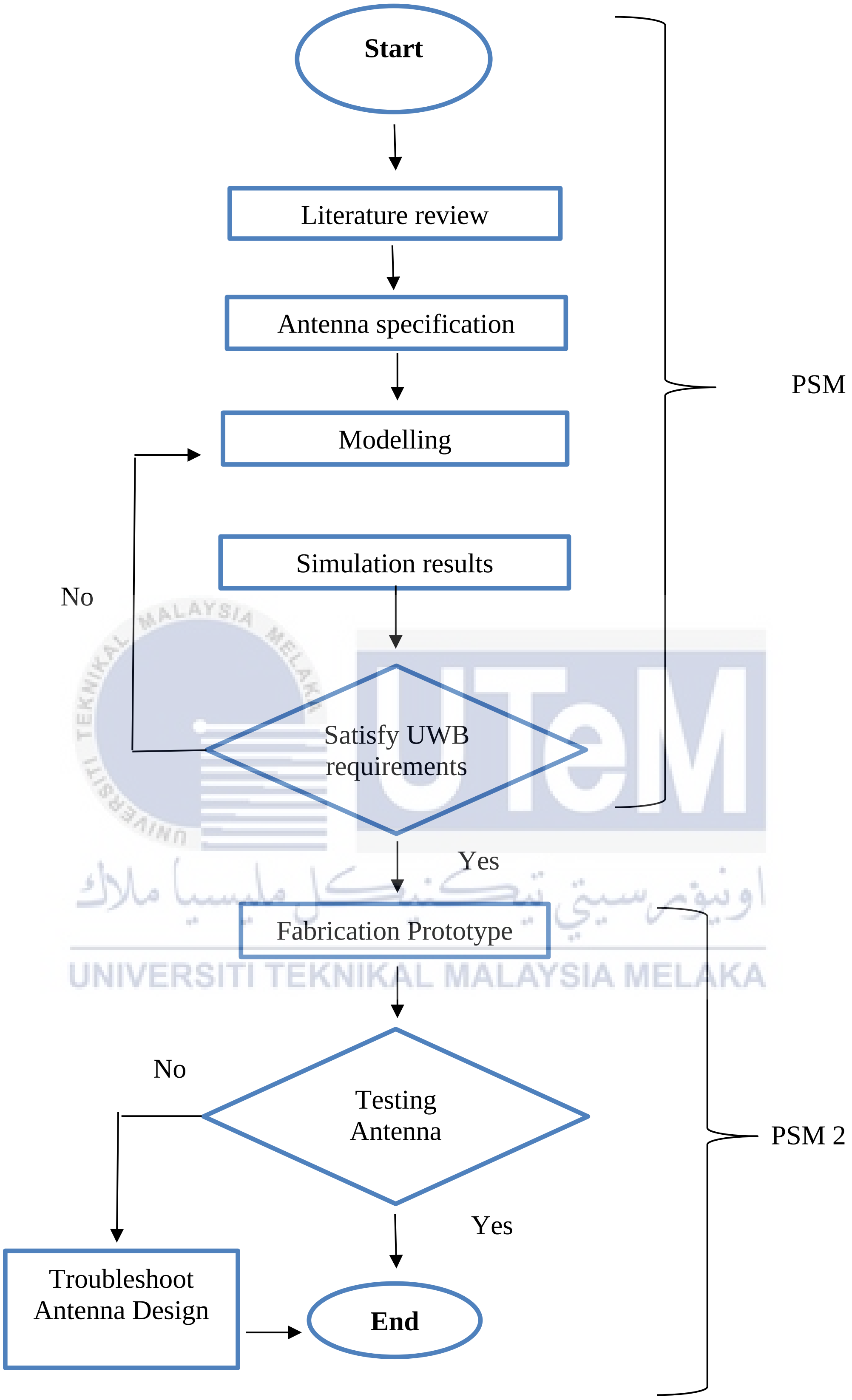
METHODOLOGY

3.1 Introduction

To ensure the scope of the work proceeds smoothly, some of the proper procedure needs to be done. This chapter will list out the outline of research methods that will be used in this project. It also mentions every step involved in designing of UWB microstrip patch antenna and provides information on how to design and fabricate of the UWB antenna. This chapter also discusses some of the calculation parts for the designing of an antenna. The chapter ends with comparing parameters of both antennas.

3.2 Methodology

Before the early stage in designing for both antennas, some literature review and background research on basic design techniques and materials chosen as the substrate or radiating patch for designing an antenna. Next, design specifications such as frequency range, return loss, gain, radiation pattern and VSWR needed to identify in an antenna designing. It follows with the selection of substrates and radiating patches. The S-parameter analysis is done on the selected substrate and patch with different techniques applied to it to obtain parameters that meet the design specifications. All of the simulation results are done by using CST. The flow chart for this project is shown in below.



Flow Chart for the Project Management

3.3 Design Specifications

The details of the design specifications of both antennas which are the rectangular with slot patch antenna and the irregular patch antenna is listed in table 3.1. The antenna that designed should have return loss that not more than −10 dB within the frequency range from 2 to 12 GHz. For the gain also should be above 5 dB and the efficiency need to be more than 50%. Lastly is the VSWR should be below than 2 in operating frequency.

Table 3.1: Design Specification for Rectangular and Irregular Patch Antenna

Frequency range	2-12 GHz
Return loss	Below than -10 dB
Gain	Greater than 5 dB
Efficiency	More than 50%
VSWR	Less than 2

3.4 Formula to Calculate Width and Length for Microstrip Line

Equation 3.1 and 3.2 is used to obtain width and length for the microstrip line.

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}} \; ; \; \varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right] \qquad 3.1$$

$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left[\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.3)\left(\frac{w}{h}+0.8\right)}\right] \qquad 3.2$$

Where,

c = speed of light in free space,

fo = resonance frequency,

ε_R = dielectric constant,

ε_{eff} = effective dielectric constant,

h = height of the patch,

w = width of the patch

3.5 Antenna configuration

The rectangular with slot patch antenna that designed is a planar UWB antenna with the overall size is 15 mm x 20 mm with two rectangular slots and a triangle slot. The antenna is designed by a rectangular patch at the top of the FR4 substrate with 50 ohms microstrip line with defected ground structure technique. For the second designed UWB antenna is leaf-shaped patch antenna with the overall size 30 mm x 30 mm with irregular slots. FR4 has been chosen as the substrate of these UWB antennas with dielectric constant 4.3 with magnetic permeability, μr as 1 and the loss tangent of 0.025. The material chosen as the radiating patch, microstrip feed line and ground plane for both antennas are copper. Materials for the patch and ground plane are using copper which is also define as Perfect Electric Conductor (PEC). For the rectangular patch antenna, the thickness of the substrate is 1.60 mm with 15 mm of length x 20 mm of width. Dimensions for the microstrip line is 1.10 mm x 2.10 mm. Next, slots also applied on the half ground plane while notching and beveling techniques applied on the radiating plane with defected ground plane structure. The results of the designed antenna are recorded in Table 3.2 with labelling in figure 3.1 and figure 3.2. For the leaf-shaped patch antenna, the dimension of the substrate is 30.0 mm x 30.0 mm x 1.60 mm. In addition, irregular and triangular slots are applied on the patch with defected ground plane structure. More details regarding of this designed antenna are recorded in Table 3.3 with labelling in figure 3.3 and figure 3.4.

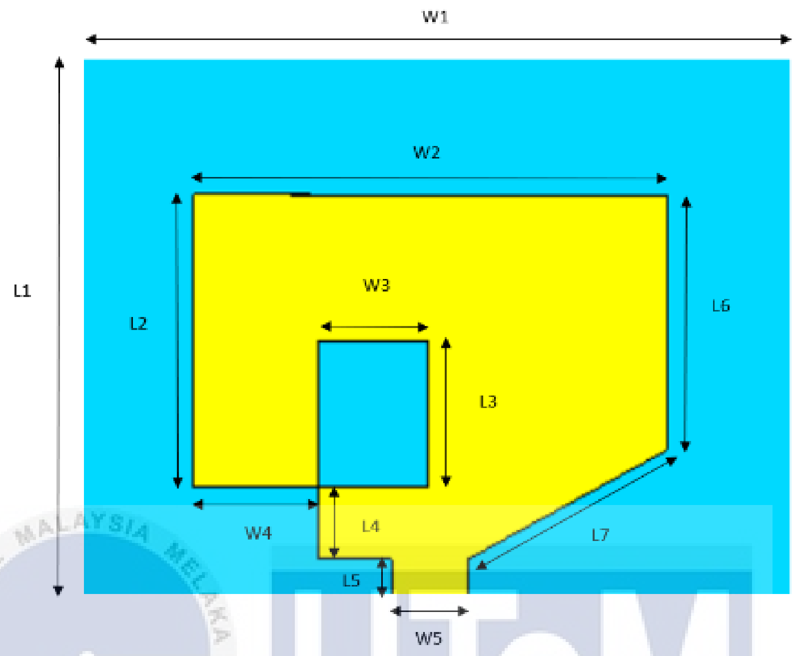


Figure 3.1: Front View for the Rectangular Patch

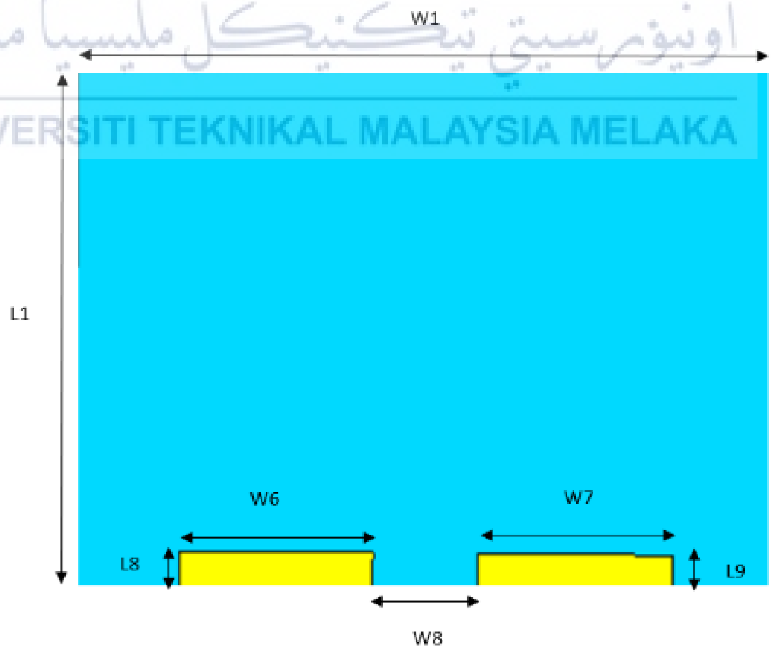


Figure 3.2: Back View for the Rectangular Patch

Table 3.2: Dimension for Rectangular Patch Antenna

Basic configuration	Length, mm
W1	20
L1	15
W2	13
L2	8
W3	3
L3	4
W4	3.45
L4	2
W5	2.1
L5	1.1
L6	7
L7	6.22
W6	5.5
W7	5.5
W8	3
L8	1.1
L9	1.1

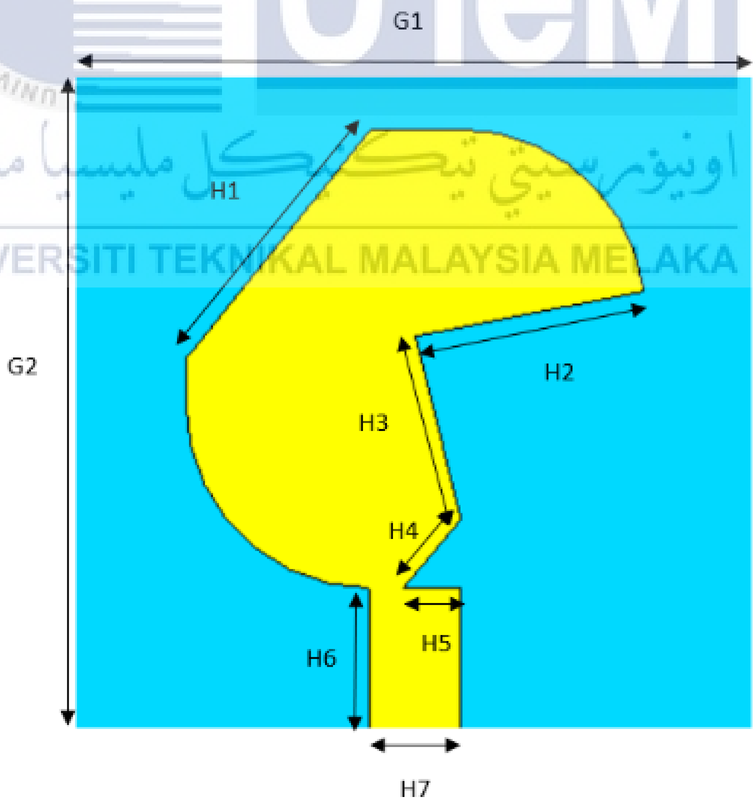


Figure 3.3: Front View for the Irregular Patch

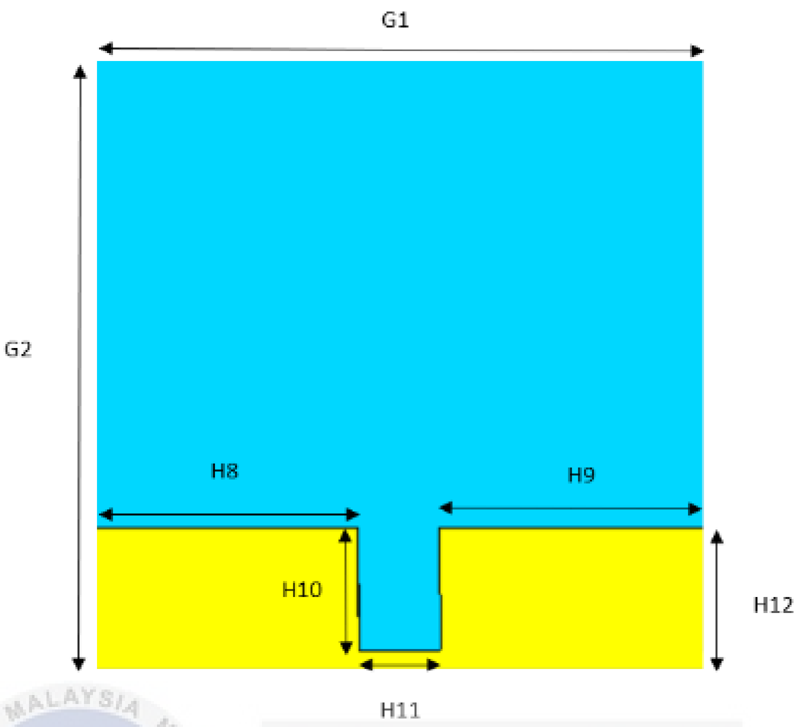


Figure 3.4: Back View for the Irregular Patch

Table 3.3: Dimension for Irregular Patch Antenna

Basic configuration	Length, mm
G1	30
G2	30
H1	12.8
H2	10.14
H3	8.25
H4	3.91
H5	2.5
H6	7
H7	4
H8	13
H9	13
H10	6
H11	4
H12	7

3.6 Different Design of Rectangular Patch and Leaf-shaped Patch UWB Antenna with Comparison S-parameters

From numbering 3.6.1 to 3.6.7 are the description on how to lower down the return loss that obtained by applying different techniques on the rectangular radiating patch UWB antenna. The comparison of s-parameters has been recorded.

3.6.1 Initial Design of Rectangular Patch UWB Antenna

The initial design of UWB antenna is using rectangular radiating plane, microstrip line with defected ground structure technique. By remaining the size of radiating plane, ground plane was changed as shown in figure 3.6, 3.7 and 3.8. Figure 3.9 is the comparison s-parameters of different ground plane.

