DESIGN AND ANALYSIS OF TRIANGULAR ARRAY ANTENNA FOR UHF RFID READER

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ENGINEERING (ELECTRONIC)

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Thesis submitted in fulfillment of the requirements
for the award of the
B.Eng (Hons) Electrical Engineering (Electronic)

College of Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2022

ACKNOWLEDGEMENTS

I am sincerely grateful to ALLAH “S.W.T” for giving me wisdom, strength, patience, and assistance to complete my “Projek Sarjana Muda”-PSM. If it had not been due to His will and favor, the completion of this study would not have been achieved.

This dissertation would not have been possible without the guidance and the help of several individuals who contributed and extended their valuable assistance in the preparation and the completion of this study. I am deeply indebted to my supervisor, Mr. Mohd Hisyam Bin Mohd Ariff for his patient, guidance, comment, stimulating suggestions and encouragement which helped me in during my research on this topic, writing of this thesis and assistant throughout my project work.

I also like to thank the Kolej Kejuruteean (KEJ) for providing the laboratory facilities for this research. My sincere appreciation also extends to all my friends, lecturers, technical staff, and others who provided assistances and advice, including the crucial input for my planning and findings. The guidance and support received from all was vital for the success of this research.

Lastly, I would also like to address my unlimited thanks to my family for their unconditional support, both financially and emotionally throughout my studies. My deepest gratitude goes to my family for their support, patience, love, and trust during my study. Finally, I would like to thank everyone who had involved in this study either directly or indirectly

ABSTRAK

Dalam Dalam kertas kerja ini, tujuan kajian ini adalah untuk mereka bentuk dan menganalisis antena tampalan jalur mikro tatasusunan segitiga untuk aplikasi Frekuensi Radio (RFID) Frekuensi Ultra Tinggi (UHF). RFID ialah teknologi yang menggunakan gelombang radio secara automatik mengenal pasti dan membaca maklumat daripada tag dengan jarak. Reka bentuk tampalan pada projek ini terdiri daripada tampalan segi tiga dengan tatasusunan. Antena tatasusunan digunakan dalam aplikasi RFID kerana ia menawarkan keuntungan tinggi dan kearah arah untuk membolehkan julat bacaan jarak jauh. Tampalan jalur mikro disusun dalam susunan 2 x 1 dan bahan yang digunakan ialah FR-4 dengan pemalar dielektrik 4.7 dengan ketinggian 0.16 cm. Bahan untuk tampalan adalah tembaga dengan ketinggian 0.035 mm dan digunakan untuk mereka bentuk segi tiga. Reka bentuk tampalan antena 919MHz hingga 923MHz direka, dibina dan diukur untuk aplikasi RFID UHF di Malaysia. Kajian teori dan pengiraan parametrik dijalankan untuk menganalisis perubahan dalam operasi dalam aplikasi pengenalan frekuensi radio (RFID) (UHF). Simulasi antena dijalankan menggunakan CST Studio Suite 2019 sebagai perisian utama untuk memodelkan dan mensimulasikan keputusan, terdapat beberapa parameter yang akan dianalisis termasuk pekali pantulan (S11), Nisbah Tetap Voltan (VSWR), kearaharah, keuntungan , corak sinaran dan lebar jalur.

ABSTRACT

In this paper, the purpose of this study is to design and analysis the triangular array microstrip patch antenna for application of Radio Frequency (RFID) Ultra High Frequency (UHF). RFID is a technology that uses of radio waves automatically identify and read information from tag with distance. The patch design on this project consists of triangular patch with array. Array antennas are used in RFID application as it offers high gain and directivity to allow a long distance read range. The microstrip patch is arranged in 2 x 1 array and material used is FR-4 with dielectric constant 4.7 with height of 0.16 cm. The material for patch is copper with height 0.035 mm and used to design triangular shape. Design of antenna patch 919MHz to 923MHz is designed, built, and measured for UHF RFID application in Malaysia. Parametric theory and calculation studies are conducted to analysis changes in operations in radio frequency identification (RFID) application (UHF). The antenna simulation was run using the CST Studio Suite 2019 as the primary software to model and simulate the results, there are a few parameters that going to be analyses which includes reflection coefficient (S11), Voltage Standing Ratio (VSWR), directivity, gain, radiation pattern and bandwidth.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Hz	Hertz
k	Kilo
M	Mega
G	Giga
L	Length
W	Width
mm	Millimetre
cm	Centimetre
dB	Decibel
Ω	Ohm
π	Phi
εr	Dielectric
fr	Operating Frequency
δ	Loss Tangent
h	Substrate Thickness
t	Patch Thickness

LIST OF ABBREVIATIONS

UHF	Ultra-High Frequency
RFID	Radio Frequency Identification
LF	Low Frequency
HF	High Frequency
MF	Microwave Frequency
VSWR	Voltage Standing Wave Ratio
S11	Return Loss
SMA	Surface Mount Connector
CAD	Computer Added Drawing
CST	Computer Simulation Technology
PCB	Printed Circuit Board
IC	Integrated Circuit
MWS	Microwave Software

CHAPTER 1

INTRODUCTION

1.1 Background

In telecommunication, Radio Frequency Identification (RFID) system have become very popular in many industries such as services, purchasing, distribution logistics, and manufacturing companies. RFID systems are consisted of a tiny transponder, a radio receiver and transmitter. The ability to detect object by radio wave frequency in several range using tags and reader and sent the information to the host server.

RFID is depends on radio communications for mark and recognize objects. The system work based on the alternating electromagnetic fields are mostly made up from two major component which are transceivers (tag readers) and transponders [1]. The transponders (tags) of RFID are included with a small complex circuit to capture data and antenna for connection medium. Generally, an RFID tag consists of an Application Specific Integrated Circuit (ASIC) microchip connected to an antenna. The small microchip and the antenna used to transmit and receive the radio signals from the transceivers (reader) in the same frequency within same time. The antenna produces radio signal to enable the tag, write and read data. Tag and reader communicate each other using the antenna.

Antenna also plays a big role as conduits between the tag and the reader for RFID system to manage data receiver and transmitter. Many easier shape and sizes for antenna depends on operating frequency and application. Antenna can be design for many remote sensor systems such as a mounted-on toll booth to avoid heavy traffic on a highway or door frame to act as a transceiver from human or anything that passes through the door. The reader will capture the data using antenna and sending to computer host for process purpose

1.2 Introduction to Project

To RFID (Radio Frequency Identification) is one of the identification technologies which can realize contactless intercommunication using wireless channel. RFID technology used in many applications in the world such as barcode system, door access control, healthcare industry and transportation. The purpose of this project is to develop and analysis antenna for RFID reader using substrate material such as FR-4 with triangular shape of patch. The frequency range of this project is 919 MHz to 923 MHz that legally in Malaysia [2]. The microstrip patch antenna consists of patch plane on one side and ground plane on the other side. The advantages of microstrip patch antenna are high gain and high signal strength, low profile configuration and suitable for many RFID application.

1.3 Problem statement

The microstrip patch antenna has certain weakness based on the low gain of antenna. The microstrip patch antenna produced low gain and it affected the read range between antenna and reader. The challenge in the RFID application is to have a perfect communication between tags and antenna.

Many of UHF RFID antenna produce low gain. The gain of antenna reflects the capability of the antenna to radiate its energy in a specific direction when it connected to the power sources. The value of gain is importance in UHF RFID antenna. The antenna cannot detect the tag in long range with high value of gain, while the antenna that produce high value of gain can easily detect the tag in long range.

Other than that, microstrip patch antenna have a problem to detecting UHF RFID frequency due to low efficiency (S11) of antenna. The bandwidth size may affect the scanning process between tag and reader. The microstrip that have a wide bandwidth can detect many tags at the same time. The normal antenna datasheet does not specify the bandwidth details related to the S11 graph. Thus, it will affect UHF RFID antenna performance.

Lastly, the range of operating frequency for UHF RFID reader system is between 860 MHz to 960 MHz with appropriation frequency from other countries also cause some problem. The UHF RFID frequency range in Malaysia is between 919 MHz to 923 MHz. Most of commercial antenna reader that sell in Malaysia is normally operate in different operating frequency region and not comply with Malaysia rules and laws.

1.4 Objective of Study

The primary goal of this project is to develop, design, and analyse the performance of a microstrip patch antenna for a UHF RFID antenna reader that can work in Malaysia's allotted frequency range of 919 MHz to 923 MHz. The purpose is also to see how different microstrip antenna shapes and parameters affect the microstrip patch antenna. Aside from that, we have additional goals in mind for this research, such as:

i. To design a long detection range of microstrip patch antenna for UHF RFID Reader using array technique.

ii. To increase the antenna efficiency by decrease the return loss S11 value compare single patch antenna and triangular array antenna.

iii. To verify and validate the design antenna between range of 919MHz to 923 MHz for RFID using tag and antenna reader.

1.5 Project Scope

The major goal of this research is to construct and analyse a triangular microstrip patch antenna that can function at frequencies between 919 and 923 MHz with a return loss of less than -10dB. To satisfy specification criteria and improve the performance of design antennas, an optimization is applied. The antenna will be designed, developed, and analysed using the CST Studio software. To boost the bandwidth of the design antenna, a triangular microstrip patch antenna will be developed. Finally, the antenna will be made from FR-4 and tested using a network analyser to ascertain the real value of S11, as well as field testing with an actual RFID reader module.

1.6 Thesis Outline

There are six chapters in this project thesis. Each chapter's explanation is as follows: Provide an overview of RFID, the project's goal, and the scope of work in Chapter 1. Chapter 2: This chapter is devoted to a survey of the literature on microstrip patch antennas, their properties, and RFID. 4 Present the approach for designing and developing microstrip patch antennas in Chapter 3. The antenna parameter is calculated using a theoretical equation. This chapter also demonstrates how to use CST Studio software to build a microstrip patch antenna and describes the fabrication process.

CHAPTER 2

STYLES

2.1 Introduction of Antenna

An antenna is a device that interfaces the RF circuit of the transmitter or receiver to free space. At the beginning of a system design project, the antenna specifications should be developed in concert with the full system specifications. If the system is designed without consideration for the antenna, there may not be adequate volume allocated to the antenna for it to meet performance specification. The antenna must gather information on the system parameters and should participate in system specification writing for the project at hand. There are many shapes of antenna become popular because of it easy to analysis and fabrication. Other than that, the triangular shape of microstrip have good characteristics of radiation particularly low cross-polarization radiation.

2.2 Microstrip Patch Antenna

Microstrip antenna means an antenna fabricated using photolithographic techniques that printed on circuit board (PCB). It mostly used at microwave frequencies. An individual antenna consists of a patch of Copper of various shapes on the surface of PCB, with a Copper ground plane on the other side of board. The antenna is usually connected to the transmitter or receiving through microstrip transmission lines. Printed circuit board (Copper) is main material to produce low cost microstrip patch antenna. This antenna basically consists of dielectric substrate, in which one side of substrate comprises of the radiating patch and another side with the ground plane [3] as show in figure 2-1.

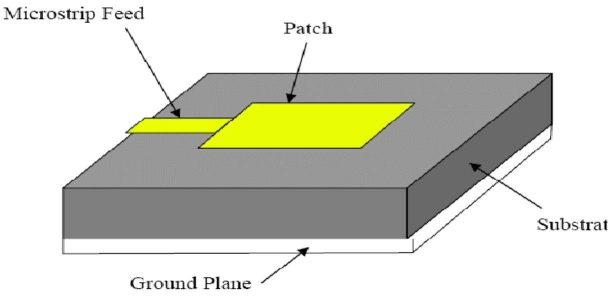


Figure 2.1 Microstrip Patch Antenna Dimension

2.2.1 Advantage and Disadvantage of Microstrip Patch Antenna

The microstrip patch antennas raise the number of users because of the popularity of wireless applications because of its low-level structure. Microstrip patch antenna usually used in wireless device such as cell phone, barcodes technology. The major advantages and disadvantages of microstrip patch antenna are:

Advantages:

- High gain.
- High signal strength.
- Low profile configuration.
- Power wastage reduced.
- Better performance.
- Increase reliability.
- Feedline and matching network can be simultaneous with the antenna structure.

Disadvantages:

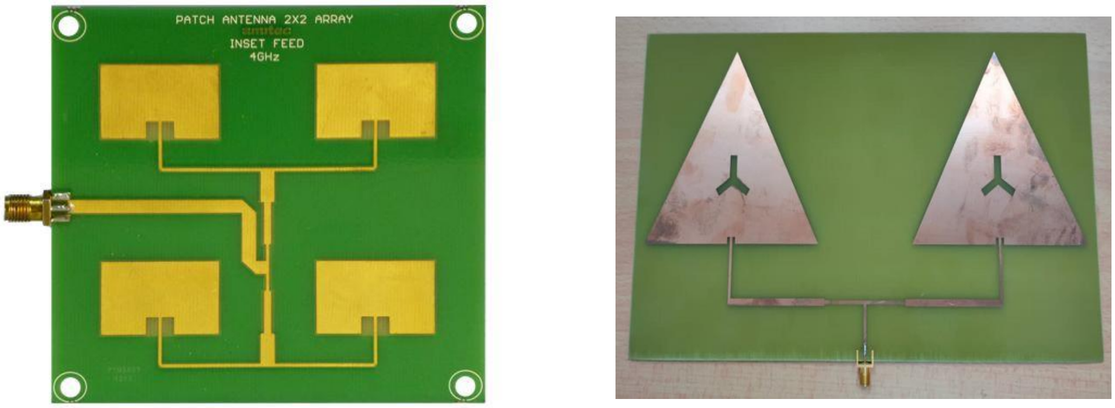
- Narrow bandwidth.
- Limited scanning range.

- Low frequency agility.
- Heavy weight.
- High fabrication cost.

However, RFID applications do not need much bandwidth, and it turns out to be an advantage, because the antenna rejects the signals that are out of the band and accordingly the quality factor increases [4].