Figure 3.5: Front View for Rectangular Patch Antenna

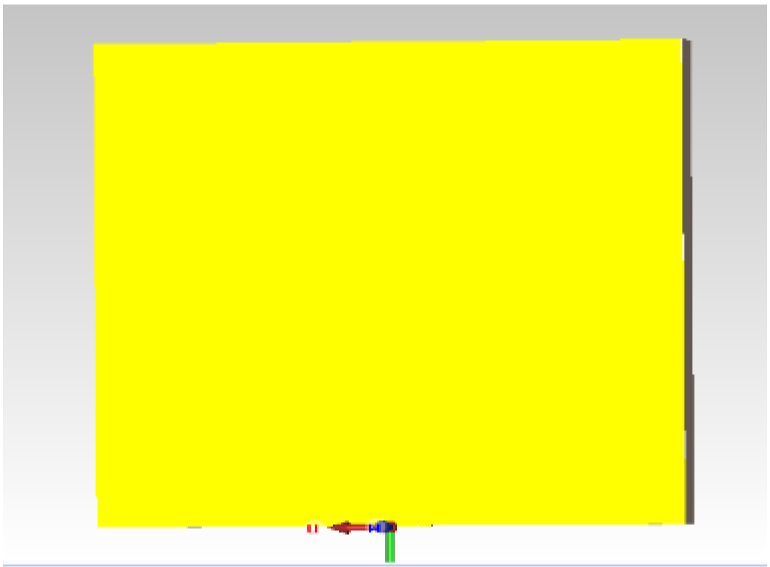


Figure 3.6: Full Ground Plane

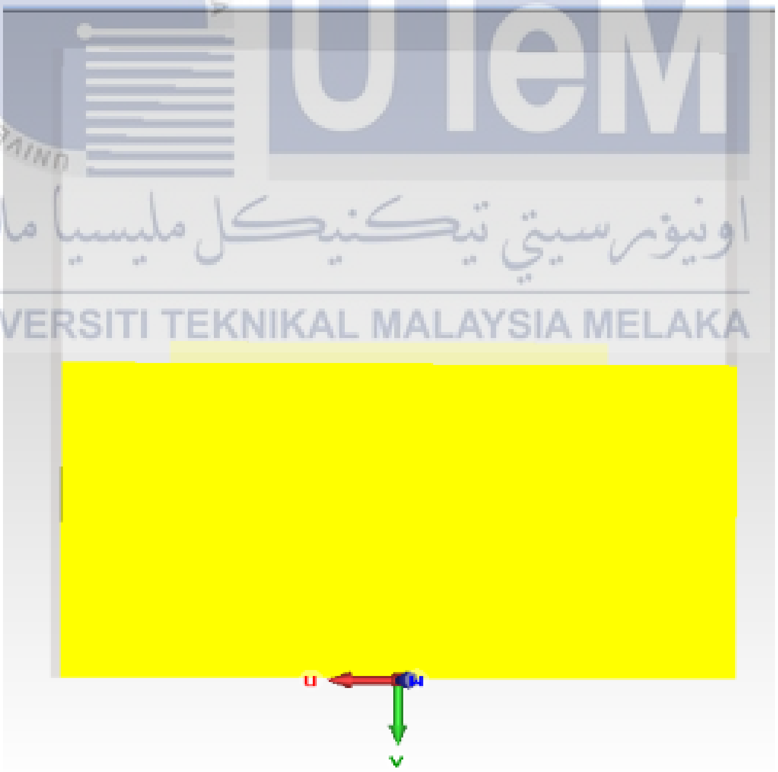


Figure 3.7: Partial Ground Plane

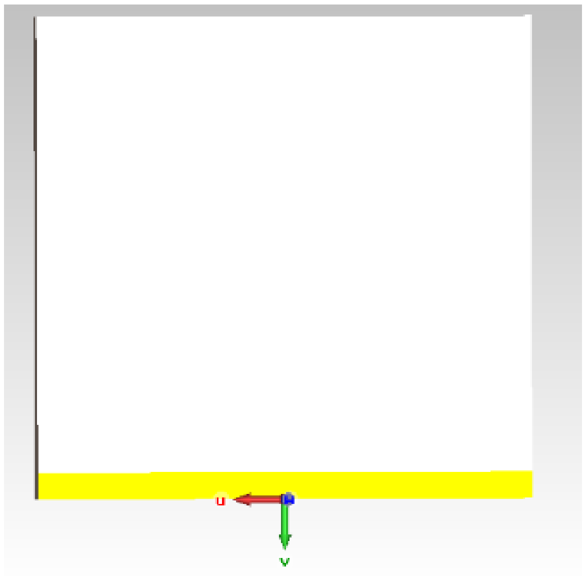


Figure 3.8: Ground Plane with Length 1.1 mm and Width 20 mm

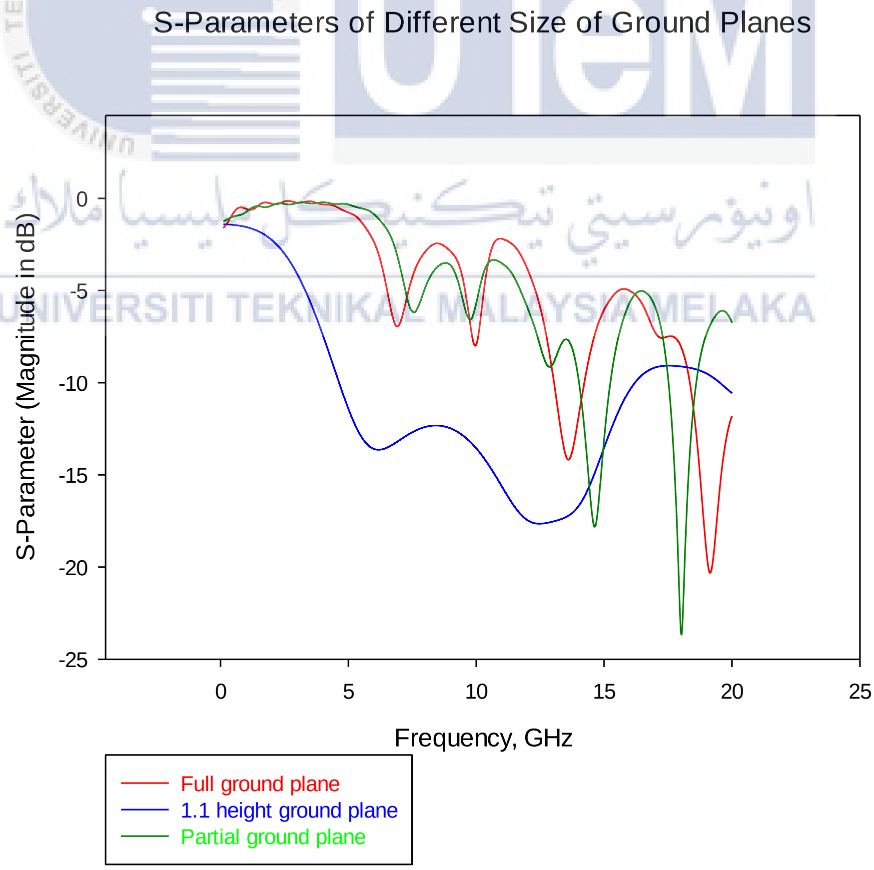


Figure 3.9: S-parameters of Different Size of Ground Planes

3.6.2 Slot 1 is Etched on the Ground Plane

Figure 3.10 shows the ground plane with different size of the slot is etched on it. 3.11 and 3.12 with maintain initial rectangular radiating patch. Figure 3.13 is the comparison between three different size of slot on the ground plane.

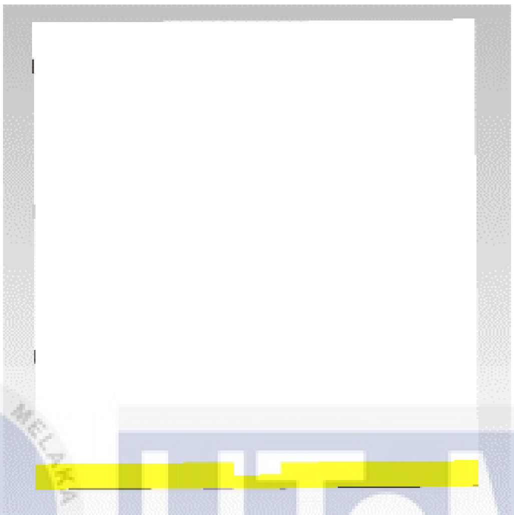


Figure 3.10: Size of Slot 0.55 mm x 1.10 mm

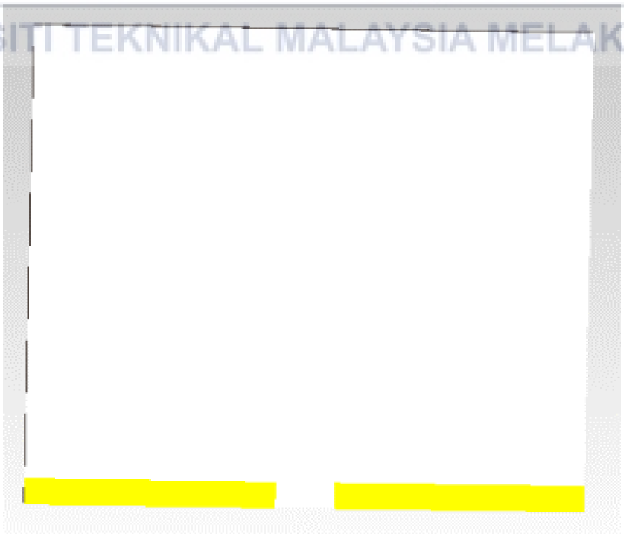


Figure 3.11: Size of Slot 1.10 mm x 2.10 mm

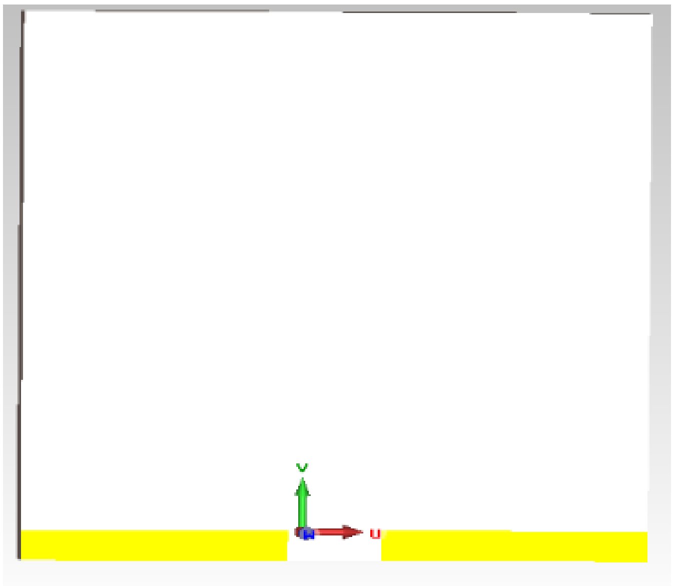


Figure 3.12: Size of Slot 1.10 mm x 3.00 mm

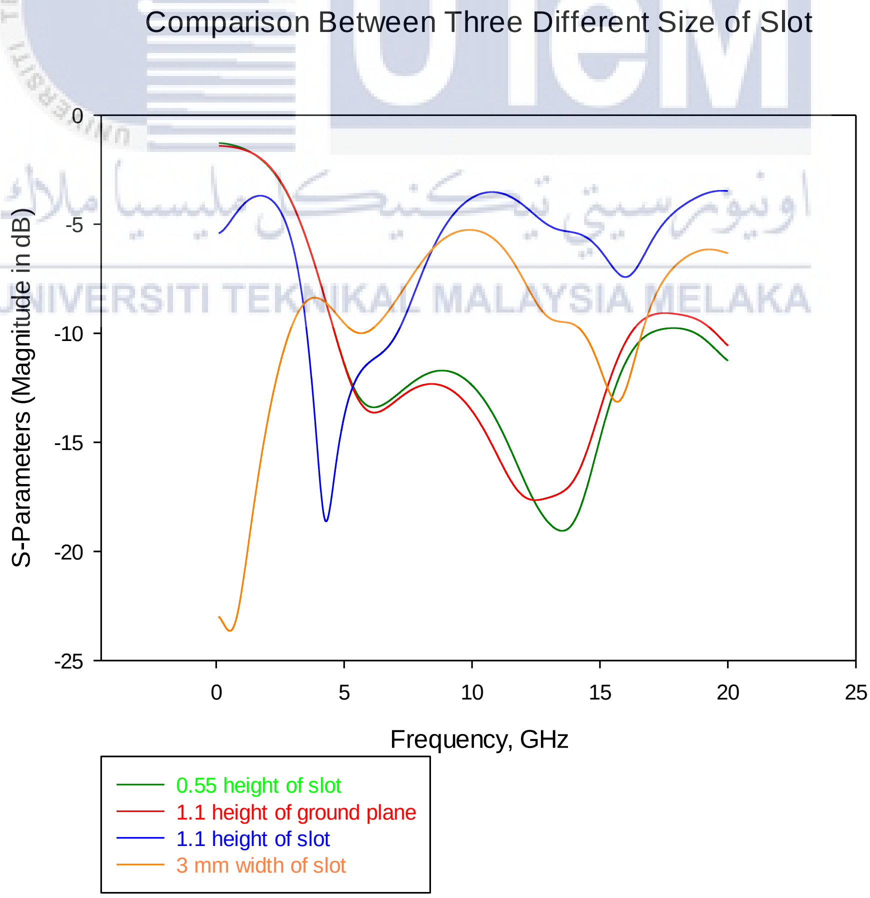


Figure 3.13: Comparison Between Three Different Size of Slot

3.6.3 Different Shapes with Different Size of the Slot 1 etched on Radiating Patch

Ground plane with a slot 1.1 mm x 3 mm is used. Next, square slot (3 mm x 3 mm) and triangle slot (3 mm x 3 mm) was etched on the patch shown in figure 3.14 and 3.15. After that, size of the square slot has changed to 3.00 mm x 5.45 mm and size of triangle slot have changed to 3.00 mm x 5.45 mm. S-parameters of different size and shape was shown in Figure 3.16 and 3.17.

Figure 3.14: 3 mm x 3 mm Square Slot

Figure 3.15: 3 mm x 3 mm Triangle Slot

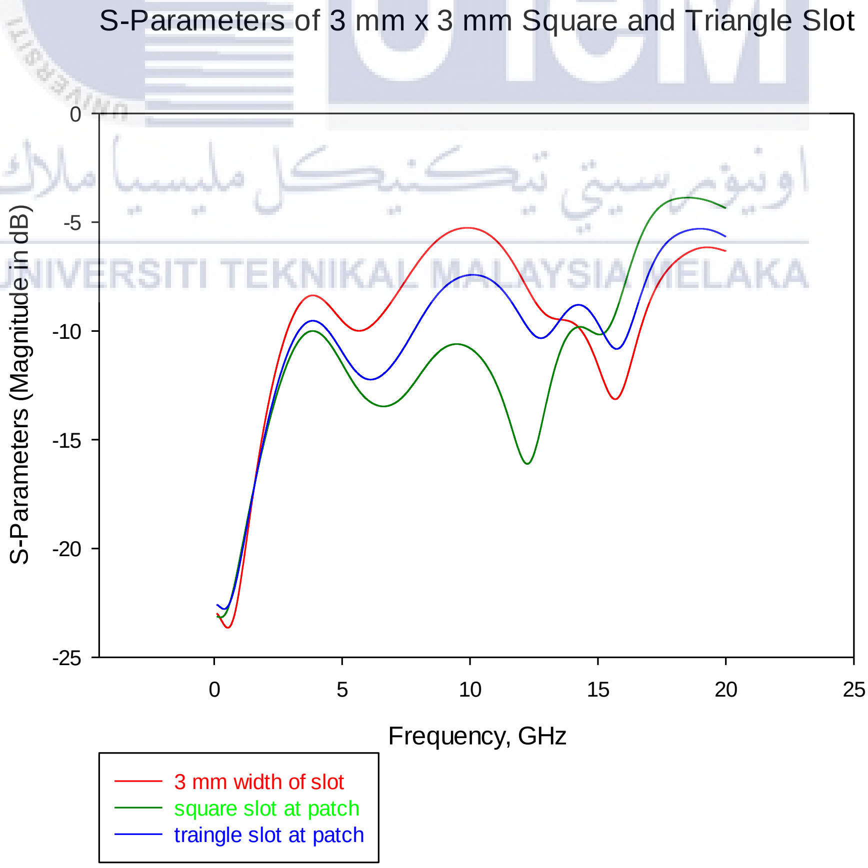


Figure 3.16: S-parameters of 3 mm x 3 mm Square and Triangle Slot

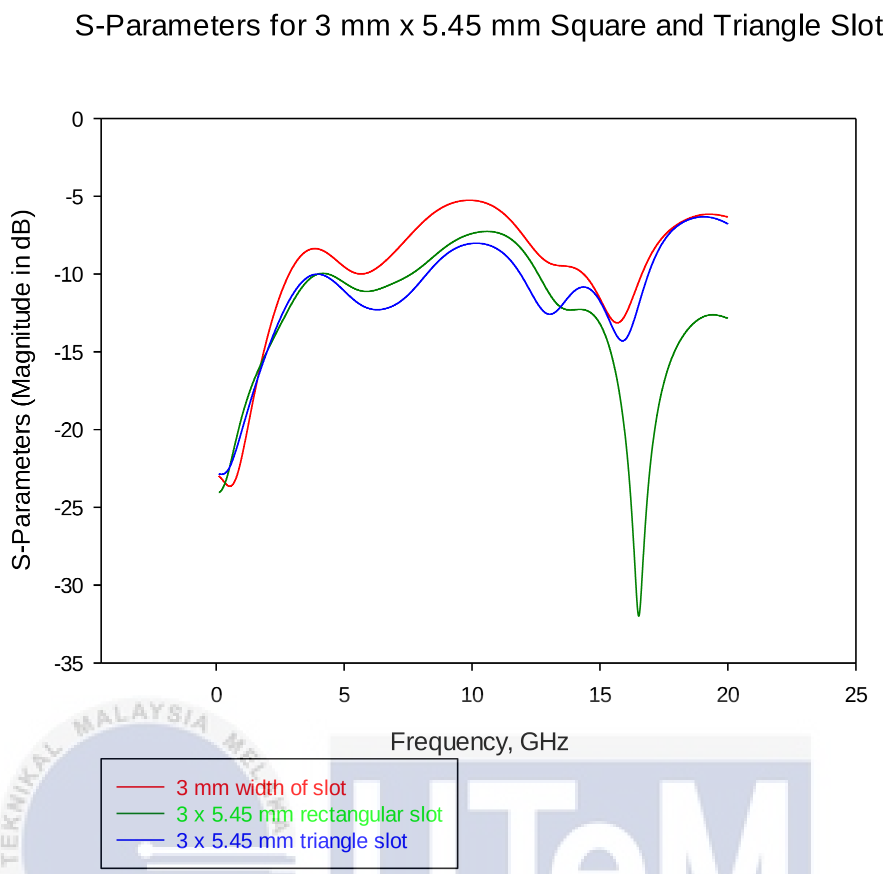


Figure 3.17: S-parameters for 3 mm x 5.45 mm Square and Triangle Slot

3.6.4 Different Shapes of the Slot 2 Etched on 3 mm x 5.45 mm Square and Triangle Slot 1

The size of the slot 2 was used for simulation is 2.0 mm x 3.45 mm and 2.0 mm x 4 mm that shown in figure 3.18 and 3.19. Figure 3.20 shows the s-parameters of different size of slot 2. The results of s-parameters in Figure 3.20 are almost similar as Figure 3.17. Next, figure 3.21 and 3.22 shows different size of slot 2 on the radiating patch while triangle slot 1 while figure 3.23 shows the S-parameters of figure 3.21 and 3.22.

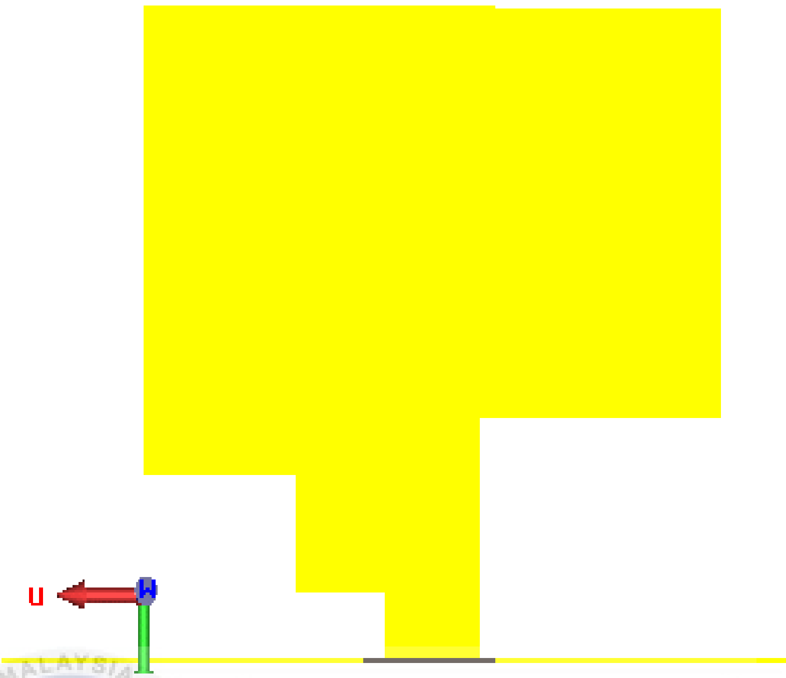


Figure 3.18: Slot 2 with the Size 2 mm x 3.45 mm

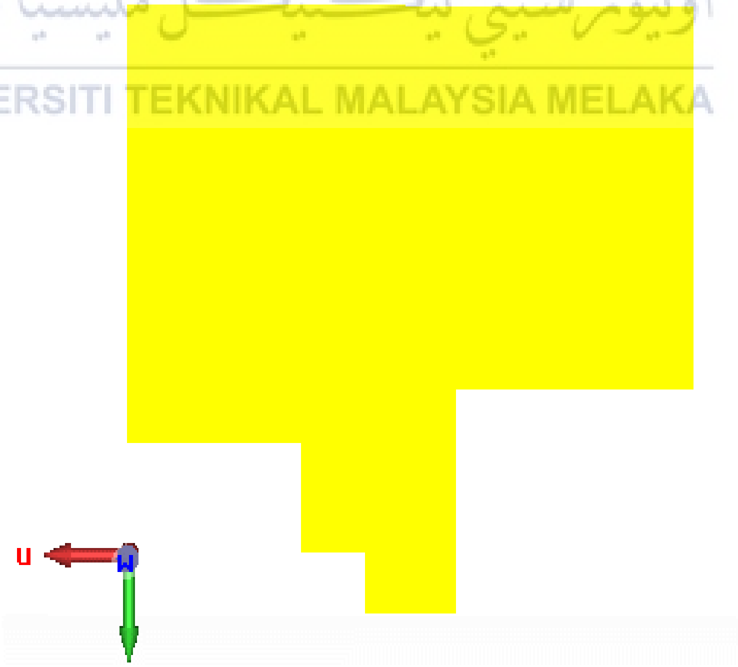


Figure 3.19: Slot 2 with the Size 2.0 mm x 4 mm

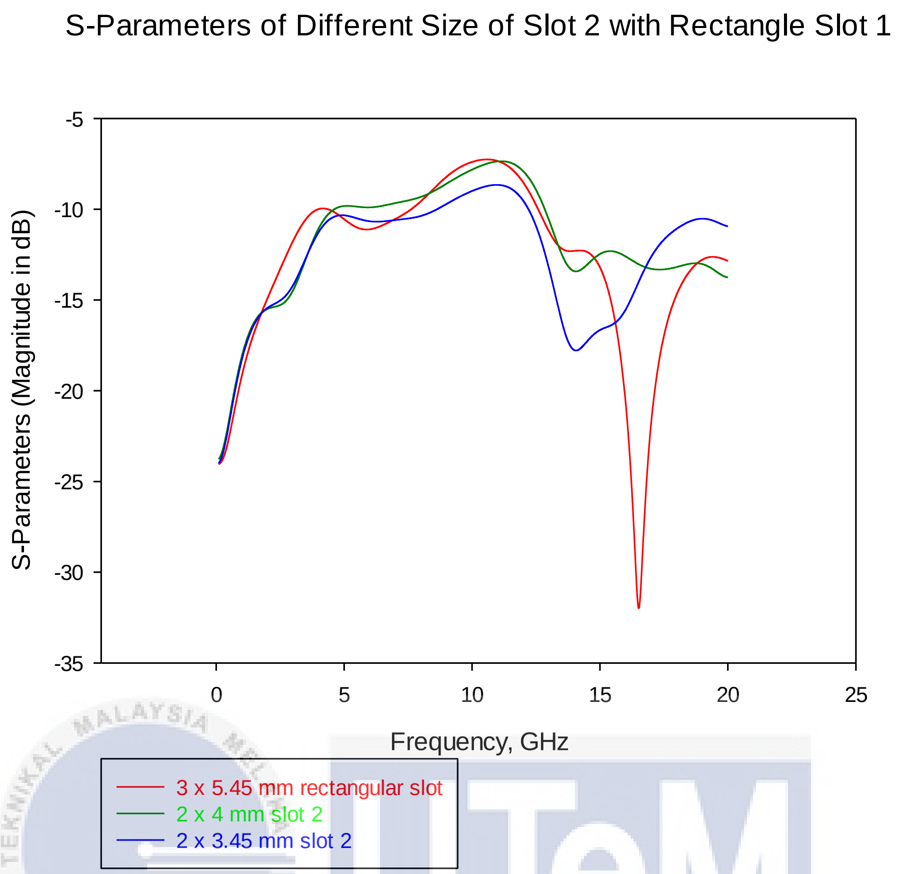


Figure 3.20: S-parameters of Different Size of Slot 2 with Rectangle Slot 1

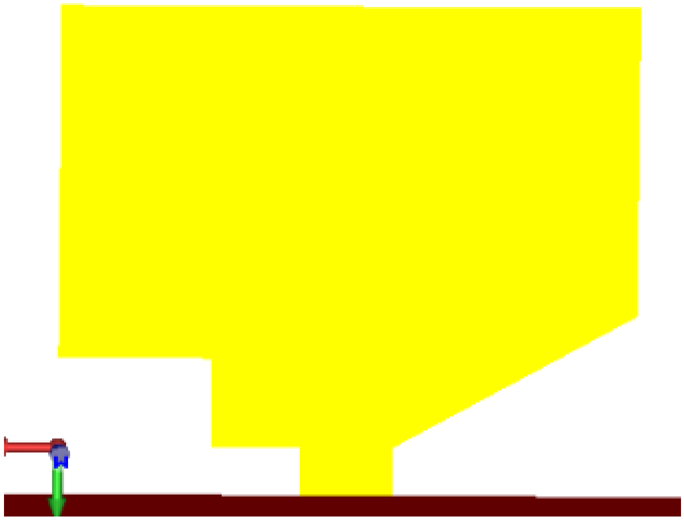


Figure 3.21: Slot 2 with Size 2 mm x 3.45 mm

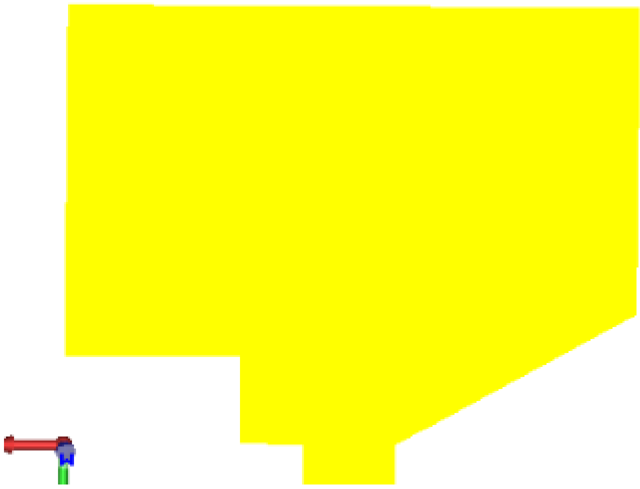


Figure 3.22: Slot 2 with Size 2 mm x 4 mm

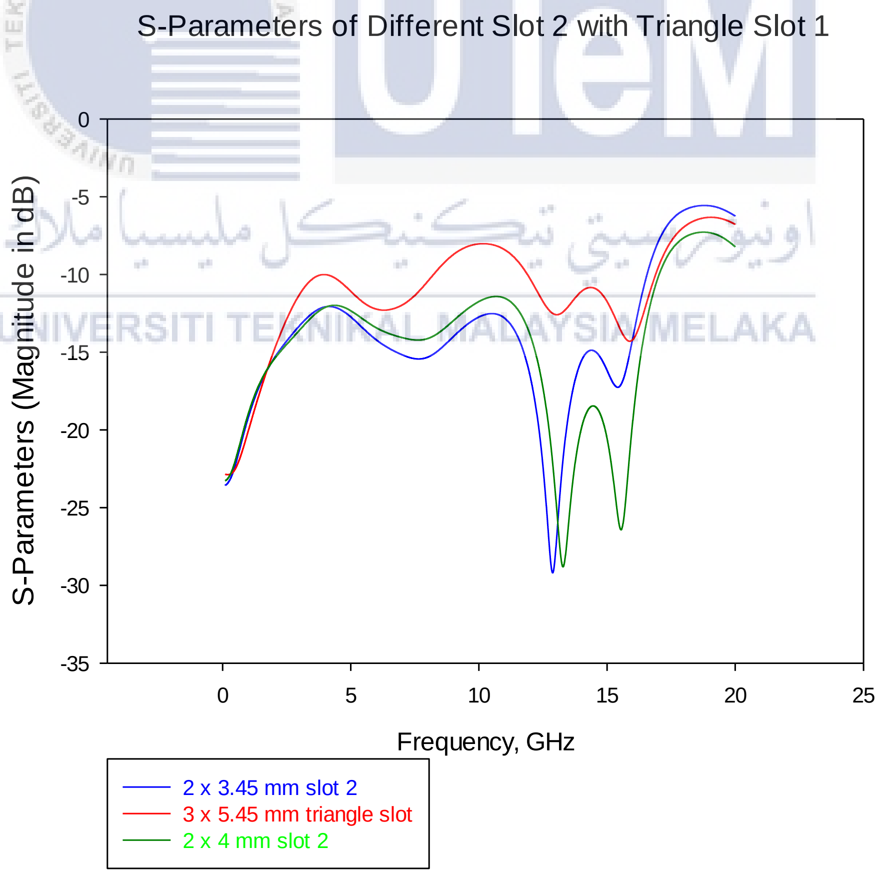


Figure 3.23: S-parameters of Different Slot 2 with Triangle Slot 1

3.6.5 Different Shapes of Slot 3 Etched on the Radiating Patch

Slot 3 is etched on the radiating patch as shown in figure 3.24 and 3.25 with the size of slot 2 (2 mm x 3.45 mm) and triangle slot 1. S-parameters of slot 3 shown in figure 3.26.