2.2.2 Array Technique

An antenna array (also known as an array antenna) is a collection of many linked antennas that transmit and receive radio waves as a single unit. Individual antennas (known as elements) are commonly coupled to a single receiver or transmitter by feedlines, which deliver power to the elements in a phase-synchronized manner as shown in figure 2.2. Each antenna's radio waves combine and superpose, enhancing (interfering constructively) the power emitted in desired directions while cancelling (interfering destructively) the power radiated in other directions. An antenna array can achieve higher gain that is narrower beam of radio waves, than could achieved by a single element. The larger number of individual antenna elements used, the higher the gain and the narrower the beam. There are some antenna arrays are composed of thousands of individual antennas such as military phased array radars. Figure 2.2 show the example of patch antenna array.



(a) (b)

Figure 2.2 Example Patch Antenna Array

2.3 Feeding Method

2.3.1 Microstrip Line Feed

A microstrip line on an indistinguishable plane from the patch for microstrip feeds the patch. The feeding line and patch frame are both attached to the same structure. In comparison to other feeding methods, the microstrip line feed is simple to construct. Aside from that, it's excellent for usage in a sustaining system for accepting wire exhibits. However, microstrip line feed has a flaw in that it has a low data transmission capacity and emits some unwanted radiation.

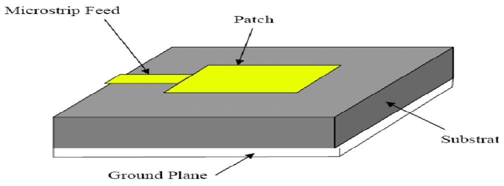


Figure 2.3 Microstrip Line Feed

2.3.2 Coaxial Feed

The coaxial feed also known as probe feed is a common technique used for feeding microstrip patch antenna. the outer conductor of coaxial connector is connected to the ground plane, while the inner conductor is soldered to the radiating patch. The advantages of this feed method are feed can be place at any desired place inside the patch to match with input impedance. However, this feed method has several weaknesses which is provides narrow bandwidth and difficult to fabricate because the hole must be drilled in the substrate and the connector protrudes outside the ground plane, making it not completely planar for thick substrates.

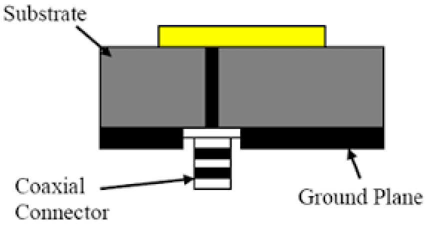


Figure 2.4 Coaxial Feed

2.3.3 Proximity Coupled Feed

Proximity couple feed method also known as the electromagnetic coupling scheme. Two dielectric substrates are needed to construct this feed method since the feed line placed between two substrate and the radiating patch is on top of the upper substrate. This feed method has several advantages which is provides very high bandwidth (as high as 13%) and it's also eliminating spurious feed radiation. In addition, this method provides choices between two different dielectric media, one for the feed line and one for the patch to level up the individual performance.

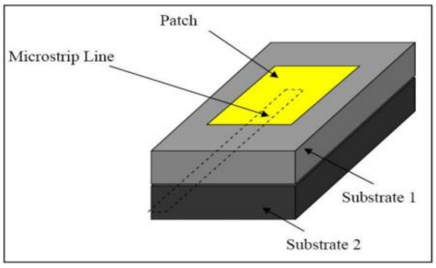


Figure 2.5 Proximity Coupled Feed

2.3.4 Aperture Couple Feed

In aperture couple feed, the microstrip feed line and the radiation patch are separated by ground plane. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane and variations in the coupling will depend upon the size i.e., length and width of the aperture to optimize the result for wider bandwidths and better return losses [5]. The position of coupling aperture usually centred under the patch. The advantage of this feed method is it can minimize the spurious radiation and provides wide bandwidth.

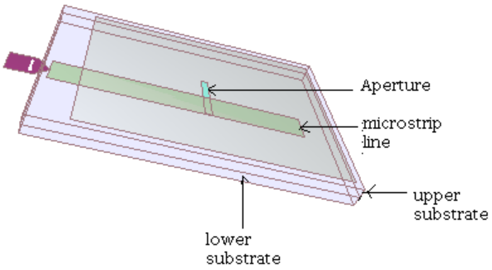


Figure 2.6 Aperture Couple Feed

2.4 Antenna Parameter

To determine the performance of an antenna, several parameter and characteristic of antenna need to be considered such as directivity, gain, bandwidth, axial ratio, radiation pattern, and polarization.

2.4.1 Directivity

The directivity of standard microstrip patch antennas is roughly 6-7dB [6]. An antenna's directivity is defined as "the ratio of the antenna's radiation intensity in a particular direction to the averaged radiation intensity in all directions." In other words, antenna directivity indicates how well an antenna radiates in various directions. Directivity may be estimated from the antenna's highest radiation in the same way that gain can be measured in each direction. In theory, a linear polarisation antenna can only emit 90 degrees in one direction and can detect tag from long distance than circular polarisation.[7].

2.4.2 Gain

When an antenna is connected to power sources, its gain represents its capacity to transmit power in a certain direction. It demonstrates how a transmitting antenna may radiate the anticipated power into space in a given direction. The antenna's potential then indicates how it converts incoming electromagnetic waves into electric power. In general, antenna gain contains efficiency and directivity. The gain is easily expressed in decibels (dB), which shows the direction of highest radiation, and the gain may be determined using equation 2.1.

$$G = \eta D \tag{2.1}$$

Where η is represent the efficiency of antenna and D is represent the directivity of antenna.

2.4.3 Bandwidth

The bandwidth of an antenna is defined as “the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard” [1]. The bandwidth of the antenna is a key parameter of the antenna that can be labelled as the frequency range over which the antenna fulfils the desired characteristics. The percentage of bandwidth depends on the size of bandwidth which can be mathematically expressed:

$$\text{Percentage of bandwidth, BW\%} = [\frac{fH - fL}{fC}] \times 100\% \qquad 2.2$$

2.4.4 Axial Ratio

The result of axial ratio can determine polarization of an antenna whether its linear polarization, circular polarization, or elliptical polarization. For linear polarization, the value of axial ratio must be greater that 3dB, while the value of axial ratio for circular polarization must lower than 3dB. The linear polarization antenna can be better when the value of axial ratio approximates greater than 3 dB to declare its as linear polarization.

2.4.5 Radiation Pattern

Radiation pattern of antenna also known as antenna pattern. Radiation pattern is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates [7]. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity phase or polarization [7]. Radiation pattern can determine the energy radiated and received by the antenna which can be measured using CST Studio simulation. The typical radiation pattern of an antenna illustrates by figure 2-7.

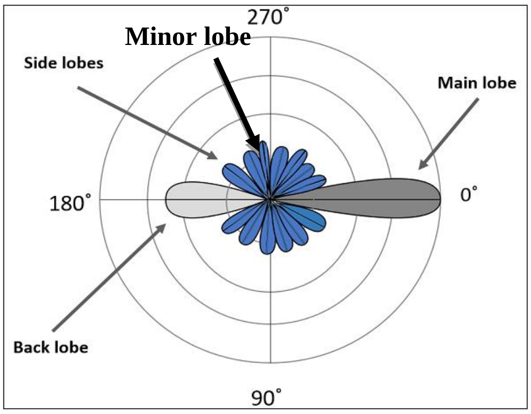


Figure 2.7 Antenna Radiation Patten

In radiation pattern of antenna usually consist of several lobes such as major lobes, minor lobes, side lobes, and back lobes that represent the power radiated of antenna.

i. Major/main lobe: major lobe also known as main beam is defined as the lobe that contains the maximum power radiation at specific direction and its pointing in the $\Theta = 0$ direction. In different antenna type such as split beam, it may consist of one or more major lobe.

ii. Minor lobe: minor lobe is any lobe except major lobe (main beam) can be classified as minor lobe. the minor lobe typically represent radiation in unwanted direction and should be minimized.

iii. Side lobe: Side lobe is radiation lobe from any direction other than recommended lobe. Usually, side lobe is adjacent to the main lobe and occupies the hemisphere toward the main lobe.

iv. Back lobe: Back lobe whose axis makes an angle of approximately 180 degrees with respect to the beam of an antenna. It usually refers to a minor lobe, which occupies the hemisphere in the opposite direction to that of the main lobe.

2.4.6 Polarization

Polarization of an antenna in each direction is defined as “the polarization of the wave transmitted (radiated) by the antenna [1]. One of the ways to improve gain is coordinated the transmitting polarization and receiving polarization of the antenna. Polarization describes the orientation movement in the plane opposite to the transverse wave bearing. Other than that, polarization coordinating help to reduce transmission loss by adjusting wave spread orientation in transmitting and receiving patch antenna.

polarization can be categories in three types which is linear polarization, circular polarization, and elliptical polarization. Linear polarization will occur when the electromagnetic waves are transmitted on single plane either in vertical or horizontal direction. To get a consistent read, the linear polarization antenna must have same orientation as RFID tag orientation. Circular polarization produces electromagnetic fields shaped like corkscrew and electromagnetic waves are broadcast on two planes and make a complete revolution in a sing wavelength. Generally, read range of circular polarization antenna is shorter than linear polarization antenna. The common polarization state of patch antenna is elliptical polarization. When the end of the electric field vector follows an ellipse at a fixed point in space, the antenna is elliptical.

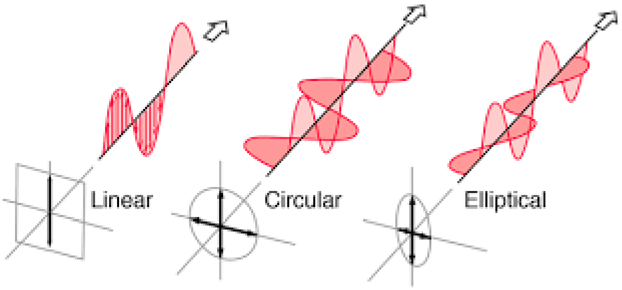


Figure 2.8 Type of Polarization

2.5 RFID Component

2.5.1 Basic Operation Of RFID

RFID is a system consist of two main components namely tag and reader [8]. Normally the tag is attached to the objects to identified. RFID tag contained read and write function to updated and protected user data and stored in RFID tag. For the RFID reader, it consists of transmitting and receiving segments. A simple RFID operating system starts when the reader sends the carrier signal and receives a scattered signal from the tag via their antenna. The reader communicates simultaneously with the tag and provides the power to operate the integrated circuits on passive tags. The tags react with a unique identifying code assigned to the reader. Then, the reader transmits the data to server.

Figure 2.9 Illustration RFID system

2.5.2 RFID Tags

RFID tags are electrical devices that use radio frequency to identify and track objects. With the use of a radio wave, it transfers data with an RFID reader. An antenna and an integrated circuit are the two main components of RFID (IC). The antenna serves as a receiver for receiving radio waves, while the integrated circuit (IC) processes and stores the information. Active and passive RFID tags are the two types of RFID tags. [10]. To operate, active tags require a power supply or an inbuilt battery. Because of their high cost, inadequate size, and short lifespan, active tags are impractical in many applications. Another example is passive tags, which are used in many RFID applications since they do not require embedded batteries. The tags are also long-lasting and tiny enough to fit 15 in many RFID applications. the most important feature of tags in the tag range the greatest distance at which RFID scanners can read or write information on a tag is referred to as tag range.

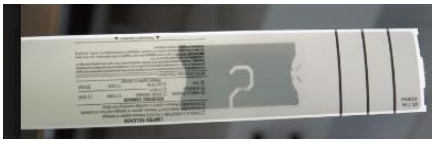


Figure 2.10 Tag

2.5.3 RFID Reader

RFID reader is electric component that receive radio wave (data/information) from RFID tags to detect specific object. RFID also consist of radio frequency module, and it can operate as transmitter and receiver to collect radio wave (data/information) sent it to the host server (the necessary supporting infrastructure, including software and hardware). The RFID reader most popular is barcode detection in the world. However, the communication protocol of UHF RFID readers inherently exposes them to strong interference signals due to transmit leakage and antenna reflection [11]. The level of distraction in the reader affects the sensitivity of the receiver, limiting the reading range, and reducing the overall performance of the RFID reader.

Separating the transmit and receive antennas would reduce the interference but it will increase the size and the cost of the reader [11]. RFID reader can be classified into three types which is stationary reader, mounted reader, and handheld reader. Stationary reader Stationary RFID readers require power efficiency as well as high output power since the power amplifier consumes the highest power in the transmitter [12]. Usually, it's mounted on divider, wall or any suitable surfaced. The high output of power amplifier should produce low harmonics in desired frequency to eliminate interference from other application frequency. For handheld reader, it's a mobile reader and required power supply to operate. Other than that, (a) (b) 16 handheld radio frequency identification (RFID) reader units become increasingly important with the adoption of passive ultra-high frequency (UHF) RFID systems in supply chain, warehouse, and retail store management [9]. Lastly mounted reader, it's usually attached on truck or other vehicle to record vehicle movement information and this system required a few frameworks to operate.

(a) Stationary

(b)Handheld (c) Mounted

Figure 2.11 Type of RFID Reader

2.5.4 RFID Antenna

The RFID reader antenna transmit information using radio wave. The information needs to change first to radio eave before transmitting. The Figure 2.10 shows the example of RFID reader known as patch antenna. While Figure 2.8 illustrates the radiation pattern has been transmit by antenna through radio wave. The antenna transmits electrical field of radiation pattern, and the wave will travel in opposite ways called as polarization which is in linear polarization or circular polarization.

While the tag of antenna used to receive the radio wave that transmitted from antenna reader and convert the radio wave into electrical signal. The UHF microwave antenna can be divided into three type which is dipole, dual dipole, and folded dipole antenna.

2.5.5 RFID Frequency Range

RFID system used radio frequency wave to communicate between the tags and reader. RFID frequency have four fundamental classes which is Low Frequency (LF), High Frequency (HF), Ultra High Frequency (UHF) and Microwave Frequency. The following table shows the outline of RFID frequency characteristics.