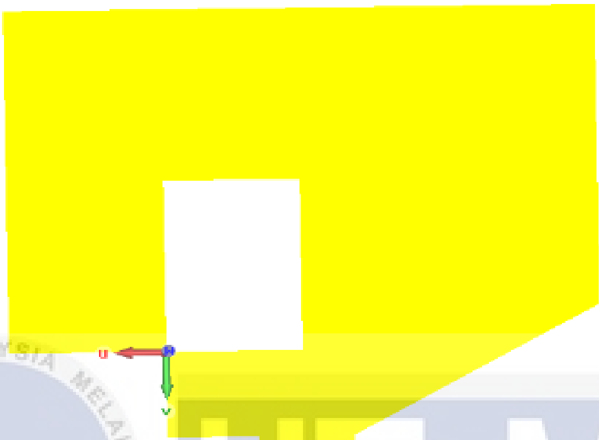


Figure 3.24: Slot 3 with the Size 4 mm x 3 mm

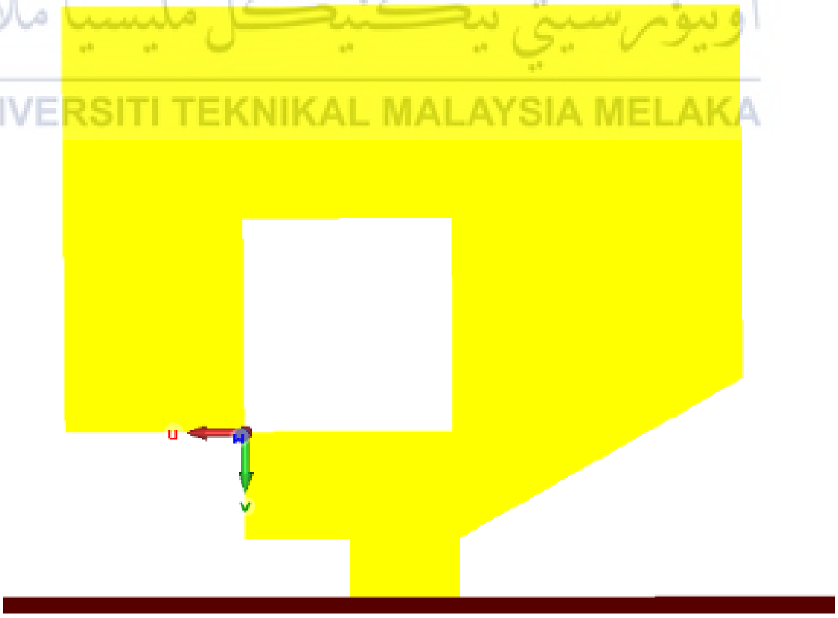


Figure 3.25: Slot 3 with the Size 4 mm x 4 mm

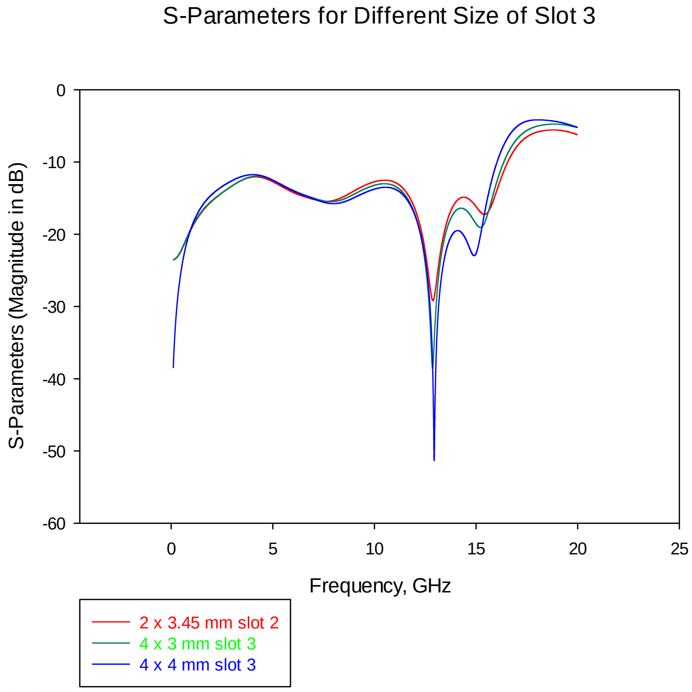


Figure 3.26: S-parameters for Different Size of Slot 3

3.6.6 Different Shapes of Slot 2 on the Ground Plane

Figure 3.27 shows a designed antenna was used to design second slot on the ground plane. Three different sizes of the slot 2 was labelled as figure 3.28, 3.29 and 3.30. S-parameters was obtained in figure 3.31.

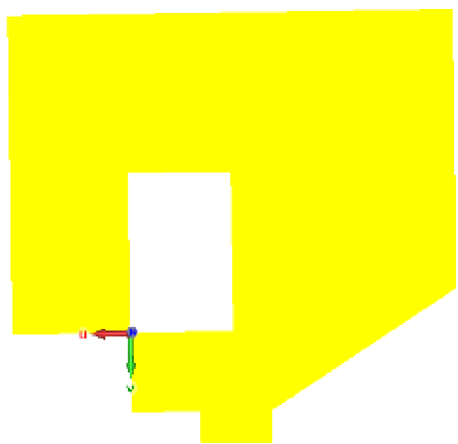


Figure 3.27: Front View of Radiating Patch

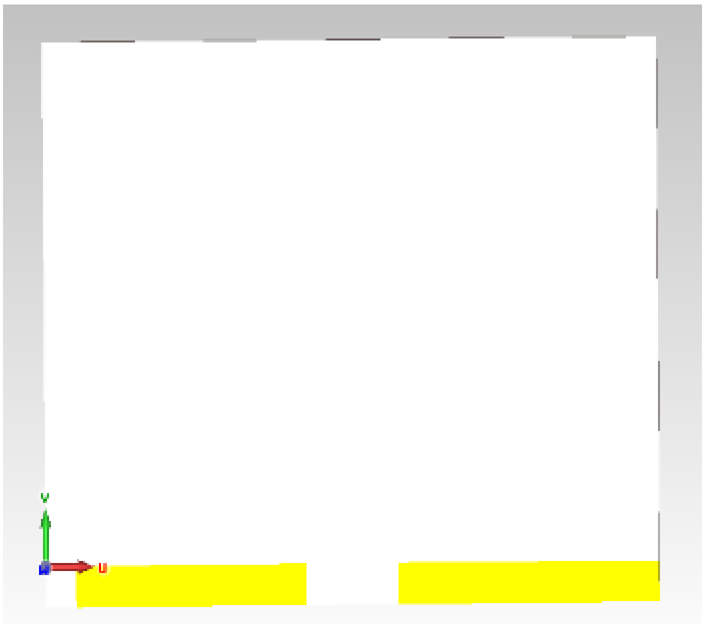


Figure 3.28: Ground Plane Second Slot with the Size 1.1 mm x 1mm

Figure 3.29: Ground Plane Second Slot with the Size 1.1 mm x 2 mm

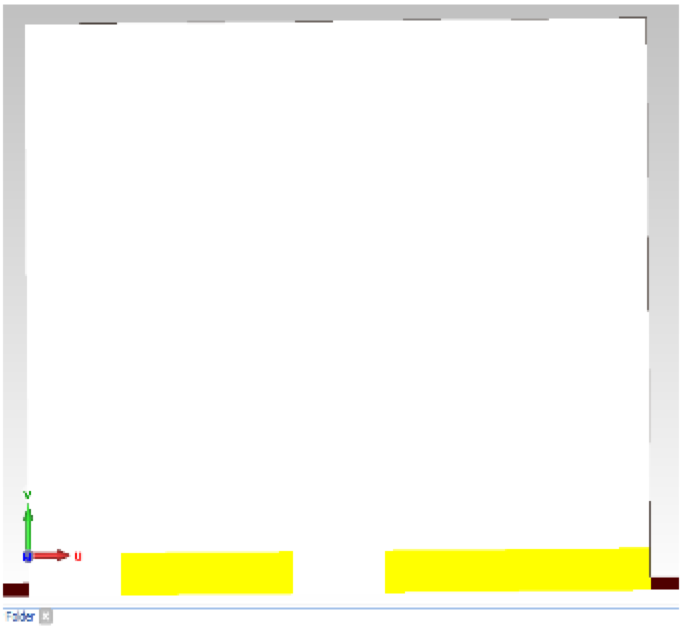


Figure 3.30: Ground Plane Second Slot with the Size 1.1 mm x 3 mm

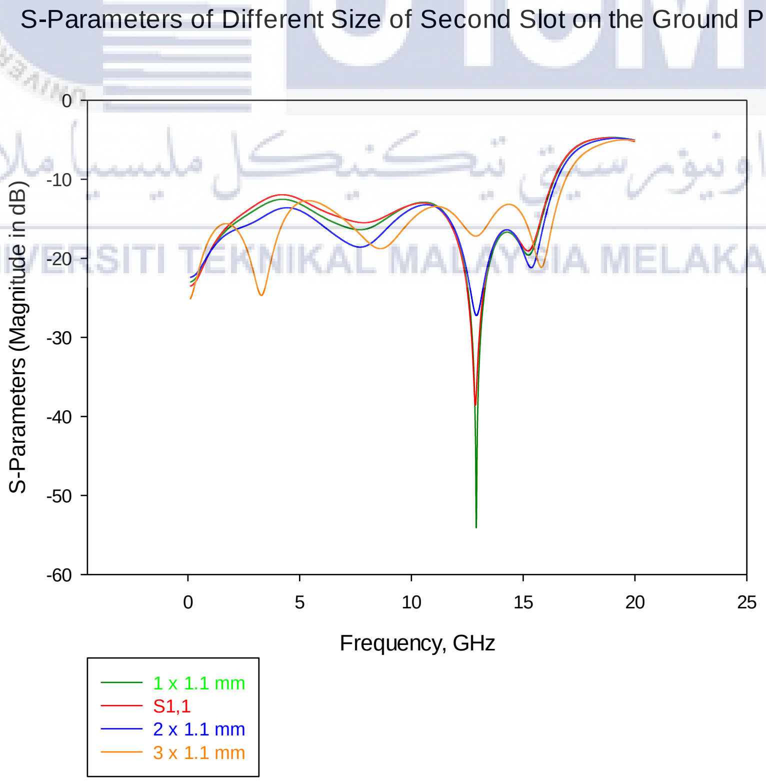


Figure 3.31: S-parameters of Different Size of Second Slot on the Ground Plane

3.6.7 Different Size of Slot 3 on the Ground Plane

Third slot was etched on the ground plane to increase the S-parameters results. Figure 3.32, 3.33 and 3.34 shows different sizes of slot on the ground plane. The results of this S-parameters are shown in figure 3.35.

Figure 3.32: Ground Plane Third Slot with the Size 1.1 mm x 1mm

Figure 3.33: Ground Plane Third Slot with the Size 1.1 mm x 2 mm

Figure 3.34: Ground Plane Third Slot with the Size 1.1 mm x 3 mm

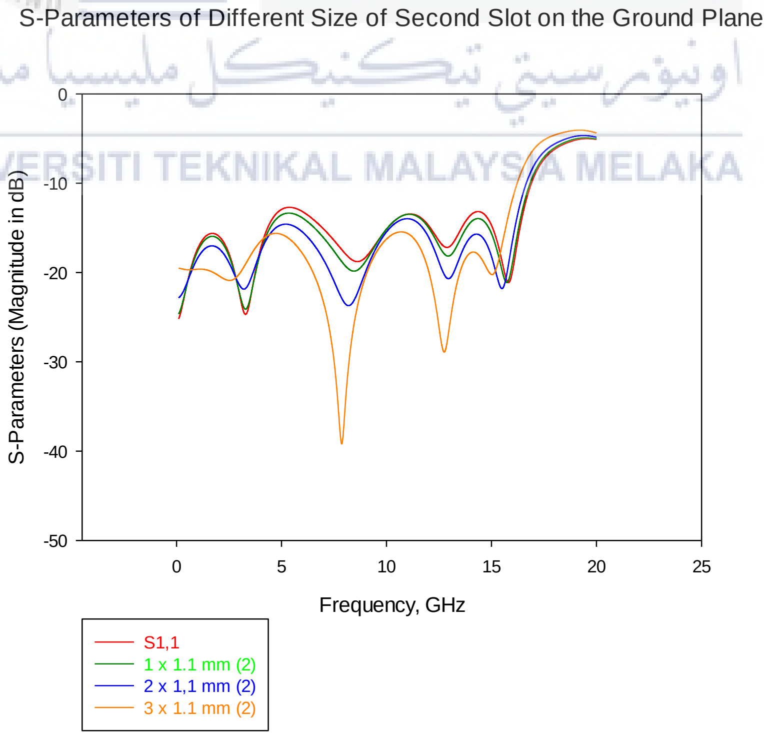


Figure 3.35: S-parameters of Different Size of Second Slot on the Ground Plane

3.6.8 Initial Design of Irregular Patch UWB Antenna

The initial design of UWB antenna is leaf shape patch antenna with full ground plane shown in figure 3.36 and figure 3.37. Figure 3.38 and figure 3.39 show the changes of different lengths of the ground and comparison of the S-parameters of three different lengths of the ground is shown in figure 3.40.

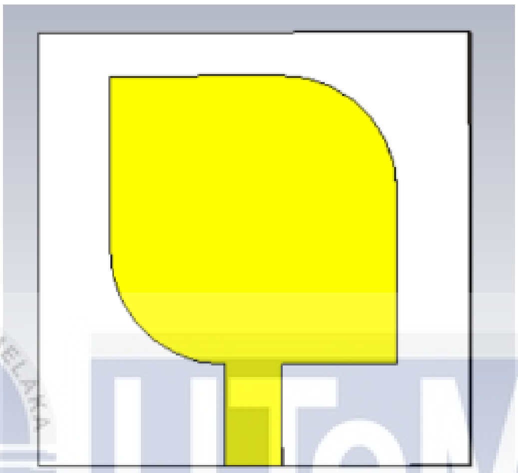


Figure 3.36: Front View of the Leaf-shaped Patch

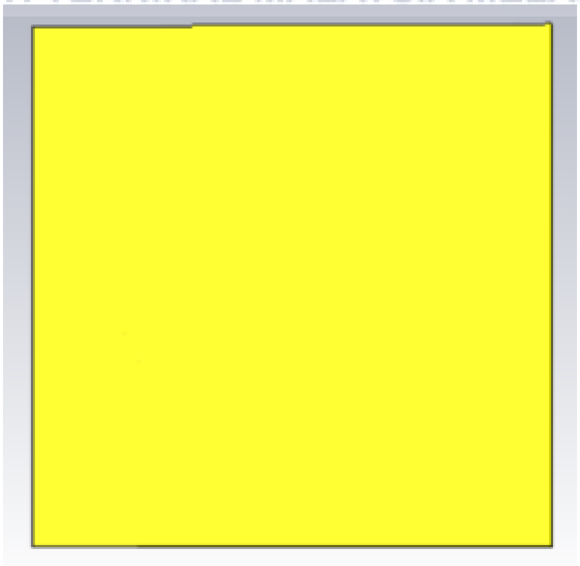


Figure 3.37: Full Ground Plane

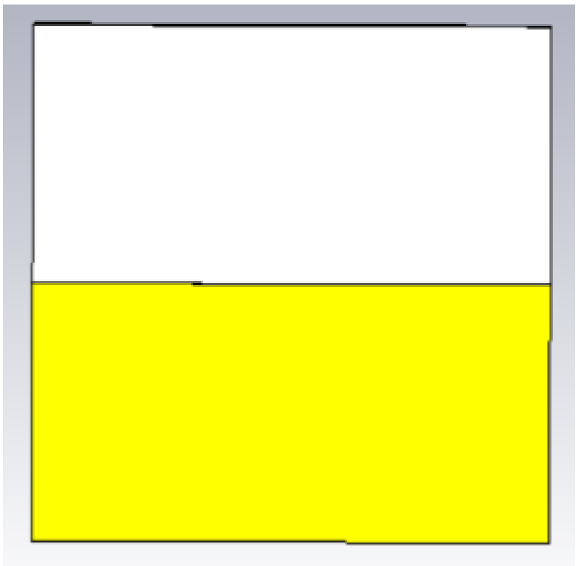


Figure 3.38: Partial Ground Plane

Figure 3.39: Ground Plane with Length 7 mm and Width 30 mm

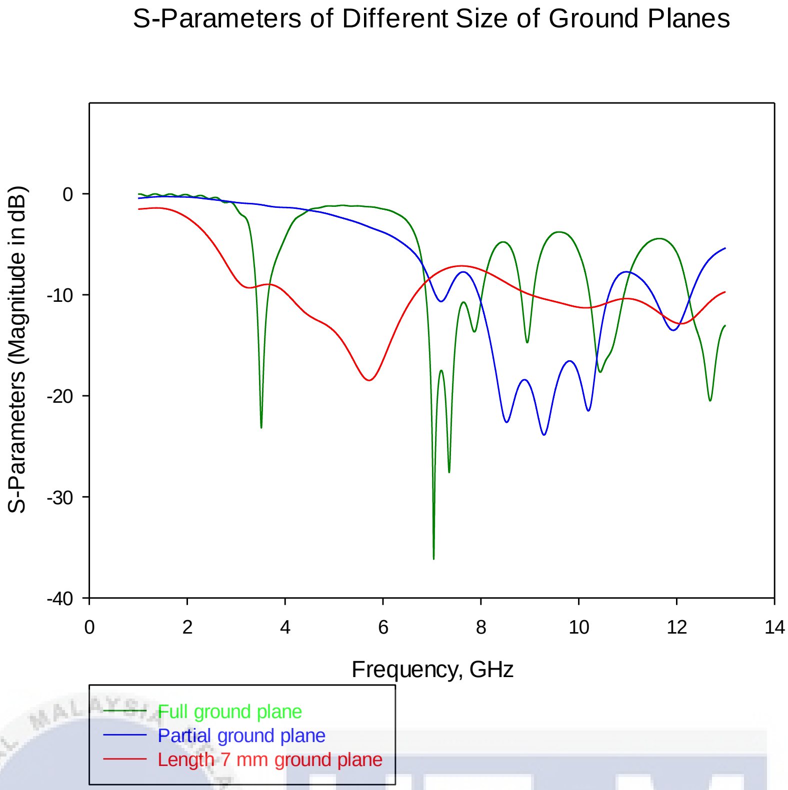


Figure 3.40: S-parameters of Different Size of Ground Planes

3.6.9 Upper Left Side and Lower Right Side Have Been Cut by Triangle Slots

From figure 3.41, an oval-shaped patch is produced when triangular slots have been etched on it. Next, a S-parameters simulation on different lengths of the ground has been done and shown in figure 3.42. Alphabet B in figure 3.42 are the length of the ground which are 7, 15 and 30 mm. In figure 3.43, the S-parameters shows the comparison of leaf-shaped and oval-shaped patch by using 7 mm length and 30 mm width of the ground.

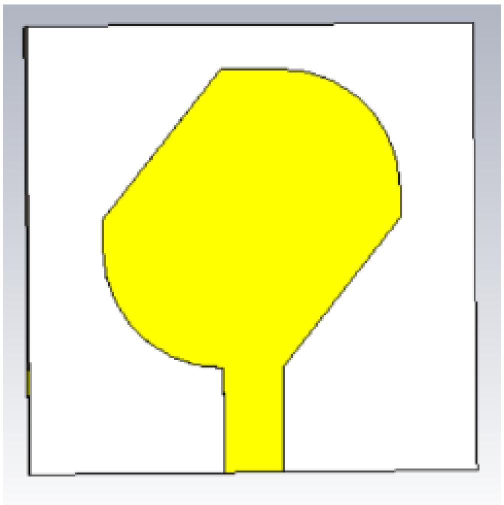


Figure 3.41: Front View of the Leaf-shaped Patch Where Edges Have Been Cut

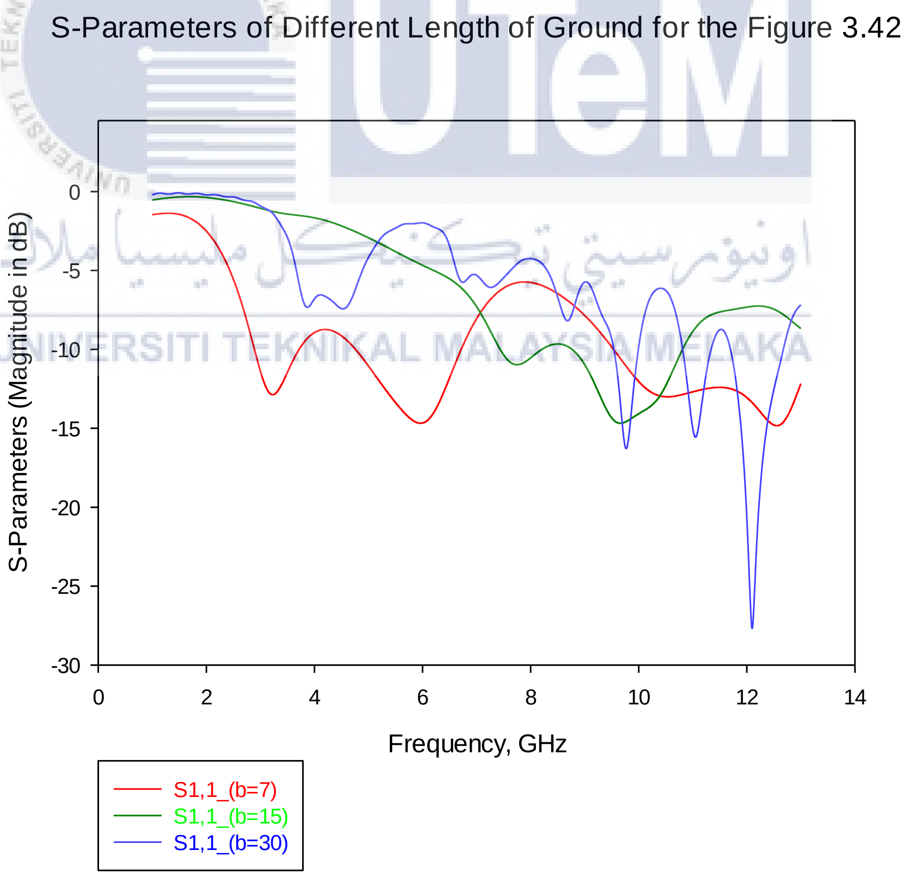


Figure 3.42: S-parameters of Different Lengths of Ground for the Figure 3.42

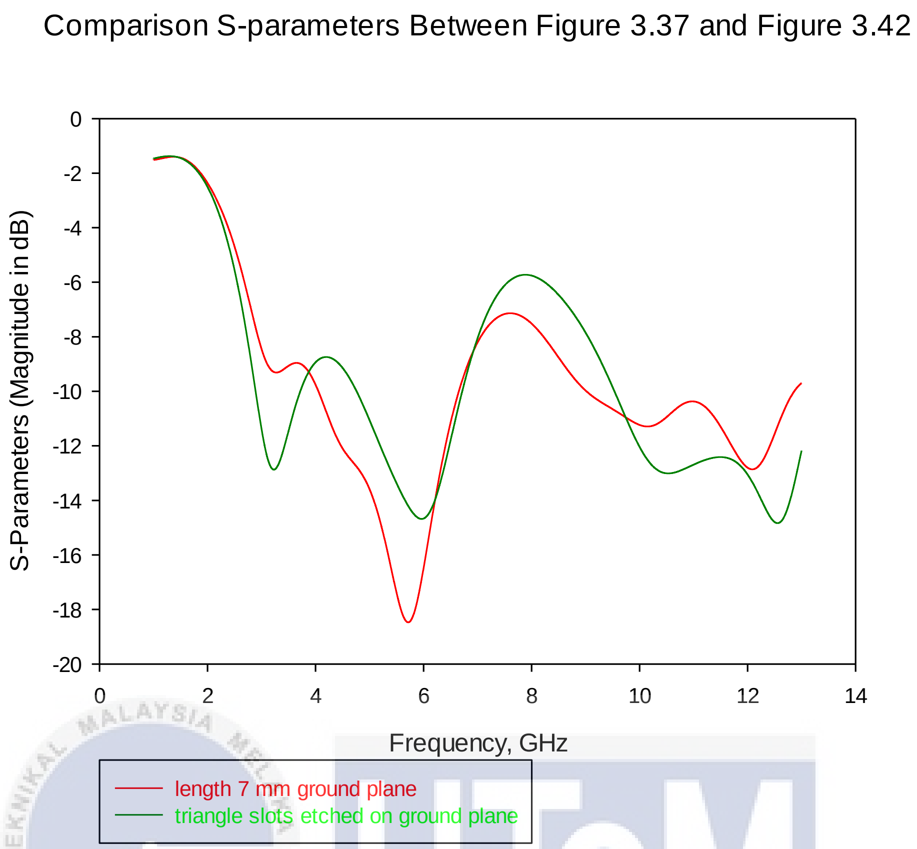


Figure 3.43: Comparison S-parameters Between Figure 3.37 and Figure 3.42

3.6.10 A Slot Has Been Etched on the Ground

A slot with length 6 mm x width 4 mm is etched at the middle position of the ground is shown in figure 3.44. As the shape of the patch remain as oval-shaped, different lengths of the simulation have been done. Figure 3.45 is the S-parameters for the length 1 mm to 6 mm and figure 3.46 only show the s-parameters for the length 6 mm of the slot etch on the ground because next improvement will be continue with oval-shaped patch from figure 3.41 and ground with 6 mm x 4 mm slot from figure 3.44.

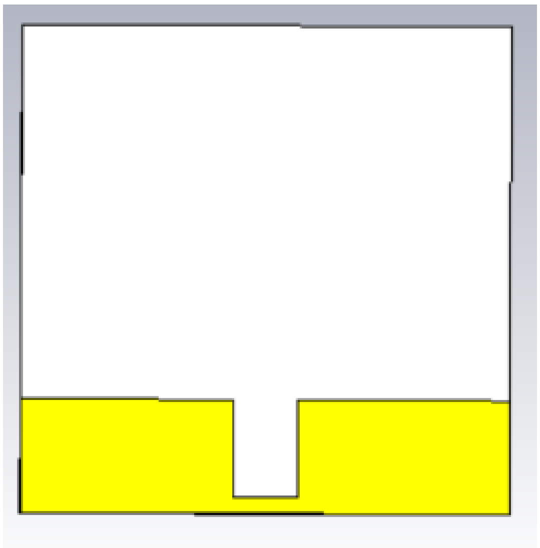


Figure 3.44: Back View of the Ground That Has A Slot Has Been Etched on It

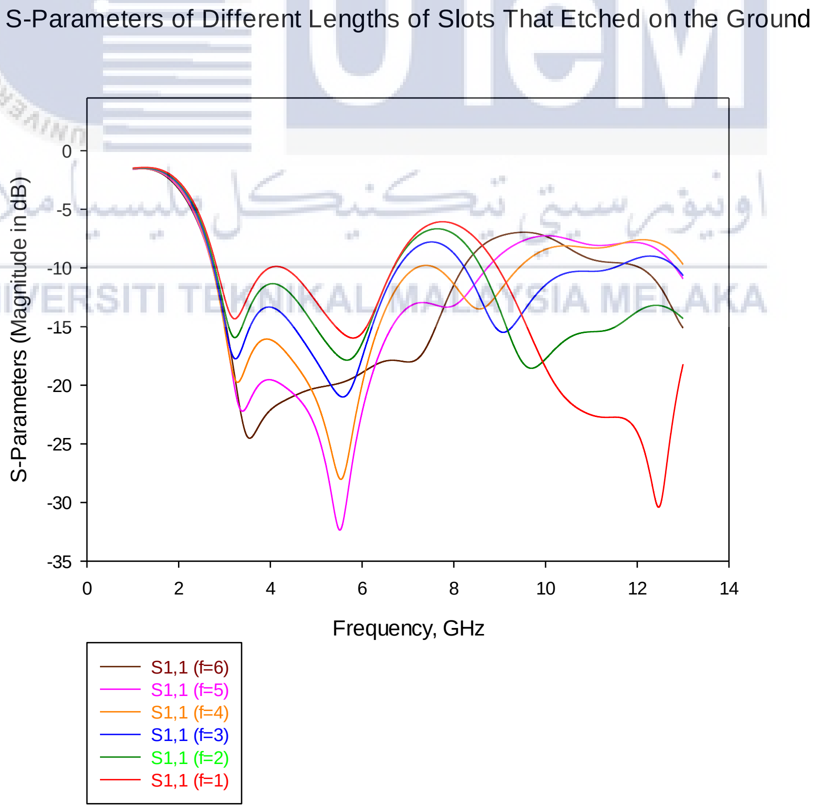


Figure 3.45: S-parameters of Different Lengths of Slots That Etched on the Ground

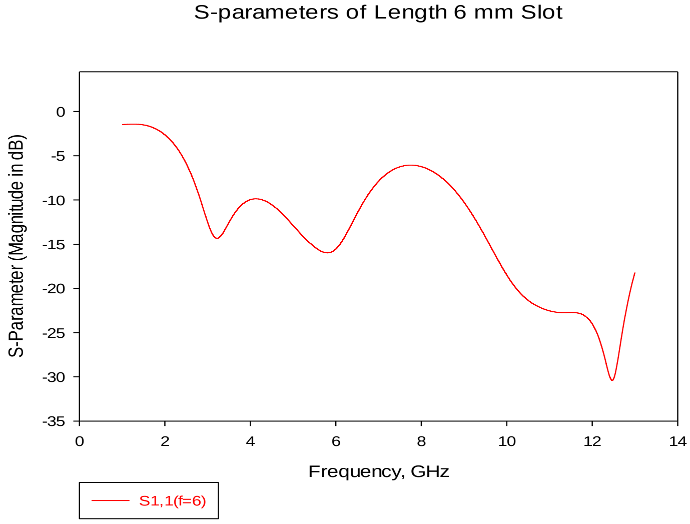


Figure 3.46: S-parameters of Length 6 mm Slot

3.6.11 Irregular Slot Is Etched on the Patch

An irregular slot is etched on the patch as shown in figure 3.47. A comparison of S-parameters between oval-shaped patch which is labelled as figure 3.41 and irregular patch which is labelled as figure 3.47 is shown in figure 3.48. Next, a simulation of S-parameters based on different lengths of the slot on the ground is recorded in figure 3.49.

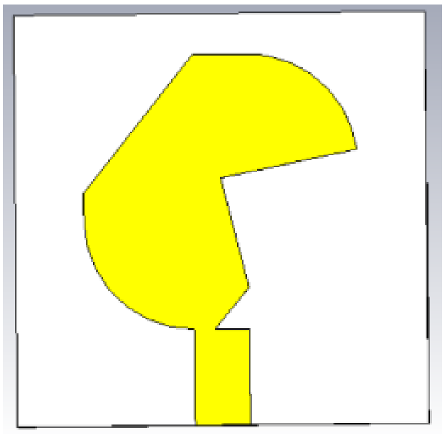


Figure 3.47: Front View of the Patch with Irregular Slot

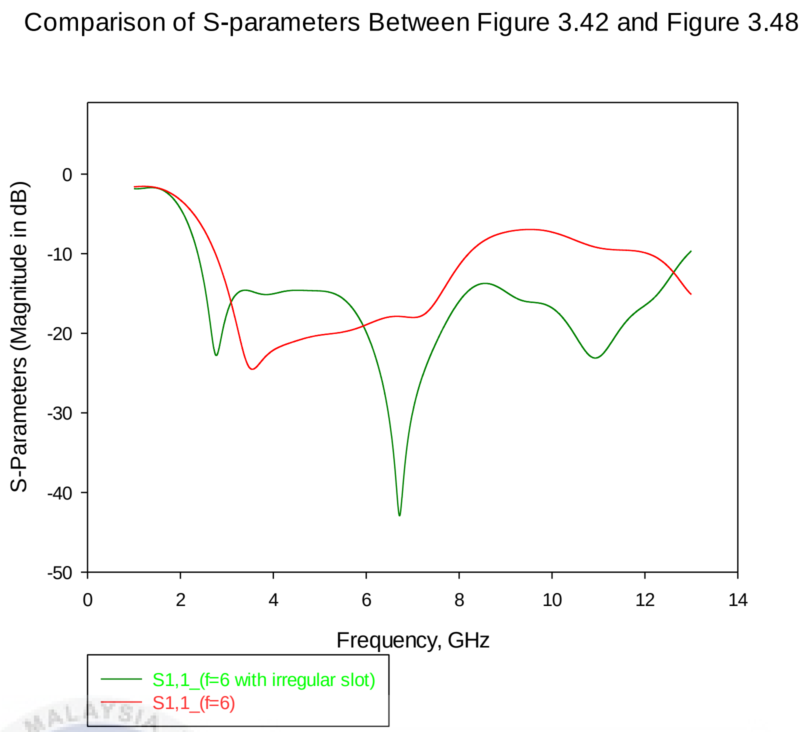


Figure 3.48: Comparison of S-parameters Between Figure 3.42 and Figure 3.48

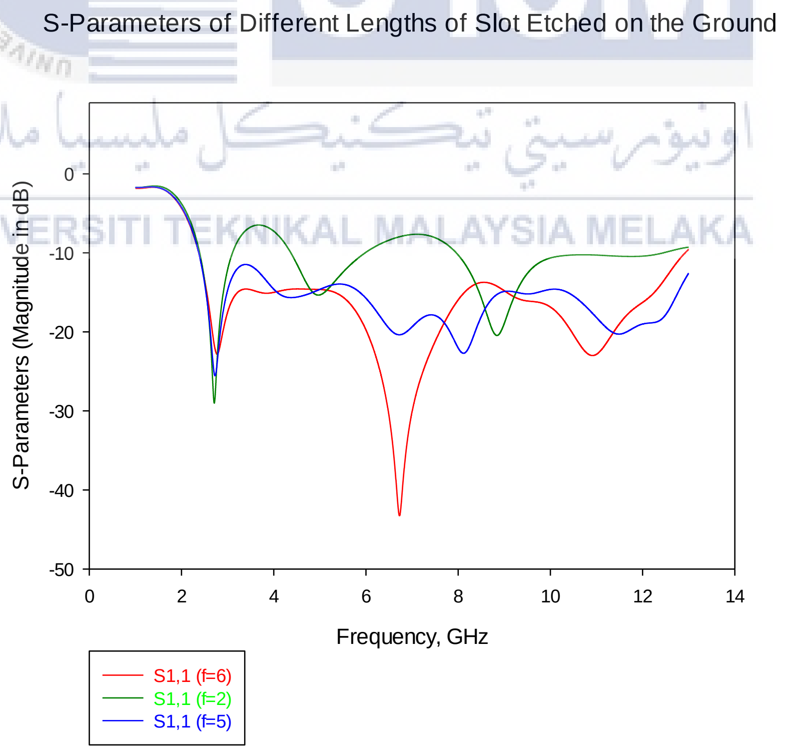


Figure 3.49: S-parameters of Different Lengths of Slot Etched on the Ground

3.7 Structure of both fabricated antennas

Figure 3.50, 3.51, 3.52 and 3.53 shows the fabricated rectangular and irregular patch antenna. Both fabricated antennas are soldered a 50 Ω SMA port at the microstrip line. After that, return loss is obtained by using VNA as shown in figure 3.54. Next, radiation pattern is obtained at anechoic chamber. Figure 3.55 shows the situation of fabricated antenna inside anechoic chamber. Lastly, the gain is calculated by using equation 2.1.