Table 2.1 RFID Frequency

Band	**Regulation**	**Range**	**Data speed**
LF:120-150kHz	Unregulated	10cm (4in)	Low
HF:13.56MHz	ISM band worldwide	0.1-1m (4in-3ft 3in)	Low to moderate
UHF:433MHz	Short range devices	1-100m(3-300ft)	Moderate
UHF:865-928MHz	ISM band	1-12m (3-40ft)	Moderate to high
Microwave:2.45GHz-5.8GHz	ISM band	1-2m (3-7ft)	High
Microwave:3.1-10Ghz	Ultra-wide band	Up to 200m (700ft)	High

CHAPTER 3

METHODOLOGY

3.1 Microstrip Patch Antenna Design

This chapter covered the procedure required for the microstrip patch antenna design. This project has been divided into five main tasks including antenna research, antenna design, simulation of antenna, fabrication of antenna and antenna testing. Figure 3-1 shows the procedure to design the microstrip antenna.

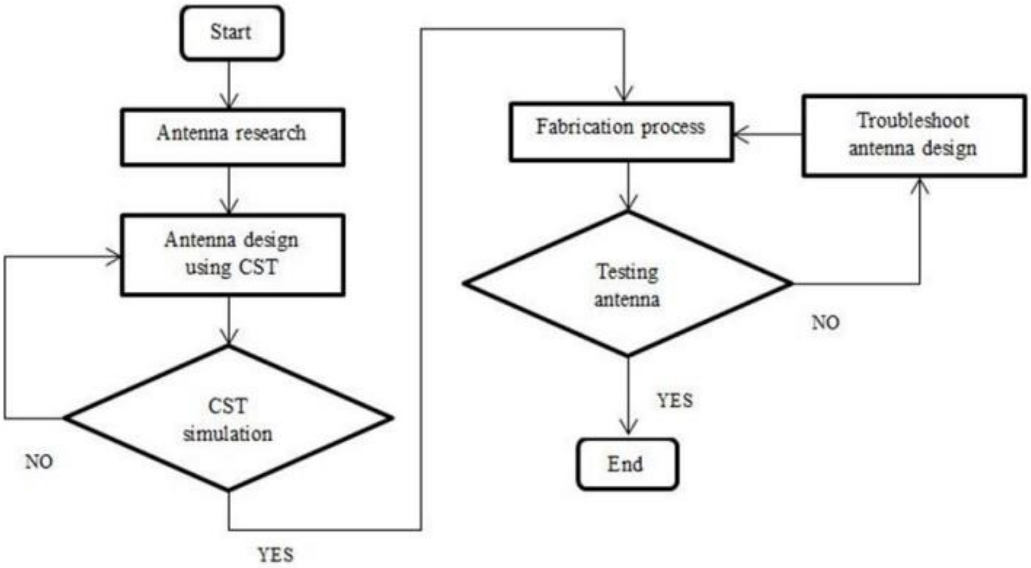


Figure 3.1 Flowchart of Designing Microstrip Patch Antenna

Due to their compatibility and ease with integrated microchip technology, microstrip antennas, also known as patch antennas, are particularly popular in the microwave industry. Rectangular patch antennas are commonly used in industry because they are suited for direct integration with microstrip circuits and can be 20 fixed on the same substrate. However, this project requires the construction of a triangular microstrip antenna array, and numerous characteristics must be addressed before beginning to build the microstrip patch antenna, including operating frequency (fo), substrate dielectric constant (r), and substrate height (h).

Antenna requirements include operating frequency, which indicates that the antenna must operate at a specific frequency. This project's operational frequency is 921 MHz, which is allowed in Malaysia. Aside from that, the dielectric constant value has a significant impact on the antenna's design and performance. For antenna design, the dielectric constant value required for FR-4 substrate material is 4.7 (loss-free). The height of the substrate (h) must be considered to achieve optimum or maximal antenna performance. The antenna in this project was designed using the height of substrate value given using FR-4 substrate material, which is 1.6mm. The size of antenna must same with the value of substrate which is length x width.

3.1.1 Antenna Research

Microstrip patch antenna research has been explored in all aspects, including articles, conference papers, books, journals, and the most recent websites in the field. It also highlighted the importance of improving wireless innovation. RFID innovation has been chosen to be the focus of this section. In this study, a variety of project-related frameworks from around the world were compared.

3.1.2 Antenna Design with CST Studio Software

CST Studio Software was used to create the microstrip patch antenna design. This programme is a three-dimensional electromagnetic simulation tool for high-frequency components. CST Studio enables the analysis of high-frequency devices, particularly antenna devices, in a quick and precise manner. CST Studio provides an analysis result of EM behaviour for antenna devices quickly and with excellent simplicity of use. CST Studio included a time domain solution and a frequency domain solver to assist users in antenna design.

3.1.3 Simulation Process

The design of a microstrip patch antenna is required to simulate an antenna utilising CST Studio Software. The CST simulation will display accurate analysis 21 results of antenna performance, including 1D results, s-parameter (S11), gain, radiation pattern, efficiency, directivity, bandwidth, and antenna polarisation plots, as well as a rectangle diagram. The s-parameter (S11) analysis result will indicate if the antenna is effective or not. To function efficiently at a given frequency, the S-parameter must be less than -10 dB. The radiation pattern should higher than 3dB to get the higher gain and long-range antenna. as well as the Voltage Standing Wave Ratio (VSWR) must nearly to zero for efficiently radio-frequency power from power source through a transmission line into a load.

3.1.4 Fabrication Process

The printed circuit board (PCB) will be used in this process for print the antenna. To fabricate the antenna, PCB prototyping machine will be used to create shape and pattern of patch antenna that have been design before using CST Studio. Before starting the printing procedure, exported the latest simulated design from CST Studio to AutoCad into a .dxf format, 2D format file and front view of antenna which contain all measurement of patch design. PCB prototyping machine will print the shape according to previous patch design.

3.1.5 Antenna Testing

After fabrication process is complete with accurate parameter for microstrip patch design, it will be soldered with SMA connector. After that, it will be tested whether the antenna performance same as simulation that execute from CST Studio software. Testing on the performance of different types of tags has shown that different tag types have different performance, especially in terms of detection coverage, maximum identification distance and return signal. The result from the testing is very importance to determine the suitable position to optimise the detection size, separation, and execution.

3.2 Design Specification

First, before determining and design the patch antenna, the importance step is considering the several antenna parameters that suitable for UHF RFID application. After performing research and study, the suitable antenna parameter for UHF RFID application were recorded in the table below.

Table 3.1 Microstrip Patch Antenna Specification

Operating Frequency, *fo*	**921 MHz**
Dielectric Substrate	FR-4
Dielectric Constant, ε_r	4.7
Substrate Height, *h*	0.16cm
Loss Tangent, δ	0.019
Patch Thickness, *t*	0.035cm

Theoretically, the operating frequency, s-parameter (S11), radiation pattern, directivity, and gain describe about antenna performance. The suitable feeding technique and Array technique can affect the performance of antenna because of two element was used. Then the accurate physical measurement must be finding because it will affect the performance of antenna. The UHF used the frequency range from 300 MHz toward 3 GHz and this project are using UHF RFID frequency from 919 MHz toward 923 MHz. Along the frequency bands, the microstrip patch antenna should be capable to operate along the frequency range. The dielectric constant affecting the size of antenna. other than that, dielectric constant value affecting the radiation power, efficiency, and bandwidth of the antenna

3.3 Design Procedure

The purpose of this section is to describe the proper ways to design triangular array microstrip patch antenna. A triangular patch is outlined for the patch antenna plan. For this design 50 Ω surface mount connector will be used to make connection between feedline and microstrip connecter, the value of feedline will be a 50 Ω feedline. The microstrip connector is placed at the feedline of patch.

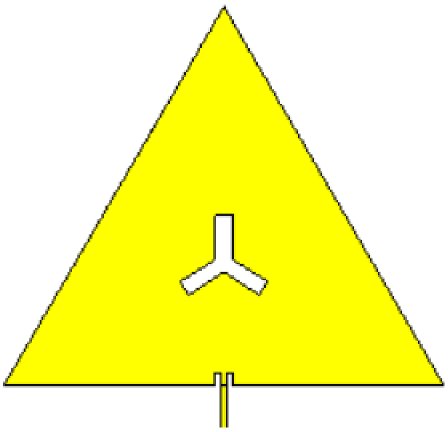


Figure 3.2 Single element of Triangular patch antenna

3.3.1 Design Simulation

The key software for this project is CST Studio, which is used to model the antenna design. CST Studio is capable of simulating antenna designs with precise analytical results. As a high-frequency device (HF), it is user-friendly and simple to operate, and it includes a solver module for a certain technology. Operating frequency, dielectric substrate, dielectric constant (ε_r), substrate height (*h*), loss tangent (δ), and patch thickness must all be considered (*t*). This is because all parameter values have an impact on the antenna's effectiveness. The return loss (S11), radiation pattern, voltage standing wave ratio (VSWR), and gain of an antenna are all determined by simulation results.

3.3.2 Array Design

In some applications, a single microstrip element may be sufficient to provide acceptable antenna properties. However, much like with traditional microwave antennas, high gain, beam scanning, and steering capabilities are only attainable when discrete radiators are coupled to form arrays. An array's components can be dispersed spatially to form a linear, planar, or volume array. A linear array is made up of pieces that are separated by finite lengths along a straight line. The array type is frequently chosen based on the application's requirements. The parallel and quarter-wave-transformer feeding techniques are used to feed the microstrip array in this study. For array 2x1 design, the antenna must use T-junction to make the patch connected each other. The T-junction will connect at feed each patch and the SMA connector will connect the ground with patch.

Figure 3.3 T-junction

For two element patches, the T-junction 50 is needed to divide for both patches. Figure 3.3 shows for the power divider to connect to triangular patch microstrip antenna.

3.3.3 Calculation of Patch Dimension

3.3.3.1 Single element

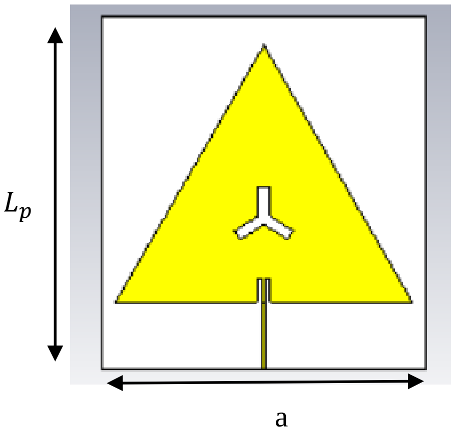


Figure 3.4 Simulation Single Element

The triangular patch antenna has been chosen to be design and analysis to predict the performance of antenna. The triangular patch antenna needs to operate at

921 MHz with 50 Ω of input impedance, 1.6 mm of substrate (h) and 4.7 of dielectric constant. The mathematical expression to figure out the length of the patch antenna (a):

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}}$$

Where:

f_r = resonance frequency

A= length of the side triangular patch

ε_r=relative dielectric constant of substrate

After substituting the above equation with the given value for f_r=921MHz as the centre frequency for WLAN, velocity of light=$3x10^8 ms^{-1}$ and ε_r =4.7, the length of a can be calculated. To determine the height of triangular patch L_p, the Eq. 3.2 is utilized.

$$H = L_p = \sqrt{a - \left(\frac{1}{2} \times a\right)^2} \qquad 3.2$$

The width and length of substrate can be calculated by using Eq. 3.3

$$W_g = 6 * h + a \qquad 3.3$$

$$L_g = 6 * h + L_p$$

The size of substrate of substrate and ground are same but different of thickness.

3.3.3.2 Array (2x1)

To make fair comparison, the same substrate used in single element is used in 2x1 array. Figure 3. Shows the configuration of 2x1 linear triangular patch antenna array.

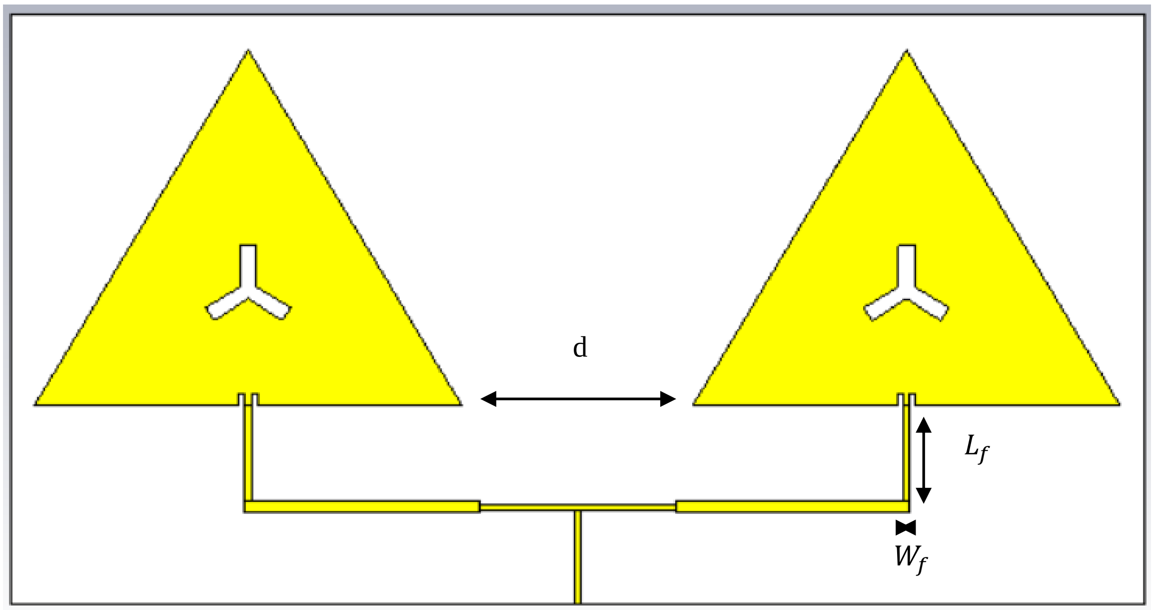


Figure 3.5 Simulation Triangular Array Antenna

The triangular patch antenna array has been chosen to design and analysis the performance of antenna. The mathematical expression to figure out the length and width of feeding and the distance between two elements.

Length of feeder

$$L_f = \frac{\lambda_g}{4} \qquad 3.4$$

To maintain the input impedance 50Ω, $\frac{1}{4}\lambda$ transformer is needed. The $\frac{1}{4}\lambda$ transformer is an impedance matching technique by providing transmission line impedance between two non-match transmission channels.