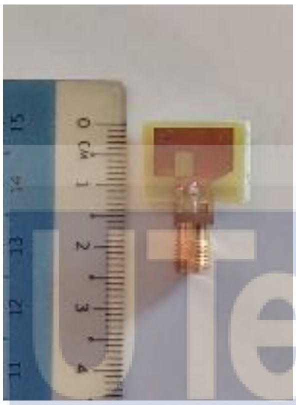


Figure 3.50: Front view for rectangular patch antenna

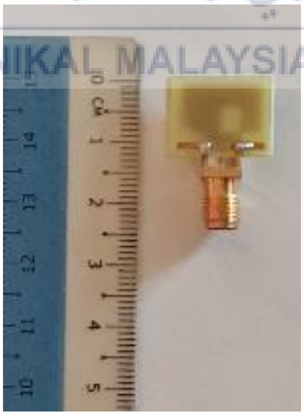


Figure 3.51: Back view for rectangular patch antenna

Figure 3.52: Front view for irregular patch antenna

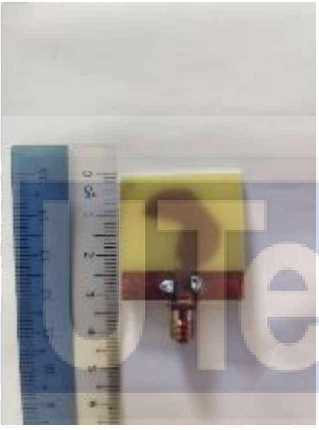


Figure 3.53: Back view for irregular patch antenna

Figure 3.54: Connections of antenna to VNA

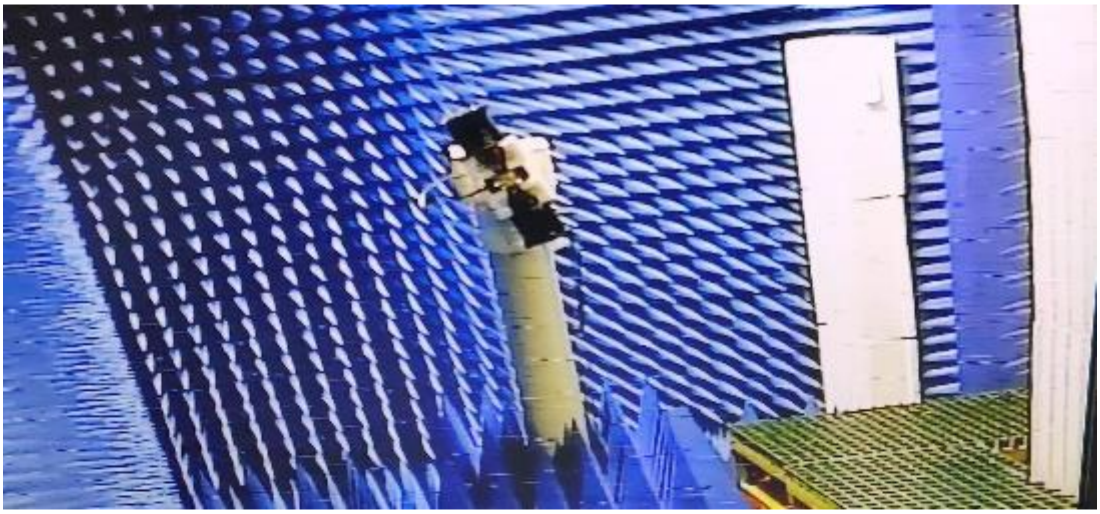


Figure 3.55: Situation in anechoic chamber

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Many UWB antennas were designed and used for wireless communication applications. A lot of researches on how to improve the performance and efficiency for the UWB antennas by keeping the antenna to a minimum size. In this thesis, different structures and shapes for the microstrip patch antenna is designed. The parameters which are return loss, VSWR, radiation pattern, gain and bandwidth will be compared and discussed in this chapter.

4.2 Antenna Performance Results and Analysis

Both UWB antennas is designed using CST 2019 to obtain parameters results such as return loss, gain, Voltage Standing Wave Ratio (VSWR), radiation pattern and bandwidth. Both antennas using same materials of substrate, patch and ground. The differences are the shape of the patch and the overall size of the antenna.

4.2.1 Return Loss

Figure 4.1 shows the simulation return loss versus frequency of the rectangular patch antenna. The return loss of the rectangular patch antenna is below than −10 dB from frequency band 1 GHz to 16.19 GHz. The lowest value of the simulated return loss is −40.44 dB at resonating frequency 7.9 GHz and follow by −30.51 dB at resonating frequency 12.73 GHz. Figure 4.2 shows the return loss versus frequency of the irregular patch antenna. The return loss of the irregular patch antenna is below than −10 dB from frequency band 2.38 GHz to 12.9 GHz. The lowest value of the simulated return loss is −42.91 dB with resonating frequency at 6.72 GHz. For the second lowest return loss is −22.72 dB at resonant frequency 2.79 GHz. Figure 4.3 is the comparison of the return loss versus frequency for the rectangular patch and irregular patch antenna. It can be observed that rectangular patch antenna has wider range of the frequency bandwidth compare with irregular patch antenna. Figure 4.4 shows the comparison return loss of simulation and measurement results for rectangular patch antenna while figure 4.5 shows the results for the irregular patch antenna. Due to fabricate tolerances or other effects such as measurement of the shape in reality, both antennas measured results is not same as simulated results in figure 4.4 and 4.5. Measurement return loss of both antennas is plotted in figure 4.6. From figure 4.6, it can see that rectangular patch has lower return loss and wider bandwidth compare to irregular patch. The simulation results also show that rectangular patch able achieve better return loss and wider bandwidth compare to irregular patch and it proven by the measurement results.

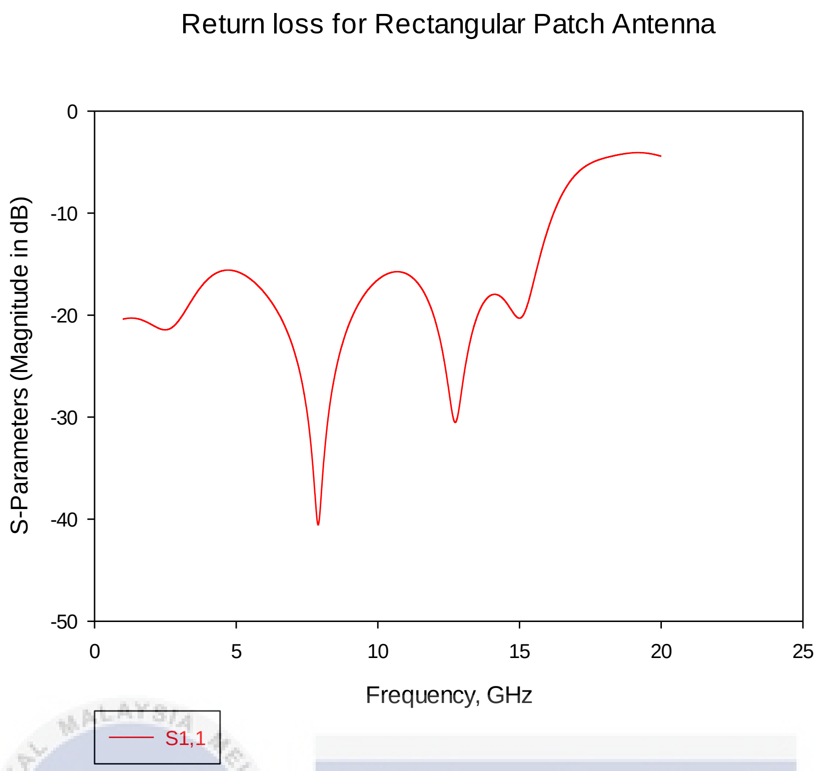


Figure 4.1: Return Loss for Rectangular Patch Antenna

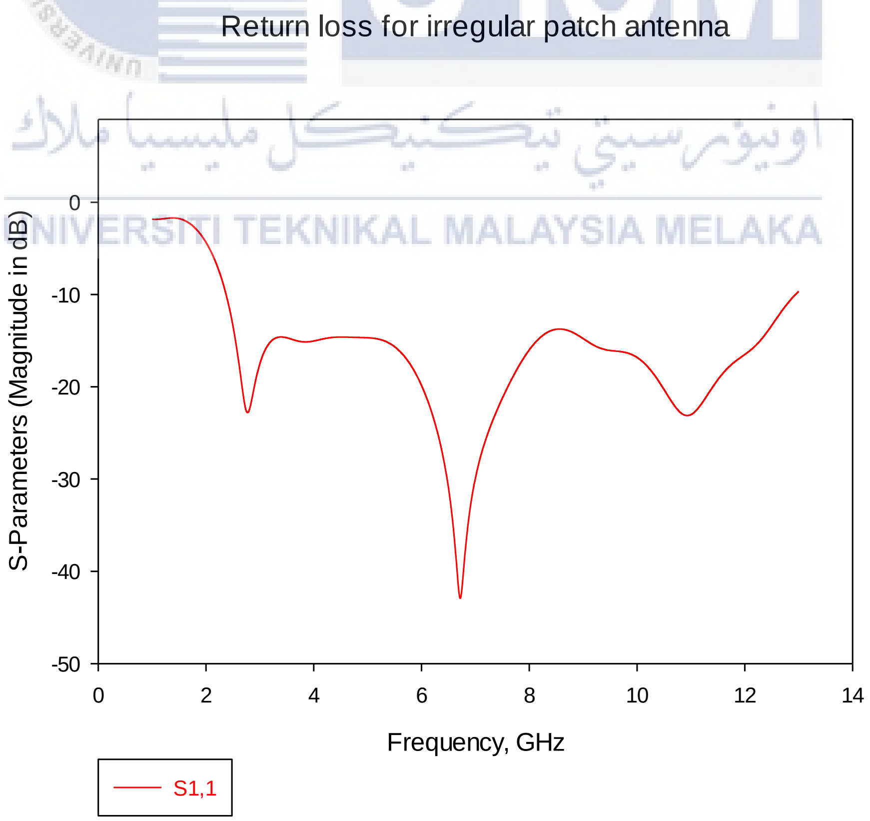


Figure 4.2: Return loss for Irregular Patch Antenna

Comparison of Return Loss Between Rectangular and Irregular Patch Antenna

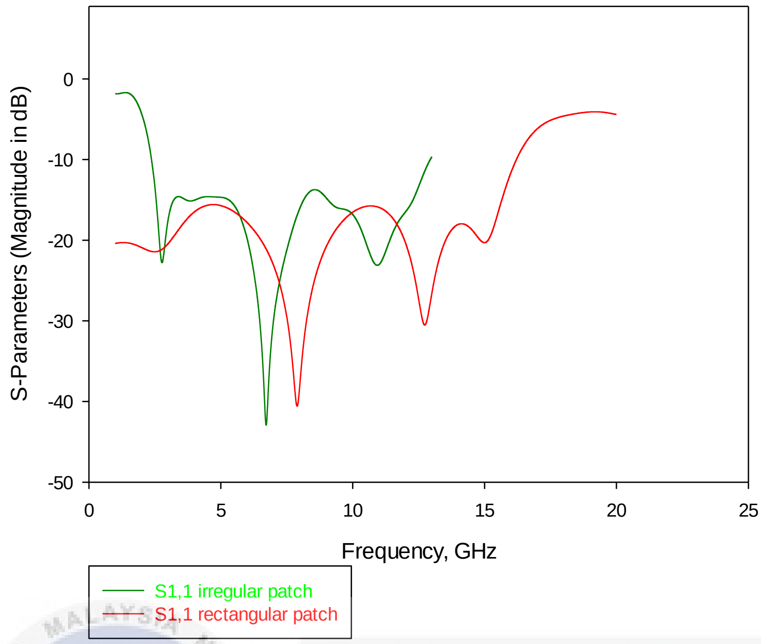


Figure 4.3: Comparison of Return Loss Between Rectangular and Irregular Patch Antenna

Comparison return loss of simulated results and measured results for rectangular patch

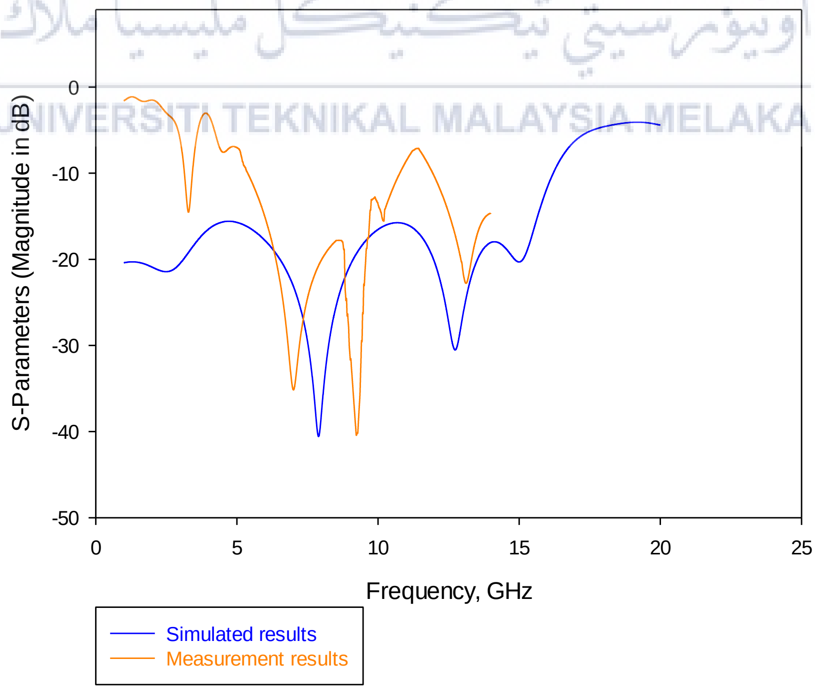


Figure 4.4: Comparison return loss for simulation and measurement results for rectangular patch antenna

Comparison return loss of simulated results and measured results for irregular patch

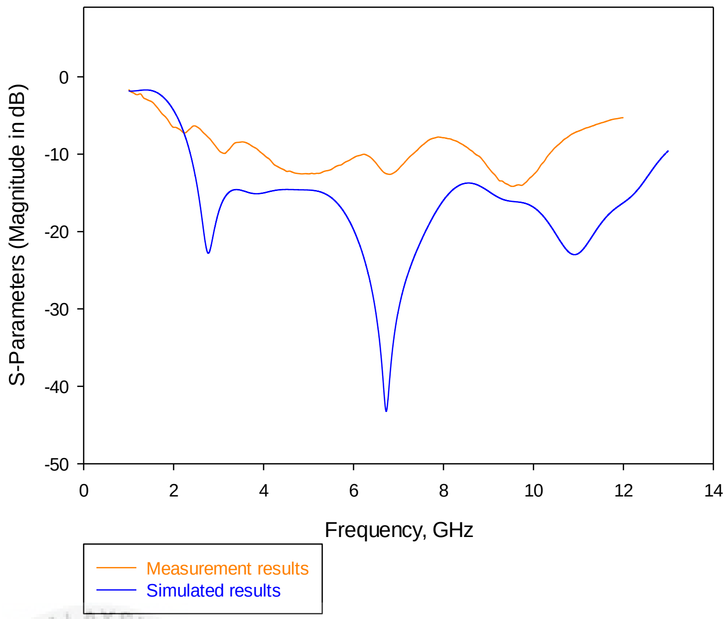


Figure 4.5: Comparison return loss for simulation and measurement results for irregular patch antenna

Comparison of measurement return loss for rectangular and irregular patch antenna

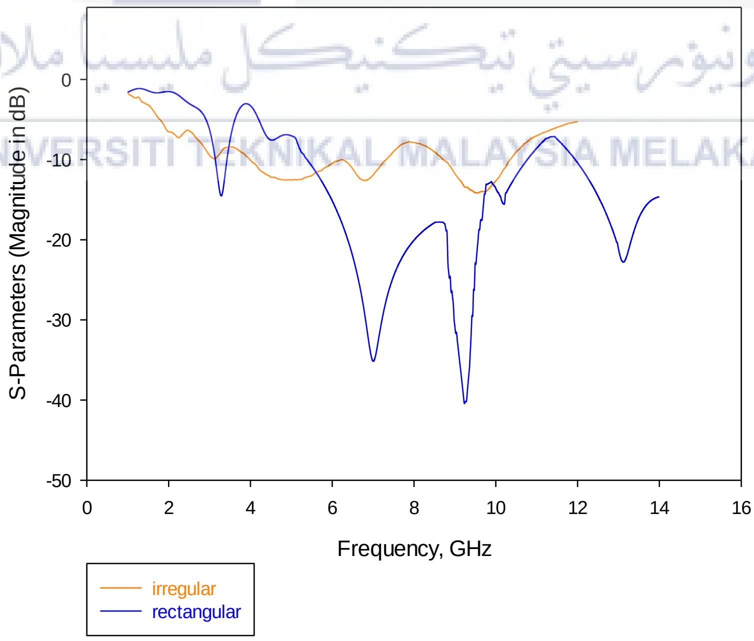


Figure 4.6: Comparison of measurement return loss for rectangular and irregular patch antenna

4.2.2 Voltage Standing Wave Ratio (VSWR)

In figure 4.7 shows the comparison of the simulation result of VSWR versus frequency of the rectangular and irregular patch antennas. For ideal situation, the minimum value of VSWR is similar to 1 which means there is no power is reflected from the antenna. This implies that both antennas have more power transmitted over the specified frequency range with VSWR less than 2. As the VSWR value increases, more power is transmitted from the antenna and means that the antenna is not matched to the transmission line.

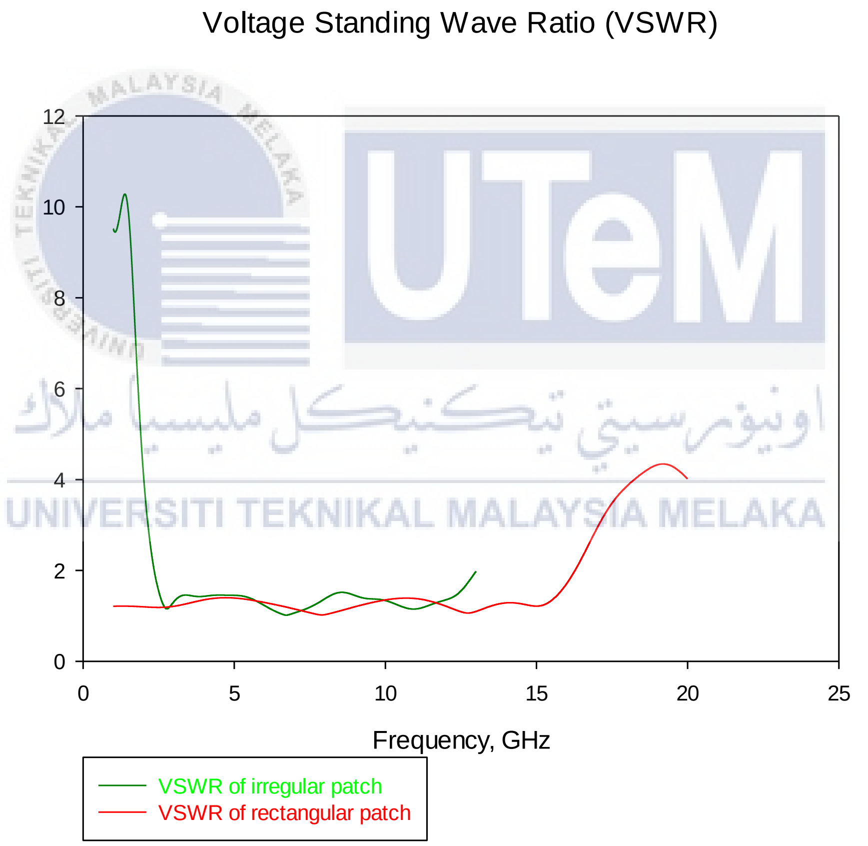


Figure 4.7: Comparison of VSWR Between Rectangular and Irregular Patch Antenna

4.2.3 Gain

Figure 4.8 shows the comparison of the simulation gain versus frequency for the rectangular patch and irregular patch antenna. From figure 4.8, both gain versus frequency curve can be observed that as the frequency increases, the gain of both antennas also increases. Therefore, the gain of an antenna is directly proportional to the frequency. The maximum gain of the rectangular patch antenna is 2.99 dB at resonant frequency 14 GHz and irregular patch antenna is 6 dB at resonant frequency 8.25 GHz. Based on figure 4.8, irregular patch antenna has achieved higher gain compare to rectangular patch antenna.

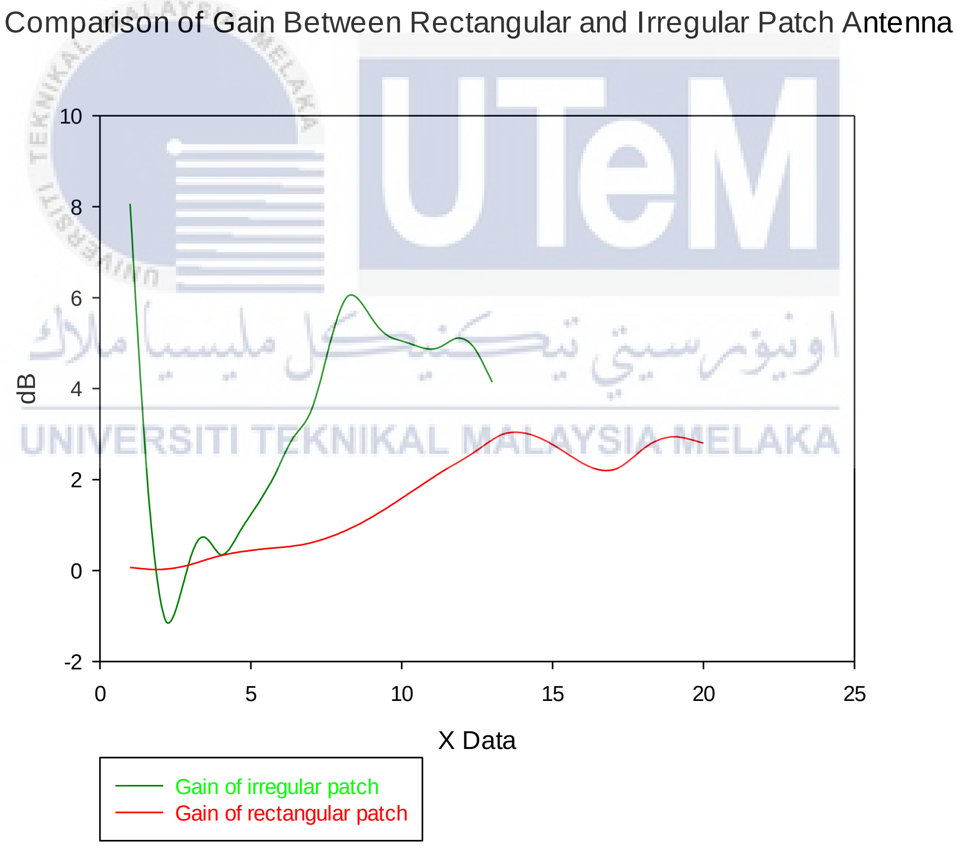


Figure 4.8: Comparison of Gain Between Rectangular and Irregular Patch Antenna

4.2.4 Efficiency

Figure 4.9 and 4.10 shows the curve of radiation efficiency and gain versus frequency. Blue colour dotted curve is represented simulation gain of both antennas while red colour curve is represented radiation efficiency. From figure 4.9 and 4.10, radiation efficiency is increases when the gain also increases. Figure 4.9 shows that rectangular patch antenna radiates highest radiation efficiency about 45 % of power supplied to it at frequency 14 GHz and figure 4.7 shows that irregular patch antenna radiates highest radiation efficiency about 75 % at frequency 8.25 GHz. This can be concluded that irregular patch antenna is higher efficiency compare to rectangular patch antenna because rectangular patch antenna has large power received as losses and transmitted away because of the impedance mismatch.

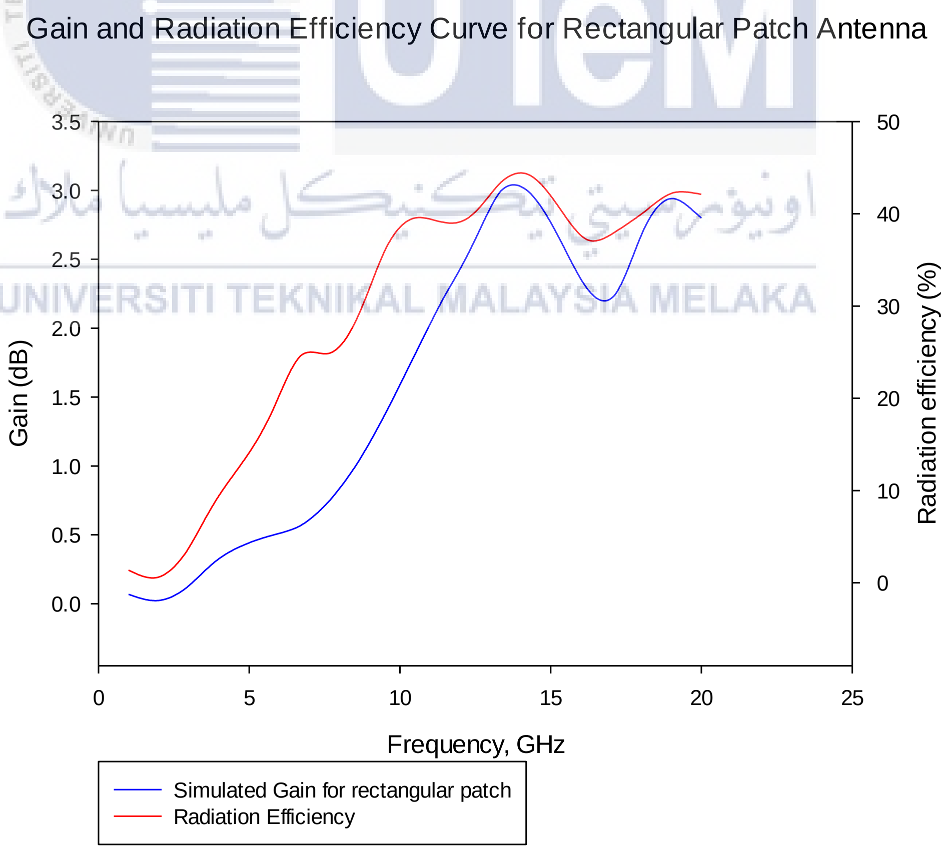


Figure 4.9: Gain and Radiation Efficiency Curve for Rectangular Patch Antenna

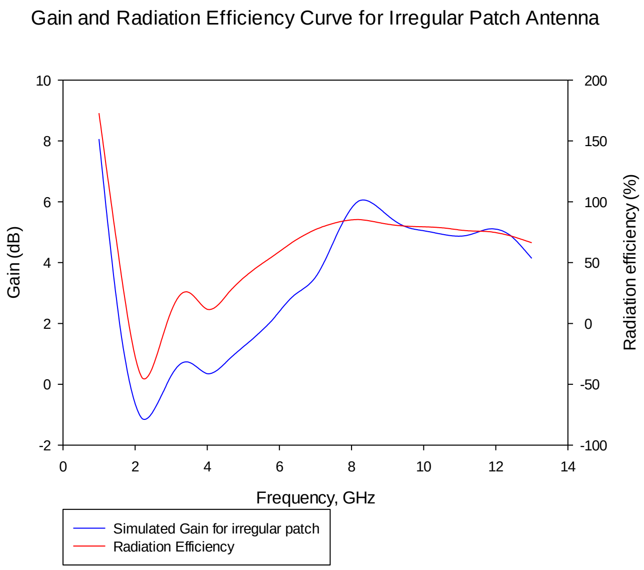


Figure 4.10: Gain and Radiation Efficiency Curve for Irregular Patch Antenna

4.2.5 Directivity

Figure 4.11 shows that the range of the directivity of both antennas is between 2.5 dB and 7 dB. As a result, low directivity has broad radiation pattern while high directivity has directional pattern.

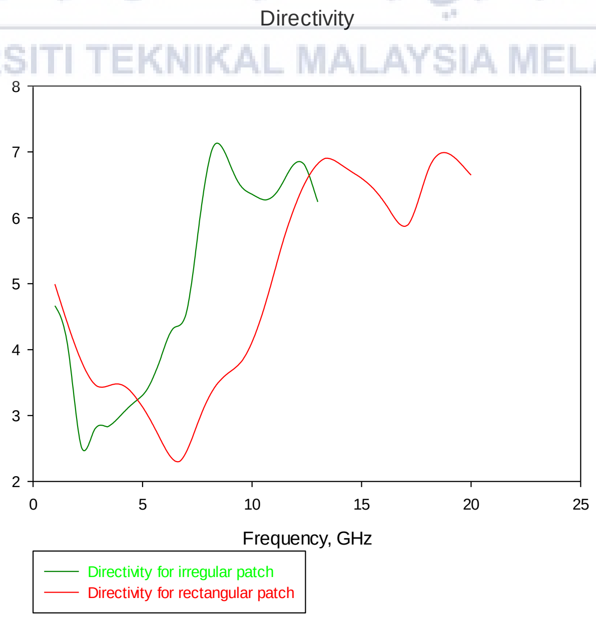


Figure 4.11: Comparison of Directivity Between Rectangular and Irregular Patch Antenna

Table 4.1: Comparison Parameters Between Rectangular and Irregular Patch Antenna

Shape of patch	Return Loss, dB	Bandwidth, %	Gain, dB	VSWR	Efficiency, %
Rectangular	-30.51	177%	2.99	Less than 2	44
Irregular	-42.91	138%	6	Less than 2	75

Table 4.1 shows the parameter results of microstrip patch antenna for two different shapes as rectangular shape and irregular shape with same substrates as FR 4. Return loss, bandwidth, gain, VSWR and efficiency values are recorded in table 4.1. Although irregular patch antenna has better return loss, gain and efficiency compare to rectangular patch antenna, but bandwidth of the antenna also important since the design for the UWB antenna suppose also has larger bandwidth.