Width of feeder

$$W_f = \frac{2h}{\pi}\left(B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right) \qquad 3.5$$

Distance between two elements

$$d = \frac{c}{2f} \qquad 3.6$$

The distance between both patches should be calculated, this due to the electromagnetically coupled effect. The mathematical expression above affected the performance of antenna. The suitable feeding technique also can be found by using optimizer.

3.4 Design Microstrip Patch Antenna Using CST Studio Software

CST Studio is the main software in this project to design and simulated the microstrip patch antenna. It able to design and analysis the antenna with accurate result of high frequency devices especially antenna. CST consist of specialist tool to produce accurate analysis result for antenna design. CST Studio software is very popular software for modelling several types of antennae for example RF, Optical, EMC/EMI etc.

The step below shows the right ways to design the antenna using CST studio.

STEP1: Run CST Studio software > Click New and Recent > Click Create Project

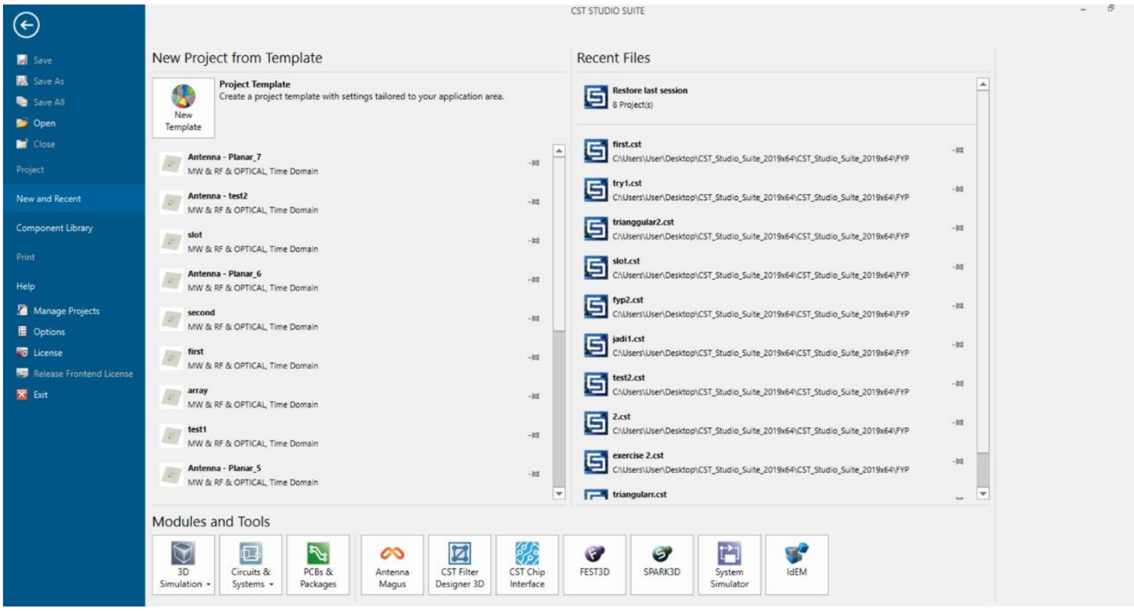
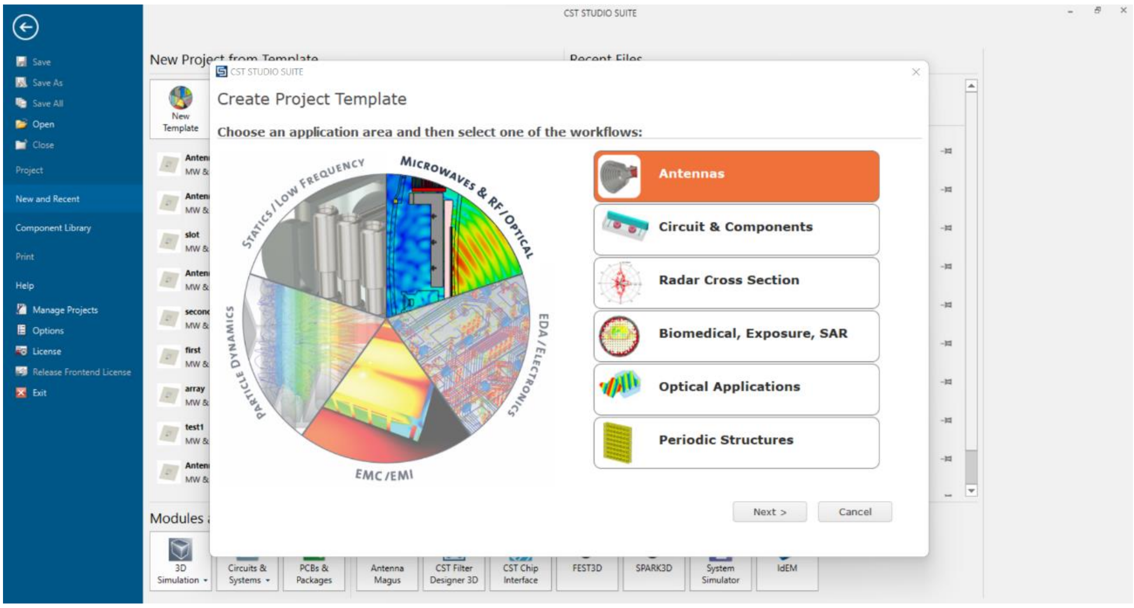


Figure 3.6 Creating New Project

STEP 2: Click New template >Microwave & RF/Optical > Click Antenna > Click Next

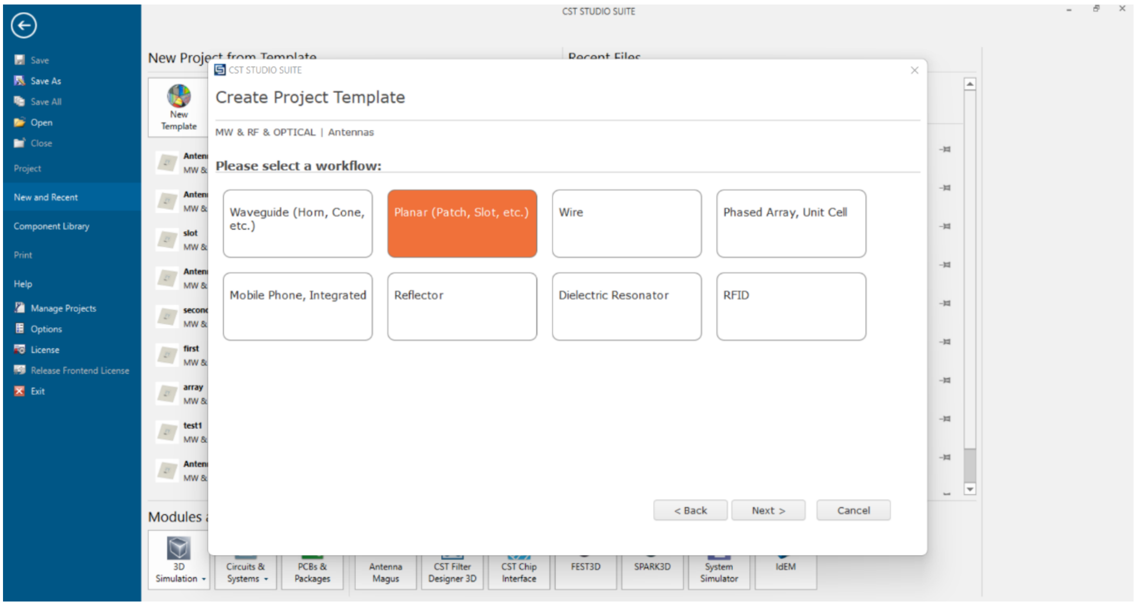


Create Project Template

Choose an application area and then select one of the workflows:

Figure 3.7 Creating New Template

STEP 3: Click Planar (Patch, Slot, etc.) > Click Next



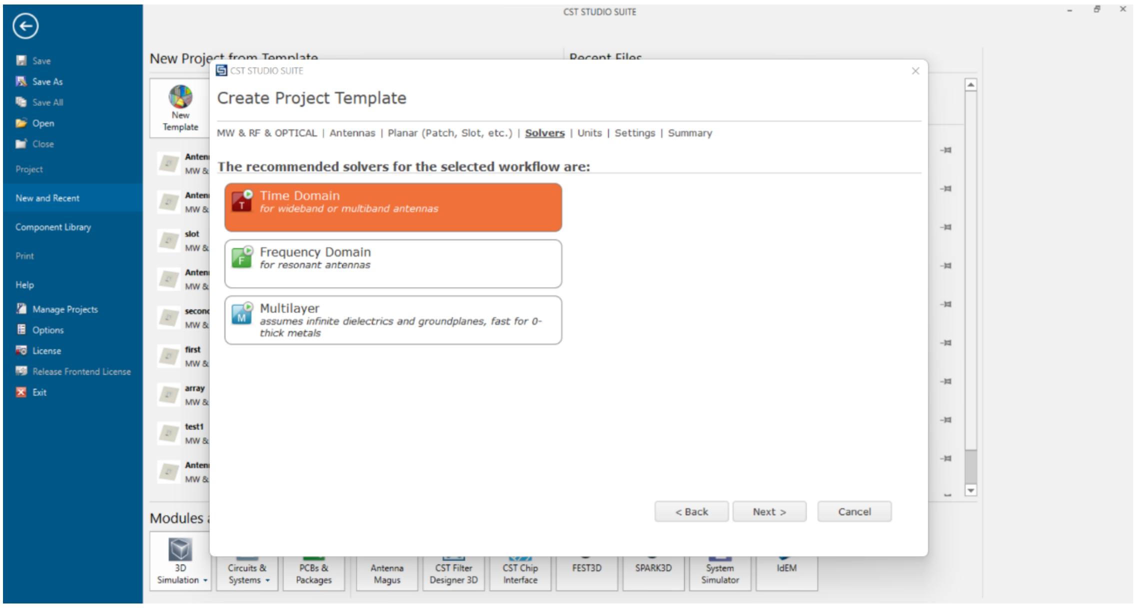
Create Project Template

MW & RF & OPTICAL | Antennas

Please select a workflow:

Figure 3.8 Selecting Workflow

STEP 4: Click Time Domain > Click Next



CST STUDIO SUITE

Create Project Template

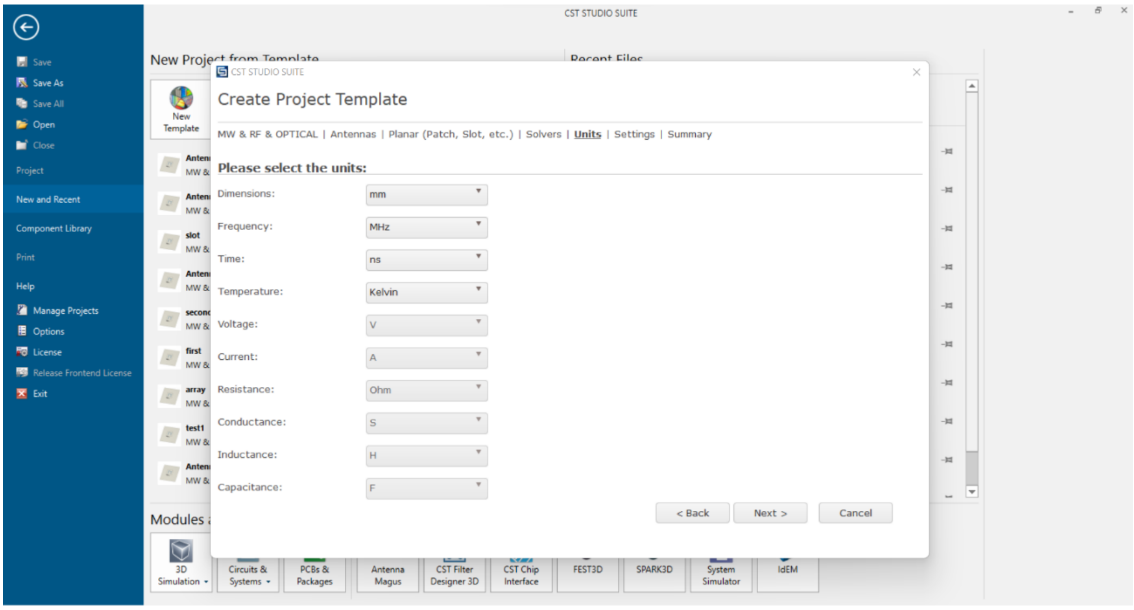
MW & RF & OPTICAL | Antennas | Planar (Patch, Slot, etc.) | **Solvers** | Units | Settings | Summary

The recommended solvers for the selected workflow are:

- Time Domain — *for wideband or multiband antennas*
- Frequency Domain — *for resonant antennas*
- Multilayer — *assumes infinite dielectrics and groundplanes, fast for 0-thick metals*

Figure 3.9 Selecting Suitable Solver for Workflow

STEP 5: Select the unit > Click Next



CST STUDIO SUITE

Create Project Template

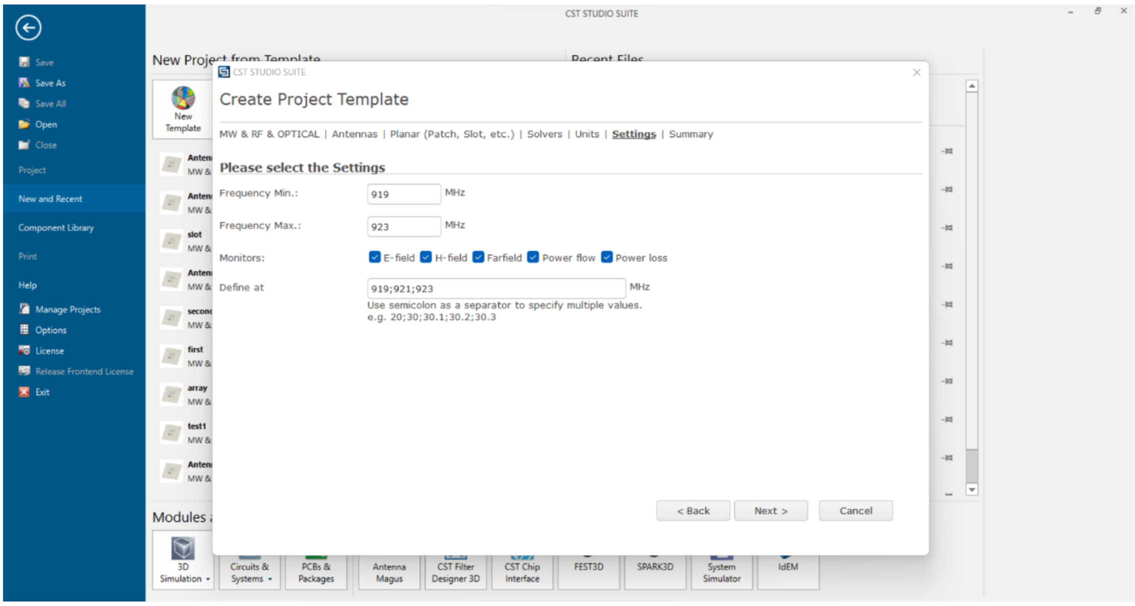
MW & RF & OPTICAL | Antennas | Planar (Patch, Slot, etc.) | Solvers | **Units** | Settings | Summary