4.2.6 Radiation pattern

For rectangular patch antenna, simulated radiation pattern at 7.9 GHz is shown in figure 4.12 and measured radiation pattern shown in figure 4.13. From simulation results, radiation pattern at E-field shows omnidirectional behavior but H-field shows linear behavior at 150° but E-field and H-field shows omnidirectional behavior in measurement results which is stated in figure 4.13. Next, for irregular patch antenna, radiation pattern at operating frequencies 2.8 GHz and 6.7 GHz is plotted in figure 4.14 to figure 4.17. By comparing the simulation results at low frequency and high frequency, it can see that E-field at 2.8 GHz has omnidirectional behavior but become linear behavior at 6.7 GHz and H-field at 2.8 GHz and 6.7 GHz remain as linear behavior. For the measurement radiation pattern, it shows omnidirectional behavior at low and high frequency, the only different is the gain obtained is smaller than simulation results.

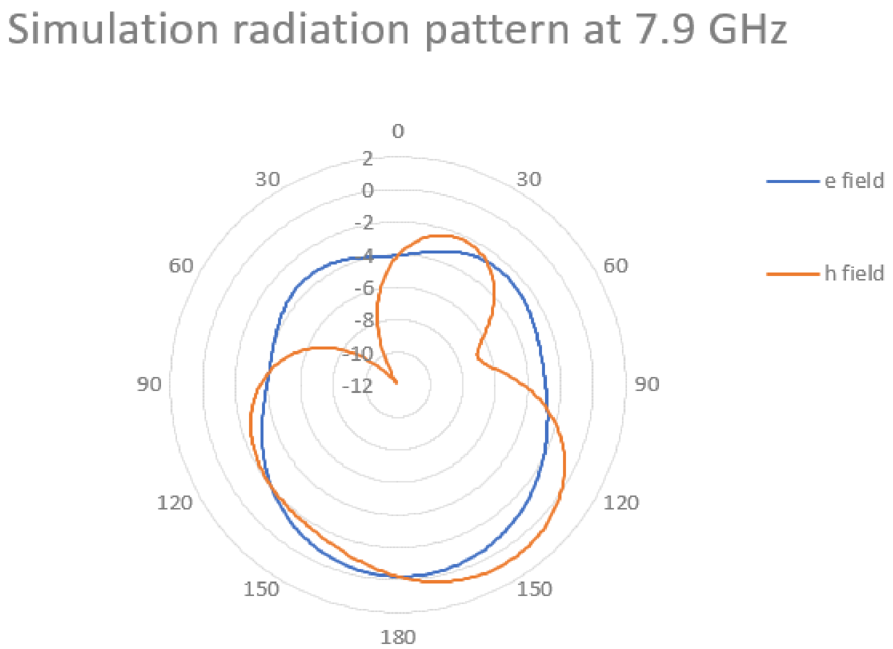


Figure 4.12: Simulation radiation pattern at 7.9 GHz

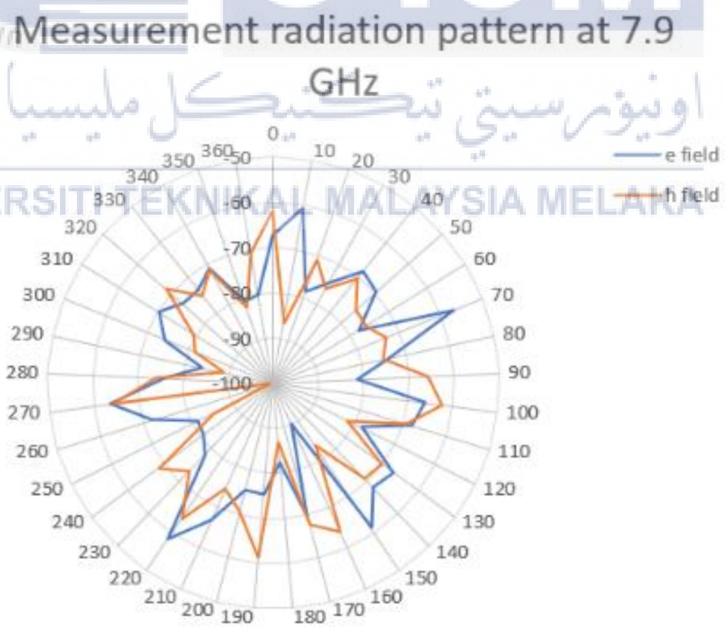


Figure 4.13: Measurement radiation pattern at 7.9 GHz

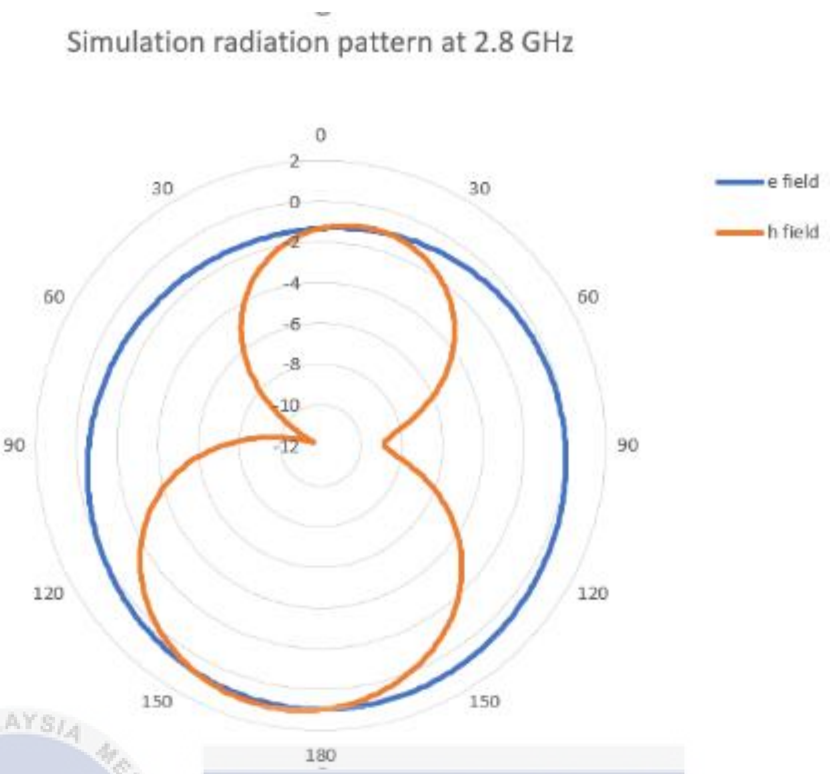


Figure 4.14: Simulation radiation pattern at 2.8 GHz

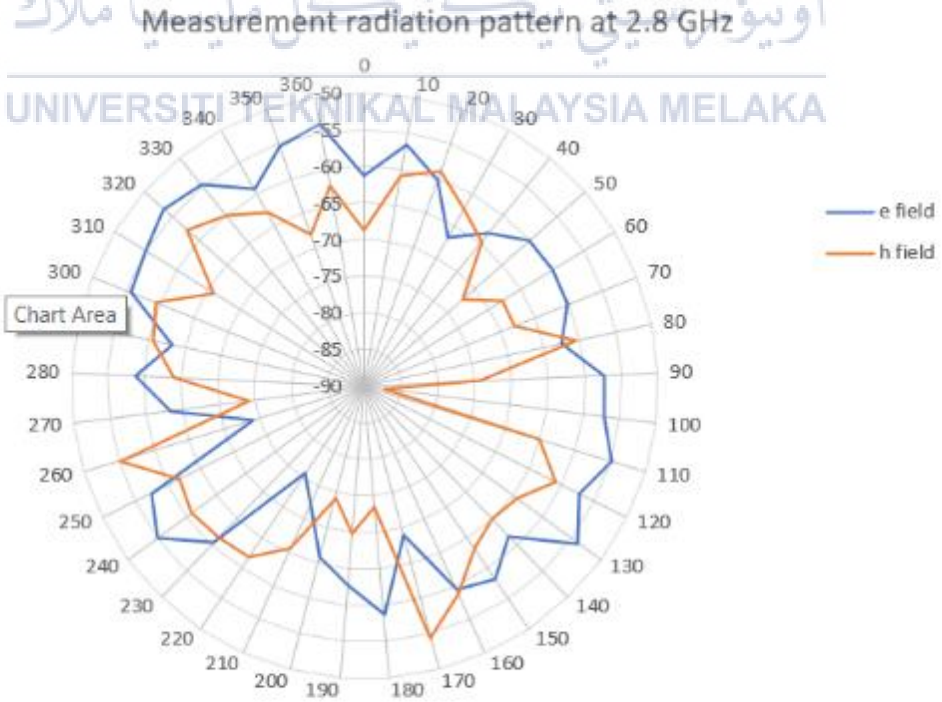


Figure 4.15: Measurement radiation pattern at 2.8 GHz

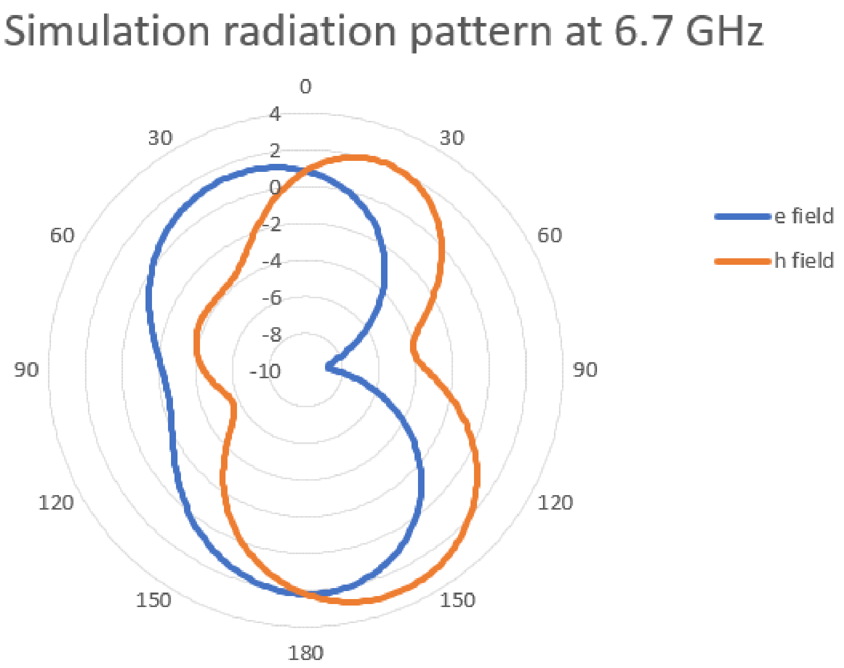


Figure 4.16: Simulation radiation pattern at 6.7 GHz

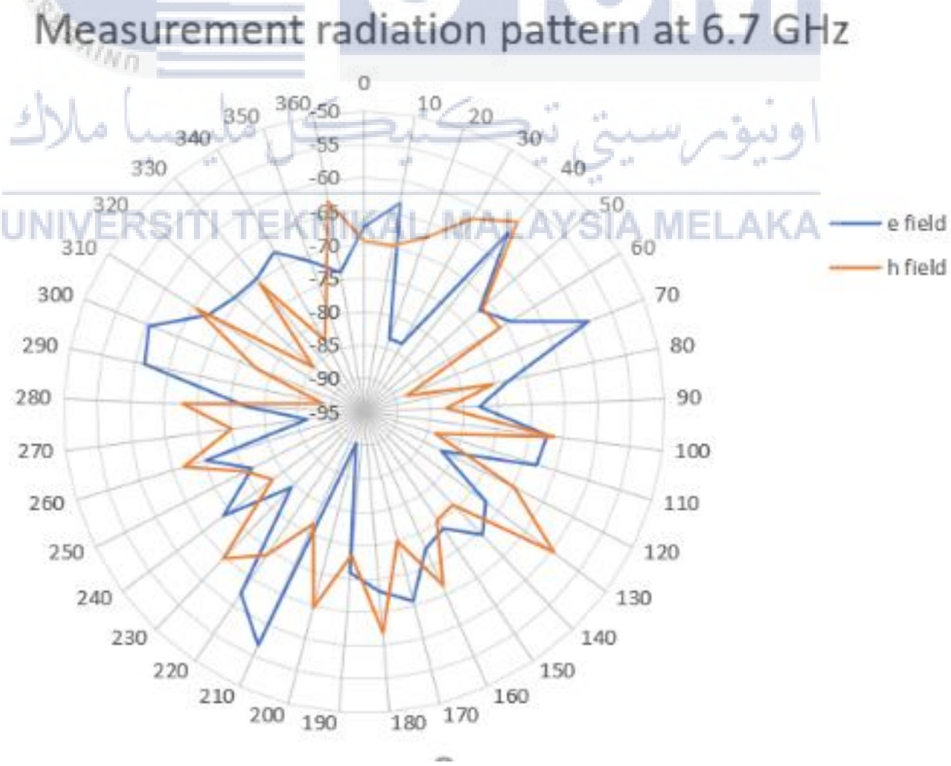


Figure 4.17: Measurement radiation pattern at 6.7 GHz

4.3 Discussion

Based on figure 4.1 and 4.2, both designed antennas are well matched at the frequencies range where return loss smaller than −10 dB. It can be concluded that higher return losses, more power is being delivered to the antenna and available to radiate. Another parameter that measure how good the antenna is matched to other system components is VSWR. Return loss providing measurement as decibel while VSWR providing measurement as ratio. In figure 4.7, a VSWR that less than 2 has more than 90 % of the power is reflected to the antenna. Therefore, if the VSWR is below 2 means that the antenna match is perfect. Next, gain equal to directivity multiply efficiency. It only shows the efficiency of radiated output in one direction. The direction of maximum radiation is used as gain when there is no specific direction is stated. Since gain only determines the efficiency in one direction, it is poor measurement to measure gain of the antenna that radiated more than one direction, therefore, radiation efficiency is preferred. From figure 4.9 and 4.10, irregular patch antenna is better to transmit its output power with minimum losses in the transmission line compare to rectangular patch antenna since its overall radiation efficiency is higher than rectangular patch antenna. Based on the radiation patterns obtained, rectangular and irregular patch antenna has omnidirectional radiation pattern in E-field and linear radiation pattern in H-field. Since there is slightly different between simulation and measurement results, there is because designed antenna in CST software is connected to waveguide port but practically is soldered with SMA connector. Second is due to material loss such as permittivity of substrate and cable losses. Lastly is the fabrication tolerance.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

A microstrip patch UWB antenna with two different shapes of patch and techniques has been designed in this thesis. The rectangular patch antenna satisfies the UWB frequency wideband from 1.0 GHz to 16.19 GHz while irregular patch antenna satisfies the UWB frequency band from 2.38 GHz to 12.9 GHz. According to the simulated results, the rectangular patch antenna achieves impedance bandwidth of 177 % from 1 GHz to 16.19 GHz while irregular patch antenna achieves impedance bandwidth of 138 % from 2.38 GHz to 12.9 GHz.

The rectangular patch antenna is designed with overall size 15 mm x 20 mm and irregular patch antenna is designed with overall size 30 mm x 30 mm. Techniques such as adding slots on the patch and reducing the size of the ground plane to enhance the bandwidth. In addition, ground plane of both antennas also applied defected ground structure to get higher return loss and gain. It can be seen that rectangular patch added three slots at the ground plane while irregular patch only added one slot.

Next, performance results which are return loss, gain, VSWR and radiation pattern were recorded and compared for both antennas. Although irregular patch antenna has better return loss and gain compare to rectangular patch antenna but overall performances of both antennas are good with VSWR less than 2. Due to the microstrip patch antenna can be fabricate easily and low budget, it is suitable used for the UWB applications. Innovative methods also needed in the antenna design to get better performance values.

5.2 Suggestions for Future Work

For future works and improvement studies, future works shown below is suggested carried out:

- Since both antennas are focus on how to improve the impedance bandwidth and return loss, therefore, future work maybe can have gain improvement in certain frequencies that required for some applications.
- In this thesis, technique defected ground structure is used on the ground plane. Other techniques such as photonic band gap and electromagnetic band gap can be used in future work.
- The bandwidth of UWB only cover ranges of frequency from 1 GHz to 16.19 GHz. For future work, frequency above 16.19 GHz could be studied to include other application.

- Other slots such as V-shaped slot, double L-shaped slots and double U-shaped slots can be applied on designing the shape of the slot for defected ground structure.
- Frequency range for 5G in Malaysia are 700 MHz, 3.40 to 3.60 GHz and 24.9 to 28.1 GHz. Therefore, the next project can focus on above frequency ranges.

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