Please select the units:

Dimensions: mm
Frequency: MHz
Time: ns
Temperature: Kelvin
Voltage: V
Current: A
Resistance: Ohm
Conductance: S
Inductance: H
Capacitance: F

Figure 3.10 Selecting the Suitable Unit for The Project

STEP 6: Key in the information of the project > Click Next



CST STUDIO SUITE

Create Project Template

MW & RF & OPTICAL | Antennas | Planar (Patch, Slot, etc.) | Solvers | Units | **Settings** | Summary

Please select the Settings

Frequency Min.: 919 MHz

Frequency Max.: 923 MHz

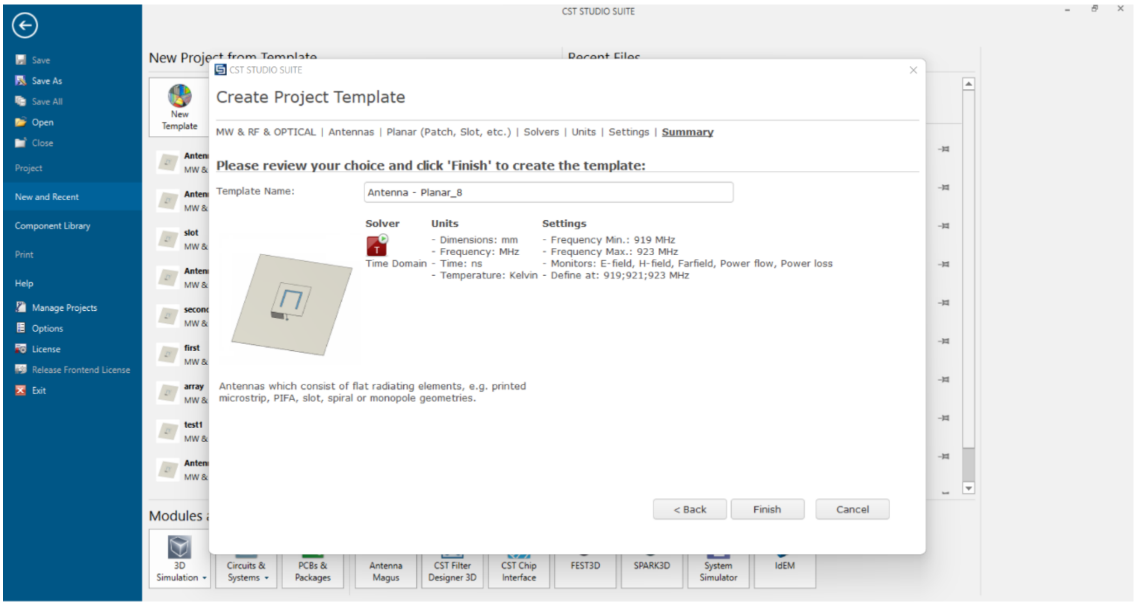
Monitors: ☑ E-field ☑ H-field ☑ Farfield ☑ Power flow ☑ Power loss

Define at 919;921;923 MHz

Use semicolon as a separator to specify multiple values.
e.g. 20;30;30.1;30.2;30.3

Figure 3.11 Selecting the Frequency, Field to Monitor and Define at

STEP 7: Click Finish



CST STUDIO SUITE

Create Project Template

MW & RF & OPTICAL | Antennas | Planar (Patch, Slot, etc.) | Solvers | Units | Settings | **Summary**

Please review your choice and click 'Finish' to create the template:

Template Name: Antenna - Planar_8

Solver
Time Domain

Units
- Dimensions: mm
- Frequency: MHz
- Time: ns
- Temperature: Kelvin

Settings
- Frequency Min.: 919 MHz
- Frequency Max.: 923 MHz
- Monitors: E-field, H-field, Farfield, Power flow, Power loss
- Define at: 919;921;923 MHz

Antennas which consist of flat radiating elements, e.g. printed microstrip, PIFA, slot, spiral or monopole geometries.

Figure 3.12 Creating the Project Template

STEP 8: Select Modelling on the Toolbar to design the propose microstrip patch antenna

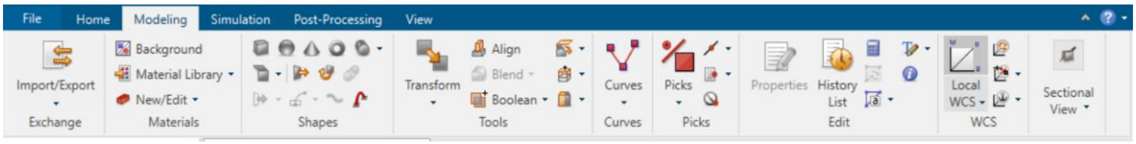
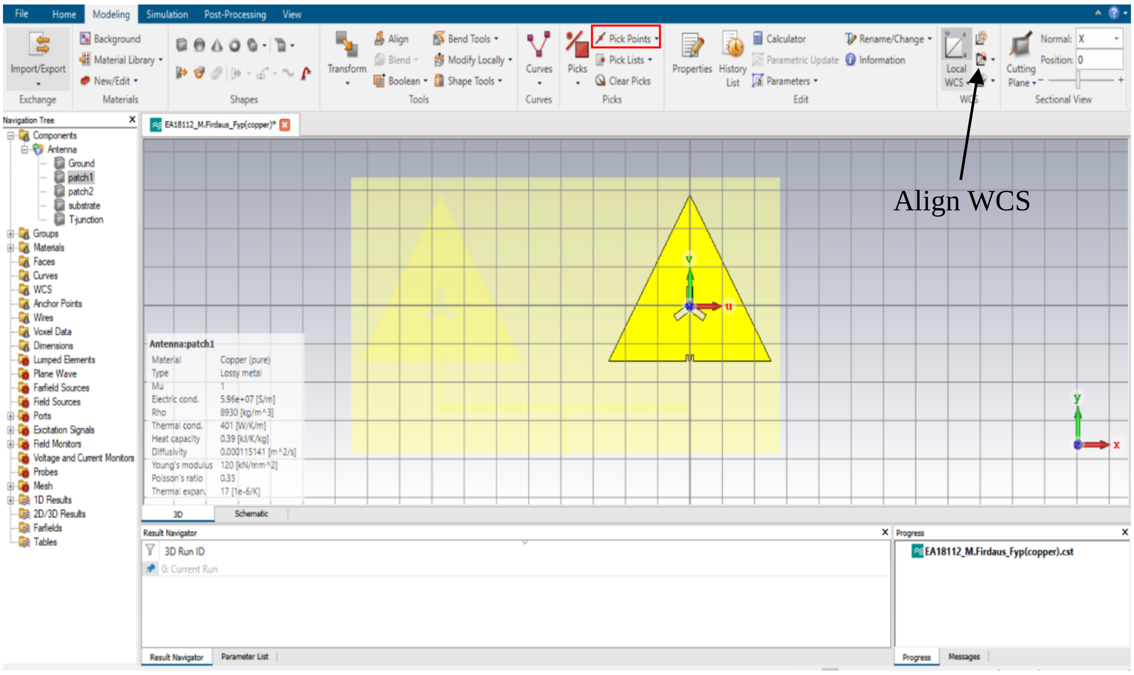


Figure 3.13 CST Toolbar to Start Designing Microstrip Antenna

STEP 9: Click at navigation tree > Select Antenna > Select Patch > Pick point >Select Pick Face Centre > Align WCS

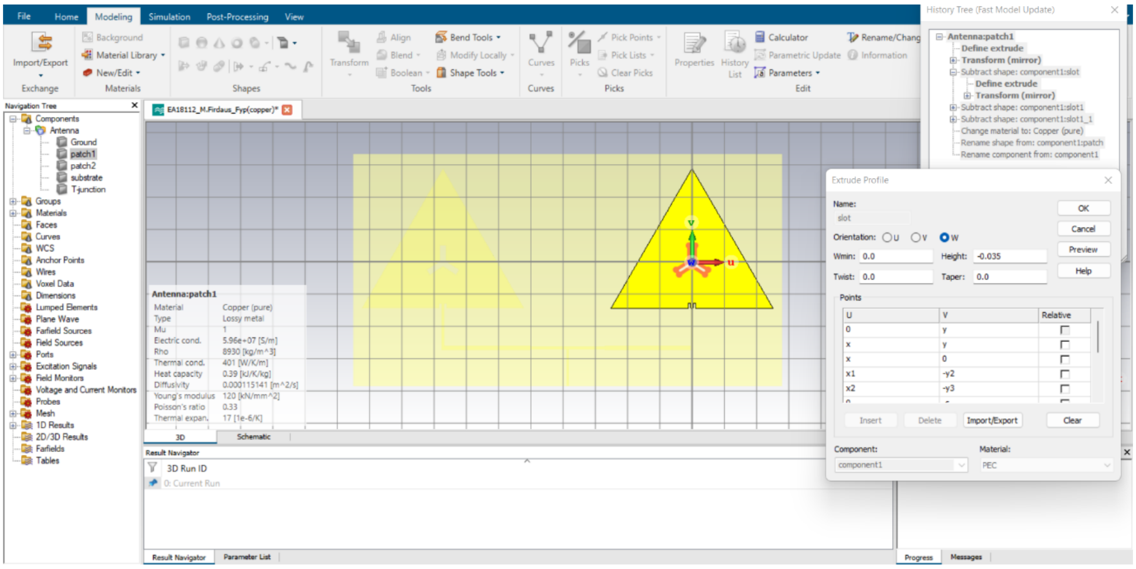


Antenna:patch1

Material	Copper (pure)
Type	Lossy metal
Mu	1
Electric cond.	5.96e+07 [S/m]
Rho	8930 [kg/m^3]
Thermal cond.	401 [W/K/m]
Heat capacity	0.39 [kJ/K/kg]
Diffusivity	0.000115141 [m^2/s]
Young's modulus	120 [kN/mm^2]
Poisson's ratio	0.33
Thermal expan.	17 [1e-6/K]

Figure 3.14 Find Centre of patch

STEP 10: Click Patch > Select Define brick > Enter point value



Extrude Profile

Name: slot

Orientation: ○ U ○ V ● W

Wmin: 0.0 Height: -0.035

Twist: 0.0 Taper: 0.0

Points

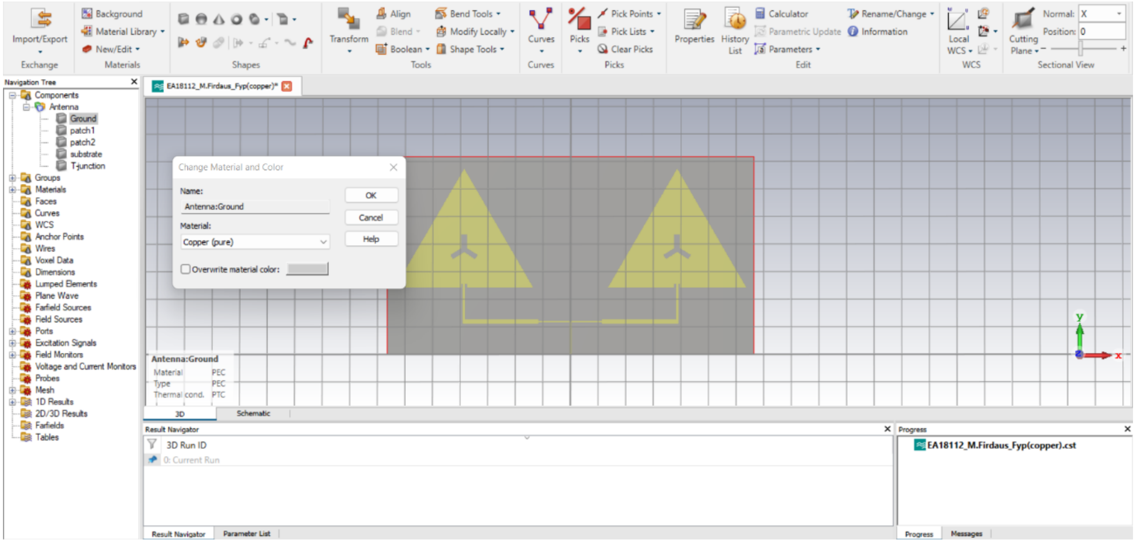
U	V	Relative
0	y	☐
x	y	☐
x	0	☐
x1	-y2	☐
x2	-y3	☐

Component: component1

Material: PEC

Figure 3.15 Create the Slot

Step 11: Click Component at navigation tree > Select Antenna > Right click at Ground > Click Change material > Select Copper > Click Ok



Change Material and Color

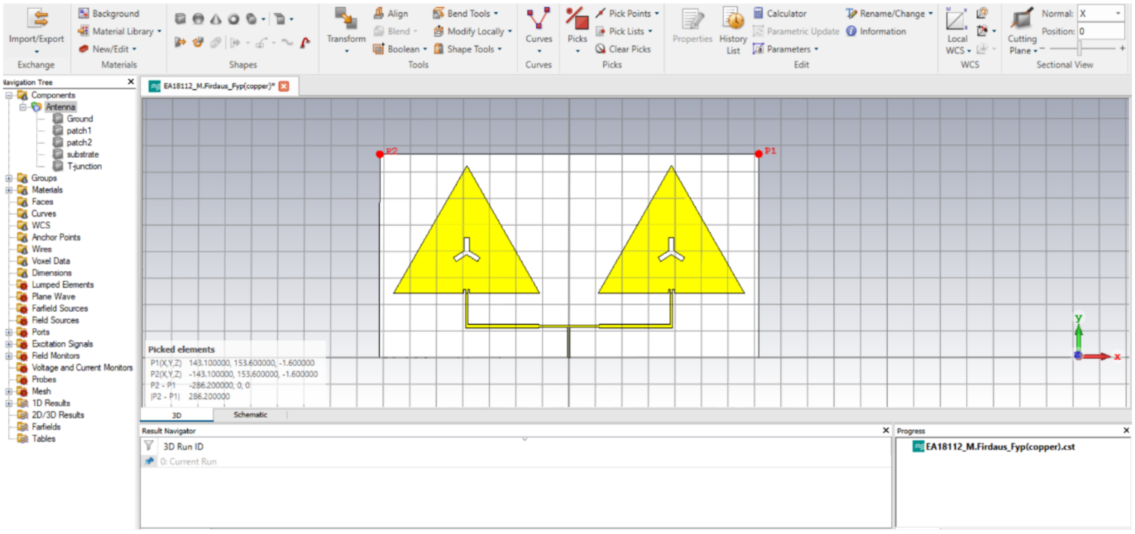
Name: Antenna:Ground

Material: Copper (pure)

☐ Overwrite material color:

Figure 3.16 Selecting the Material

Note: This step to determine the actual size of antenna after modelling.



```
Picked elements
P1(X,Y,Z)   143.100000, 153.600000, -1.600000
P2(X,Y,Z)   -143.100000, 153.600000, -1.600000
P2 - P1     -286.200000, 0, 0
|P2 - P1|   286.200000
```

Figure 3.17 Determine the Dimension of The Antenna

3.5 Fabrication Process

3.5.1 Brush Cleaning Machine 305 mm Model RBM300

Figure 3.17 shows a brush cleaning machine that is suited for use in small companies and labs. The main objective of this machine is to clean PCB boards and other metal surfaces to verify that the material's surface is free of dust and debris before proceeding to the next step. This machine can also remove the oxide layer from the PCB board. Aside from that, this machine is controlled by a conveyor. The conveyor speed has been set to 0.2 m/min, and the PCB board must be placed on the conveyor to begin the cleaning process and wait for it to finish.

Figure 3.18 Brush Cleaning Machine

3.5.2 PCB Board Drying Machine

Figure 3.18 shows the PCB board panel drier machine that was used to dry the PCB board after it had been cleaned. This unit's chassis is composed of high-quality stainless steel and has characteristics that allow it to extract and eliminate water from the PCB board after cleaning, preventing any problems during the creation process. This machine can handle panels with a maximum width of 610 mm (24 inches) and a thickness of 6 mm. The PCB board must be placed on the conveyor to begin the drying process, and the procedure must be repeated until the PCB board is completely dry.

Figure 3.19 PCB Board Panel Dryer Machine

3.5.3 Dry Film Photoresist Sheet Laminator

Figure 3.19 shows a dry film photoresist sheet laminator that is ideal for small laboratories. This equipment has a tiny control panel where the user may choose the appropriate temperature and roller speed for applying dry film on the PCB board. In the lamination process, choosing the right temperature and roller speed is crucial to avoid burning the dry film. To avoid any problems during the etching process, make sure the dry film and PCB board adhere together without any bubbles after the lamination process.

Figure 3.20 Dry Film Photoresist Sheet Laminator

3.5.4 UV Double Sided Exposure Units with Vacuum

The UV double sided exposure devices shown in figure 3.20 are ideal for double sided PCB panels. A tiny control panel and digital display were also included in this device, allowing the operator to select the process time. The UV exposure units have been set at 30 seconds for this operation, which involves employing UV beam to transfer the antenna configuration from PCB film to PCB board. Furthermore, this procedure must be carried out in a dark environment to prevent damage to the dry film prior to the etching process.

Figure 3.21 UV Double Sided Exposure Units with Vacuum

3.5.5 Rota Spray Developer Machine

In the developer process, the Rota spray developer machine, as illustrated in figure 3.21, was employed. To eliminate the undesired dry film that coated the etching region on the PCB board, the developer technique must be used. Using a hand glove and a face mask when handling this procedure is important for safety precautions before and after the operation is completed to avoid any accidents. The following steps will show you how to utilise a developer machine correctly:

1. ON main power switch.
2. Press the main button.
3. Press the heat button.
4. Wait until the temperature level reach 40°C - 43°C.
5. Ensure the PC board is clean and clear from any plastic, then insert the PCB board
6. Set the conveyor speed at 2 for the first process.
7. Set the conveyor speed at 4 for the second process.
8. Check and ensure the dry film have been removed.

Figure 3.22 Developer Machine

3.5.6 Acid Remover Machine / Etching Machine

The acid remover machine, also known as an etching machine, as illustrated in figure 3.22, was used in the etching process to remove undesirable copper from the PCB board that was not covered by a dry film, resulting in the formation of an angled slot. This machine had acid in it, which readily removed the copper layer on the PCB board. To limit the risk of an accident during the procedure, personal protection equipment (PPE) such as hand gloves and face masks should be used. The following steps will show you how to utilise a developer machine correctly:

1. ON main power switch.
2. Press the main button.
3. Press the heat button.
4. Wait until the temperature level is reach 40°C - 43°C.
5. Make sure the PCB board is clean and clean from any plastic material, then insert the PCB board into the machine.
6. Set the conveyor speed at 2 for the first process.
7. Set the conveyor speed at 4 for the second process.
8. Repeat the step until the unwanted copper fully removed.
9. Clean the PCB board after the etching process in 2 minutes.

Figure 3.23 Acid Remover Machine

3.6 Antenna Testing

3.6.1 The Vector Network Analyzer

The network analyser, as illustrated in figure 3.23, will be utilised to assess the performance of the microstrip patch antenna after the fabrication process is completed. The microstrip patch antenna must be modified using CST Microwave Studio 2019 if the intended results are not attained. This phase is critical for identifying any inconsistencies between the simulated structure, manufacturing defects, and the impact of the lead used to link the PCB layer to the feed joint. The antenna must then be redesigned until it meets all of the requirements for the intended antenna.

Figure 3.24 Microstrip Patch Antenna Tested Using Network Analyzer

3.6.2 UHF RFID Reader Antenna Length Detection Performance Field Test for Difference Tag Types

The microstrip patch antenna was created to detect a passive tag of different lengths. Then, to determine the maximum recognition length between the antenna reader and the RFID tags, this test must be performed. RFID tags are a type of tag that may be used to an illustrated in figure 3.24, the antenna reader and passive RFID tag were placed at the same height, and the maximum recognition length was tested and reported. Then repeat the procedure until all scope designs for various RFID tags have been recorded.

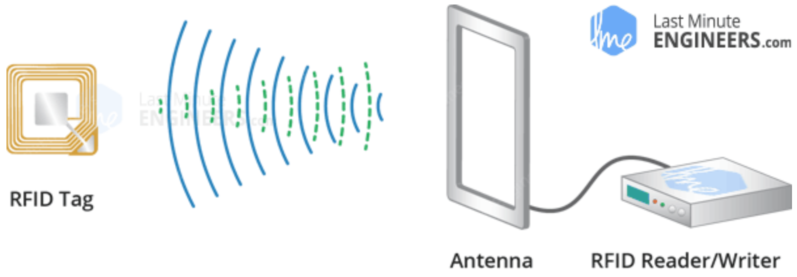


Figure 3.25 The Antenna and Tag at the same Position

The antenna reader illustrated in figure 3.25 was used to conduct the antenna testing and is appropriate for ultra-high frequency (UHF) coordinates. The RFID reader is a device that tracks RFID tag data through radio waves. When compared to barcode scanners, the RFID technology is more sophisticated. The RFID tag does not require a visible passage to the reader or the detection of a specific portion. To be detected, the tag must be inside the radio wave range.

Figure 3.26 RFID Reader

Table 3.2 Reader Specification

Categories	**Specification**
Frequency Range	UHF 860MHz – (960MHz)
Interface	RS -232
Sensitivity	-84 dBm
Total Antenna Port	4 Female Ports
Operating Condition	-20°C to +50°C

3.6.3 UHF RFID Reader Antenna Angle Detection Performance Field Test for Difference Tag Types

To evaluate the antenna performance when the location of the tag varies in various angles, the antenna angle detection test must be performed. The angles to be evaluated in this test are 30°, 45 , 60°, 90°,, with the tag placed on the field. We employed five tags in this experiment, which showed the largest distance in length detecting test we've ever done. Figure 3.24 shows how the antenna angle test is carried out.

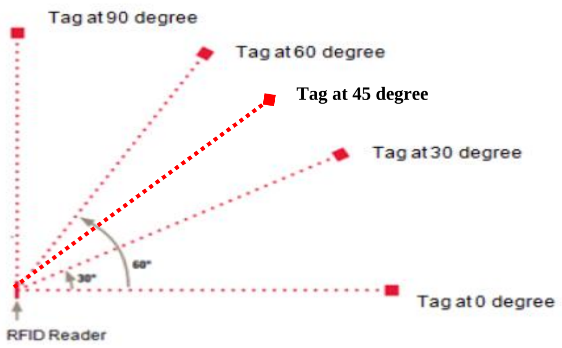


Figure 3.27 The Position of Antenna and Tag

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will focus on the performance of the proposed antenna, with the goal of comparing simulated and observed losses and s-parameters (S11). The manufacturing antenna will be tested to see if it meets the proposed operating frequency of 921 MHz and has an s-parameter (S11) of less than - 10dB, which matches the modelling result. This chapter also includes a simulation of the proposed antenna's voltage standing wave ration (VSWR) and gain. To ensure that the antenna can work, the VSWR simulation result must be less than 2. In terms of detecting range, the gain of the microstrip patch antenna is critical. It also plays an essential part in the parametric research to determine the antenna's performance in various parameters. The prototype antenna's performance in terms of near-field tag detection range at various distances and angles of RFID tags. The entire result is incredibly useful in determining the ideal antenna position for optimising detection range and execution.

The design of patch antenna discussed the development and analysis of the antenna reader work carried out on the basic triangular patch antenna to produce linear polarization antenna.

4.2 The Geometry of Purpose Triangular Array Antenna

The angular slot antenna's geometry is shown in figures 4.1 and 4.2. The antenna's angled slot is made from a single patch on top, and the ground patch is fully coated with copper in the rear. The whole design size specification of an antenna to function at the requisite resonance frequency of 921 MHz is presented in Table 4.1. Based on the operating frequency, each antenna parameter plays a significant role in generating a good efficient radiation pattern with acceptable gain and directivity. The antenna was designed using the equipment that was available at CST 2019. After that, the antenna will be examined with a Vector Network Analyzer (VNA) to determine its performance.

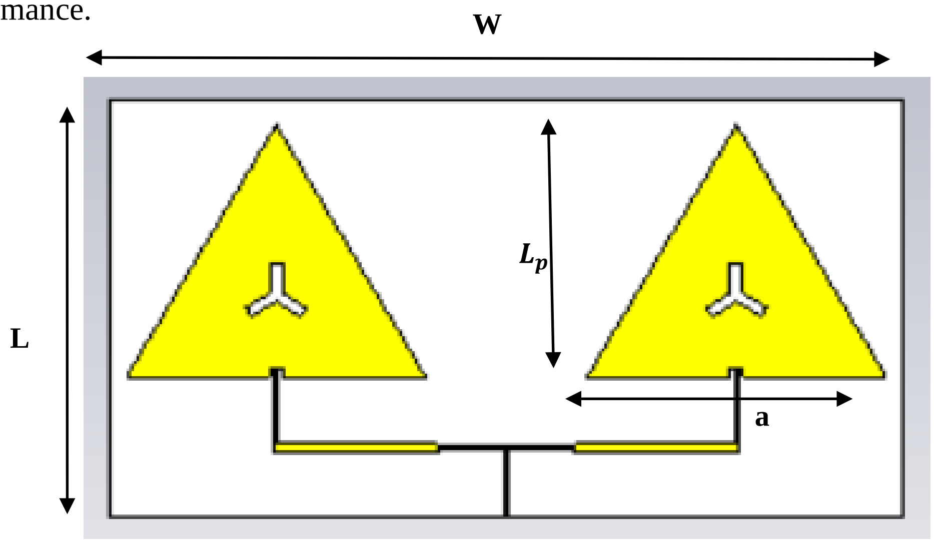


Figure 4.1 Front View of Antenna

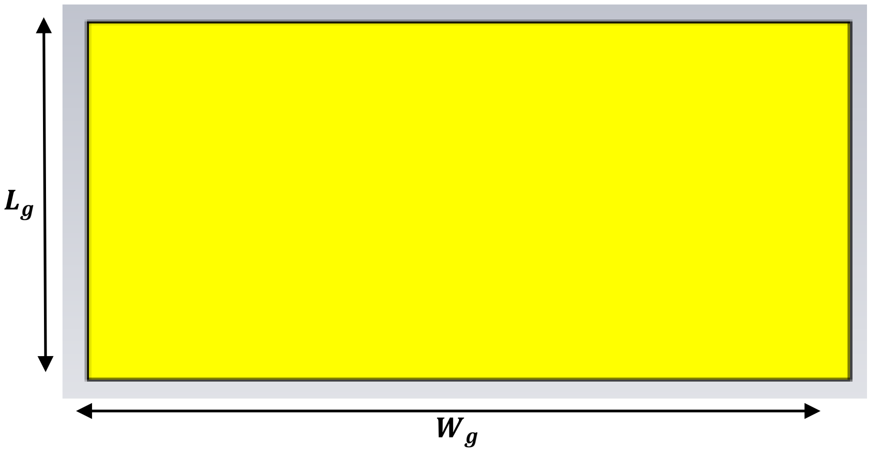


Figure 4.2 Back View of Antenna

Table 4.1 Specification of Antenna Design

Parameter	**Symbol**	**Segement**	**Dimension**
Patch	a	Length Patch	100.5 mm
	L_p	Height Patch	86.5 mm
Substrate	W	Width	266.2 mm
	L	Length	143.6 mm
	h	Thickness	1.6 mm
Ground	W_g	Width Ground	266.2 mm
	L_g	Length Ground	143.6 mm
Slot	W_s	Width Slot	2.0 mm
	L_s	Length Slot	10.0 mm

4.3 Simulation Result

4.3.1 Simulation Result of Return Loss

Result of return loss (S11) is very important to know the power level of the antenna is reflected. It also known as the reflection coefficient. The antenna can operate when the value of return loss is lower than -10 dB at certain frequency. Other than that, the antenna might operate when the value of return loss is higher than -10 dB. From return loss (S11) simulation result, the total radiated power to the antenna can be determined. The Figure 4.3 shows the antenna operate at frequency 921 MHz and -24.44 dB. So, the higher return loss than -10dB is consider good result.

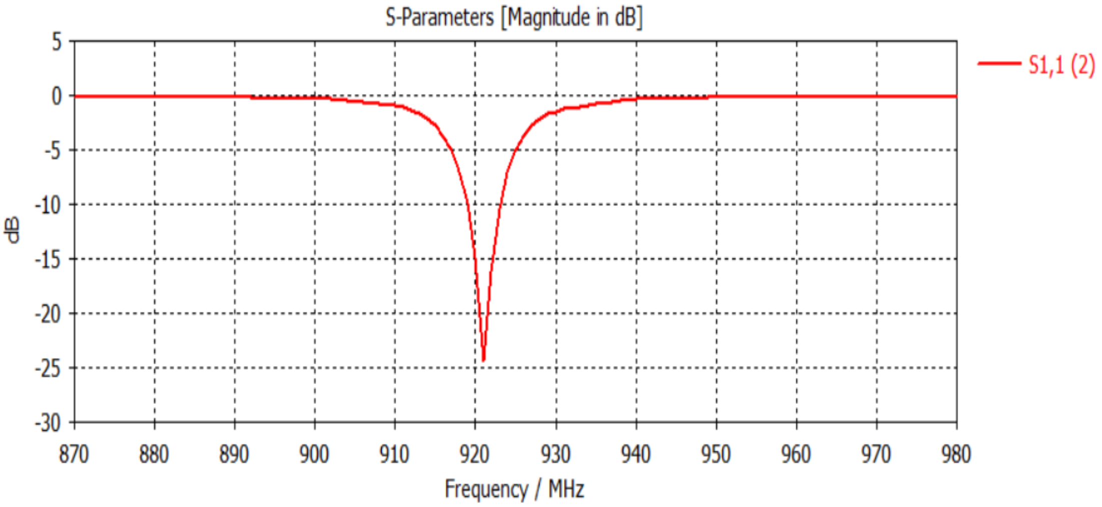


Figure 4.3 Simulation Result of Return Loss (S11)

4.3.2 Simulation Result of Voltage Standing Wave Ratio (VSWR)

The result of voltage standing wave ratio (VSWR) is related between transmission line and patch antenna. The requirement VSWR value for microstrip patch antenna is less than 2. Other than that, the value of VSWR is indicate how much the power of antenna in term of reflection coefficient. It also indicates the power level can be delivered to the antenna. Generally, the value of VSWR must less than 2 to produce the antenna that have a good performance. The figure below shows the simulation result using CST MWS for antenna design in this project. It shows the value of VSWR is less than 2 at the frequency 921 MHz and it considers good result.

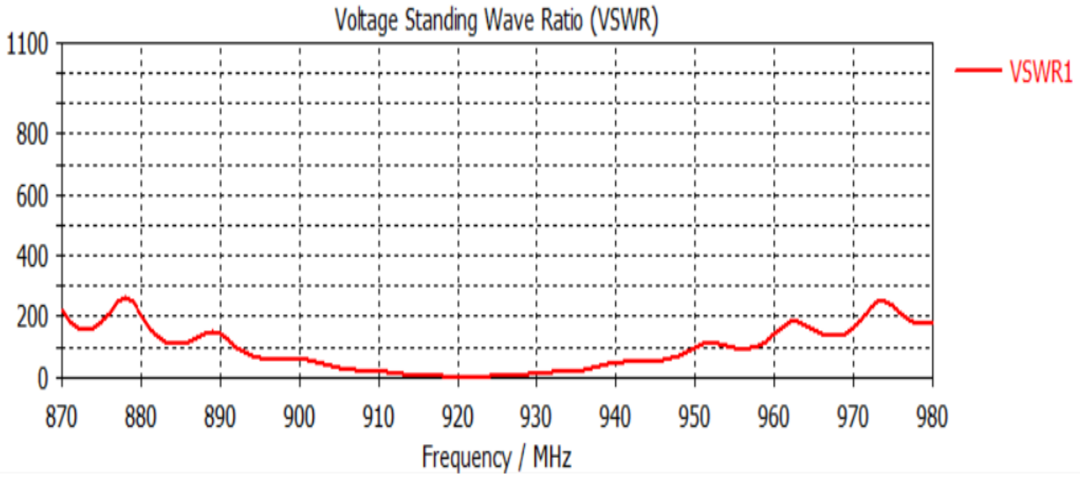
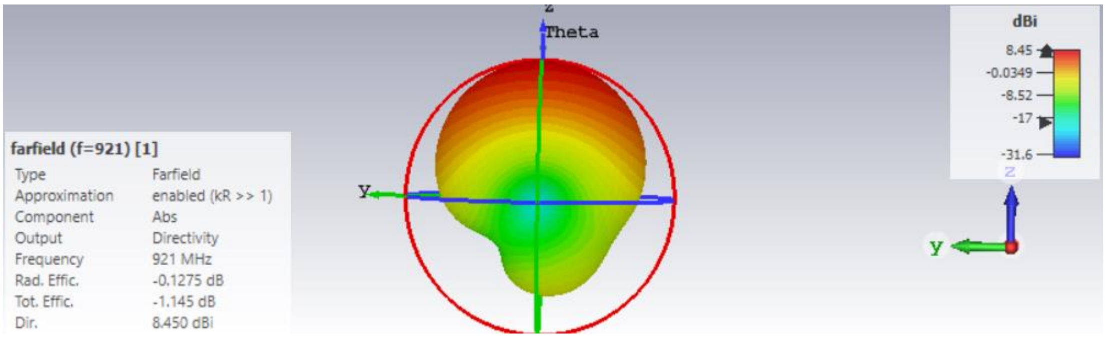


Figure 4.4 Simulation Result of VSWR

4.3.3 Simulation Result of Radiation Pattern

Simulation result of radiation pattern can determine the information about radiated energy. Generally, radiation pattern results of antenna in 360 degrees in polar form. The red area of the radiation pattern is indicating the good detection area for long detection range. The antenna can be detected in all direction based on the positive value of gain. In figure 4.5 below shows 3D radiation pattern, where the patch antenna design with 8.45 dBi at 921 MHz is demonstrated. The antenna radiation energy also can be determined by E-plane and H-plane as shown in figure 4.6 and 4.7. The H-plane and E-plane is illustrated the quantity of electric and magnetic field vector produces by the antenna.



farfield (f=921) [1]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Directivity
Frequency	921 MHz
Rad. Effic.	-0.1275 dB
Tot. Effic.	-1.145 dB
Dir.	8.450 dBi

Figure 4.5 Simulation Result of Radiation Pattern

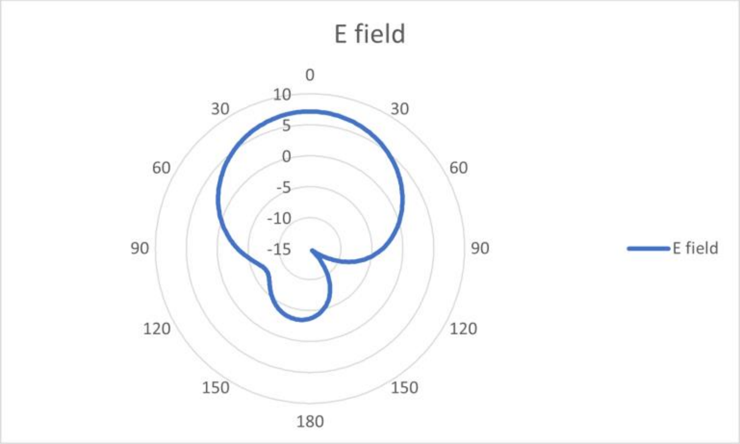


Figure 4.6 Simulation Result of E-Field

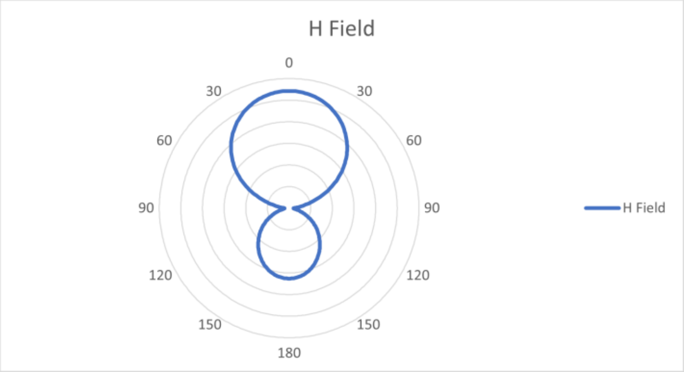
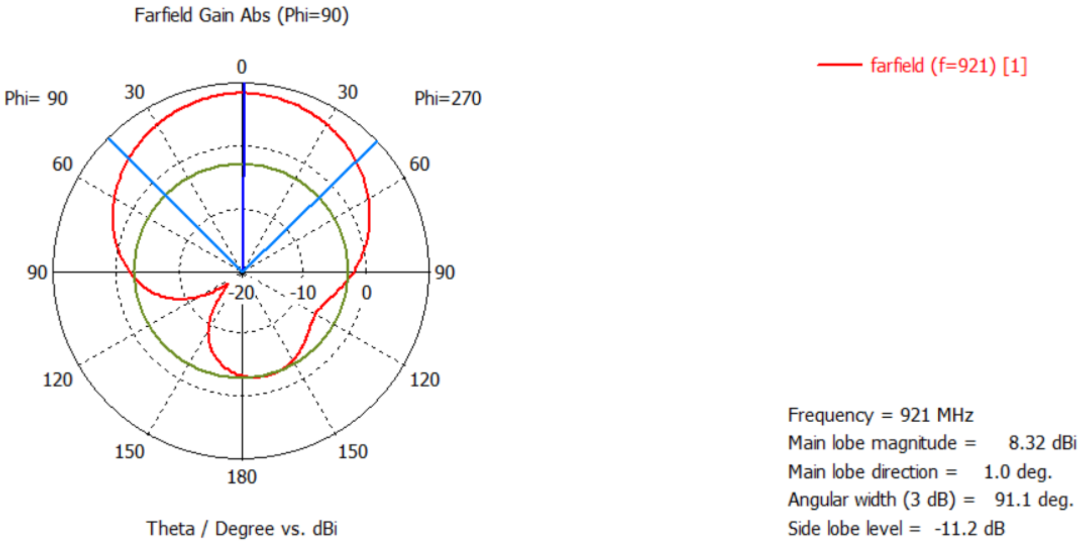


Figure 4.7 Simulation Result of H-Field

4.3.4 Simulation Result of Gain

This simulation result is also important for describing the performance of antenna whether its working or vice versa. From the simulation result, the antenna gains capable to transmit power in specific direction when connected to the power source. Antenna could be powerful if the gain value is high, and the assumed power can be transmitted into space at a certain angle or direction. The red line is represented of main lobe as shown in figure below.



Frequency = 921 MHz
Main lobe magnitude = 8.32 dBi
Main lobe direction = 1.0 deg.
Angular width (3 dB) = 91.1 deg.
Side lobe level = -11.2 dB

Figure 4.8 Simulation Result of Gain

4.4 Result of Antenna Testing

The manufacturing antenna will be evaluated in this subchapter to determine its performance and efficiency. Antenna testing using a vector network analyser, Antenna Length Detection Performance Field Test, and Antenna Angle Detection Performance Field Test are some of the tests that will be carried out. The results will then be examined to determine the performance of the suggested antenna design.

4.4.1 Antenna Testing Using Vector Network Analyzer

The Agilent E5071C vector network analyser, which is available at the ICOE lab in UMP, will be used to determine the performance of the actual antenna. This instrument is appropriate for this test since it can handle any antenna that works between 9 kHz and 8.5 GHz. The major purpose of this study is to compare the performance of simulation and real-world antennas in terms of return loss (S11). The vector network analyser must be calibrated before commencing this examination to guarantee that the results from this instrument are accurate and that no data is lost. The vector network analyser was calibrated using the calibration apparatus and techniques shown in Figures 4.9 and 4.10. The calibration technique must be performed exactly as shown in figure 4.11 to guarantee that the vector network analyser performs well during antenna testing. After the calibration procedure is done, the vector network analyser is ready to use.

Figure 4.9 Calibration kit

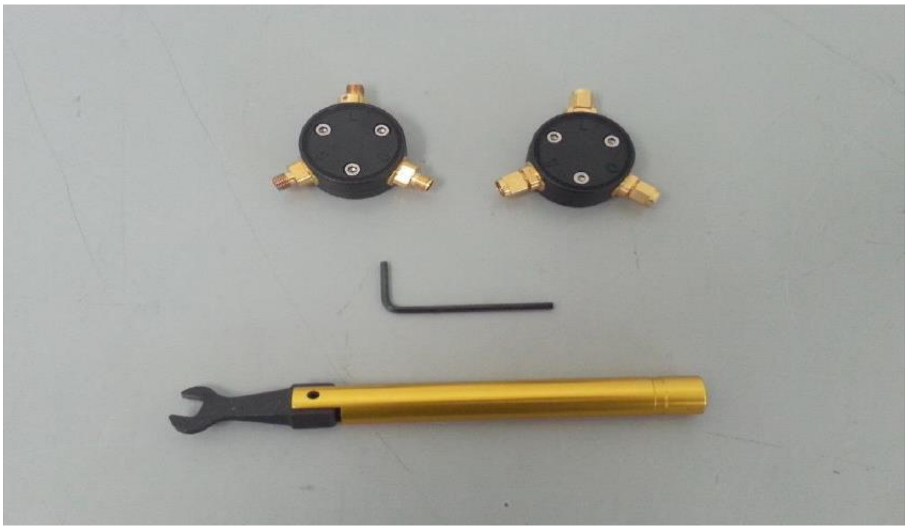


Figure 4.10 Calibration tool

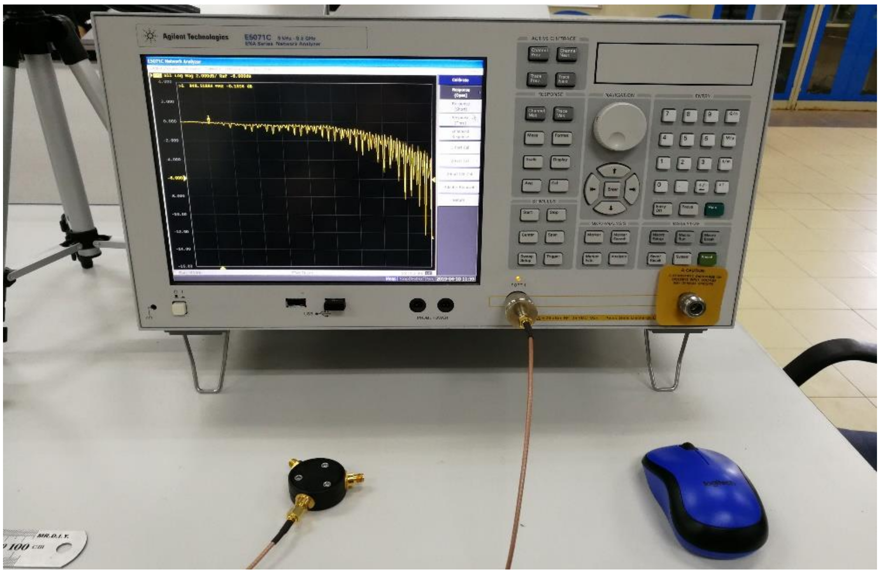


Figure 4.11Vector Analyzer Calibration Process

Figure 4.12 shows the contrast between simulation antenna result (CST) and actual antenna result (VNA) in terms of return loss (S11) value after completing antenna testing using a vector network analyzer. At a resonance frequency of 921 MHz, the real antenna result is -20.18 dB, which is higher than the simulated antenna result of -24.44 dB.

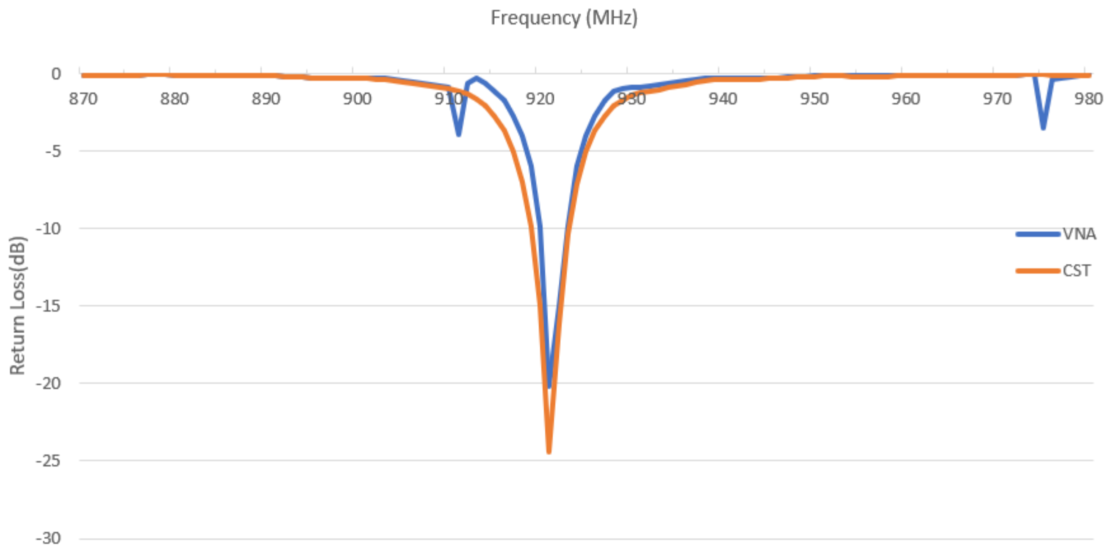


Figure 4.12 Comparison Result Between Simulation and Actual Antenna

4.4.2 Field Test of Length Detection Performance for Difference Tags Type

In general, there are many different types of RFID tags accessible in the business. It also has various properties in terms of memory capacity, frequency, detection duration, and tag size. As illustrated in the diagram below, this investigation will employ eight distinct RFID tags: AD-641, AD-381, AD-232, A-9654, H-47, AD-223, AD-828, and AD-833. The goal of this investigation is to figure out how far a tag can be tracked by an antenna before losing signal strength. The tag may be tracked and detected by radio wave using the RFID technology. Figure 4.20 depicts the proper settings for running this test.

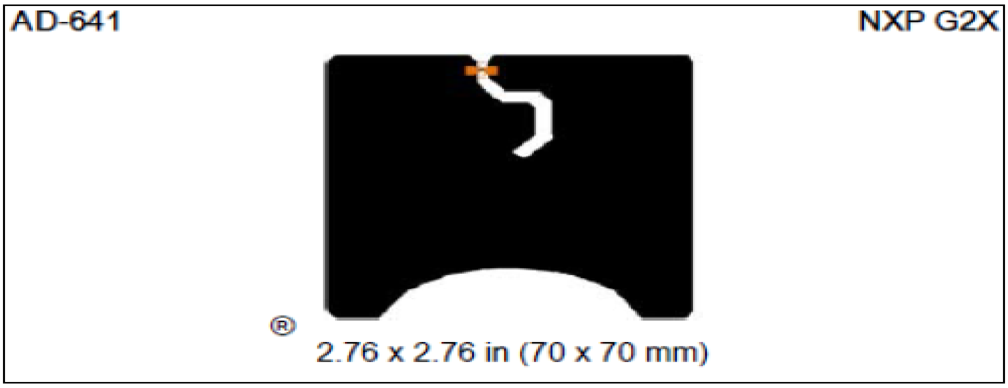


Figure 4.13 AD-641 UHF RFID Tag

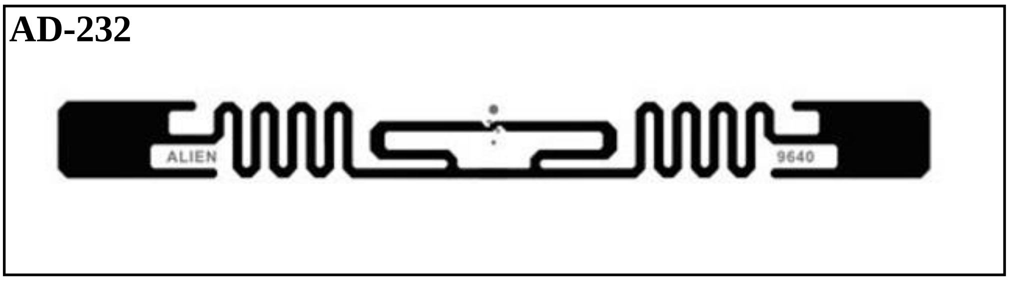


Figure 4.14 AD-232 UHF RFID Tag

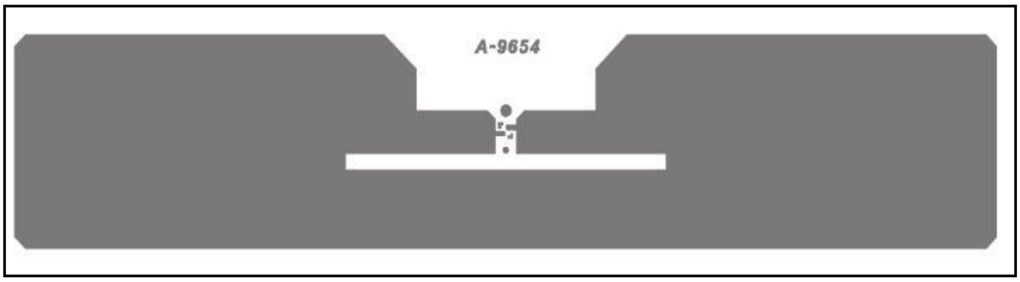


Figure 4.15 A-9654 UHF RFID Tag

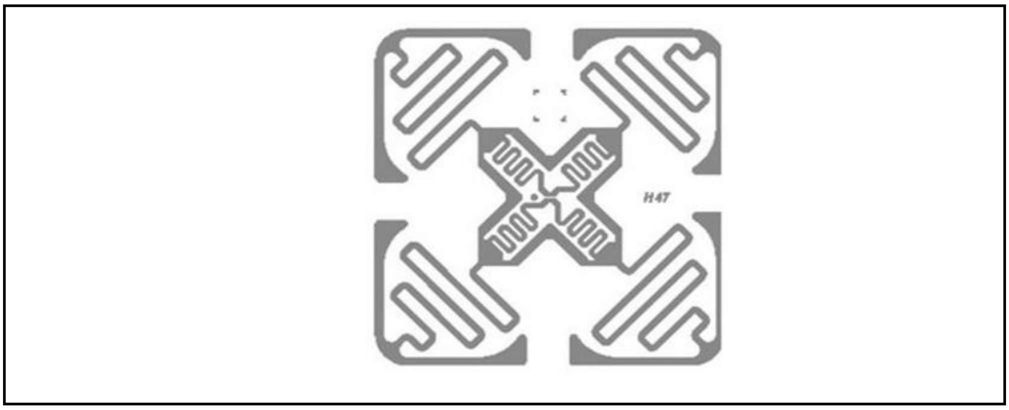


Figure 4.16 H-47 UHF RFID Tag

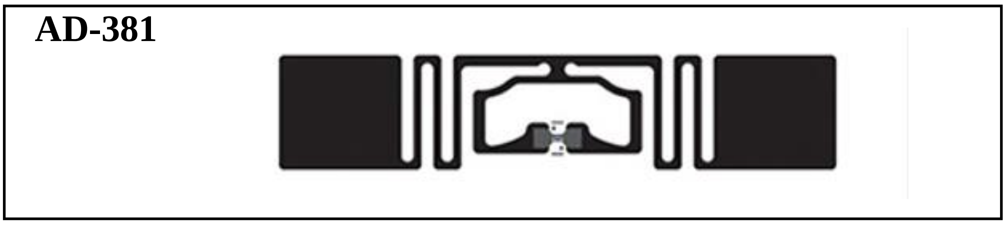


Figure 4.17 AD-381 UHF RFID Tag

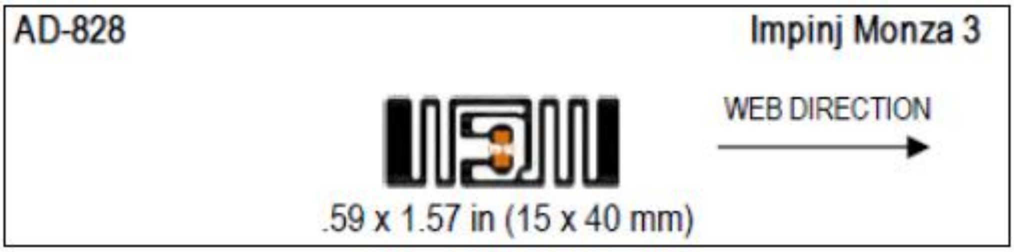


Figure 4.18 AD-828 UHF RFID Tag

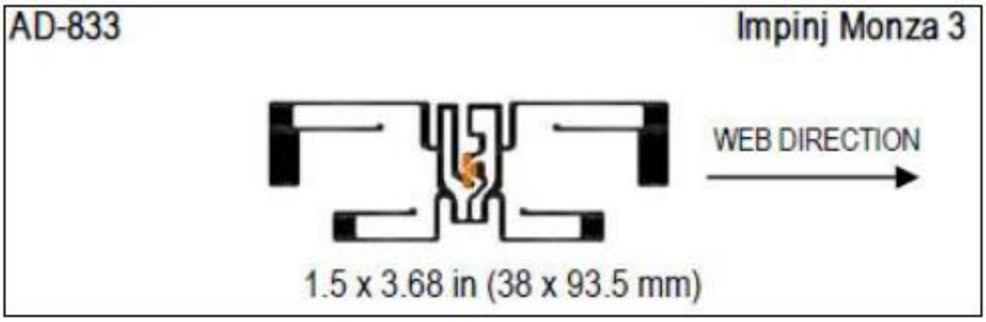


Figure 4.19 AD-833 UHF RFID Tag

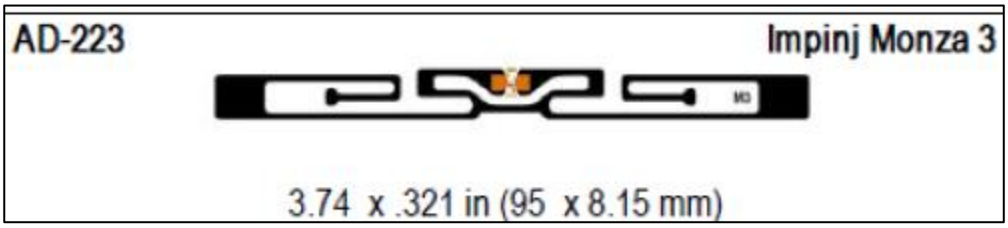


Figure 4.20 AD-223 UHF RFID Tag

Figure 4.22 depicts the results of this investigation for all eight distinct tags. AD-833 provides the greatest length of detection when compared to other tags, with a size of 38 mm x 93.5 mm, and AD-828 creates the shortest length of detection when compared to other tags with a size of 15 mm x 40 mm. The length detection area for the AD-833 tag was 95 cm, followed by 65 cm for the AD-641 tag and 60 cm for the H-47 tag. Then, AD-232 and A-9654 reported has length detection area of 20 cm and 28 cm. Finally, the AD-223 tag provides the smallest length detection area after AD-828 that is 15 cm. The length detection performance of the antenna to track and capture the data from the tags is also affected by the design, size, and shape of the tag, according to this investigation.

Figure 4.21 Length Detection Performance Test Configuration

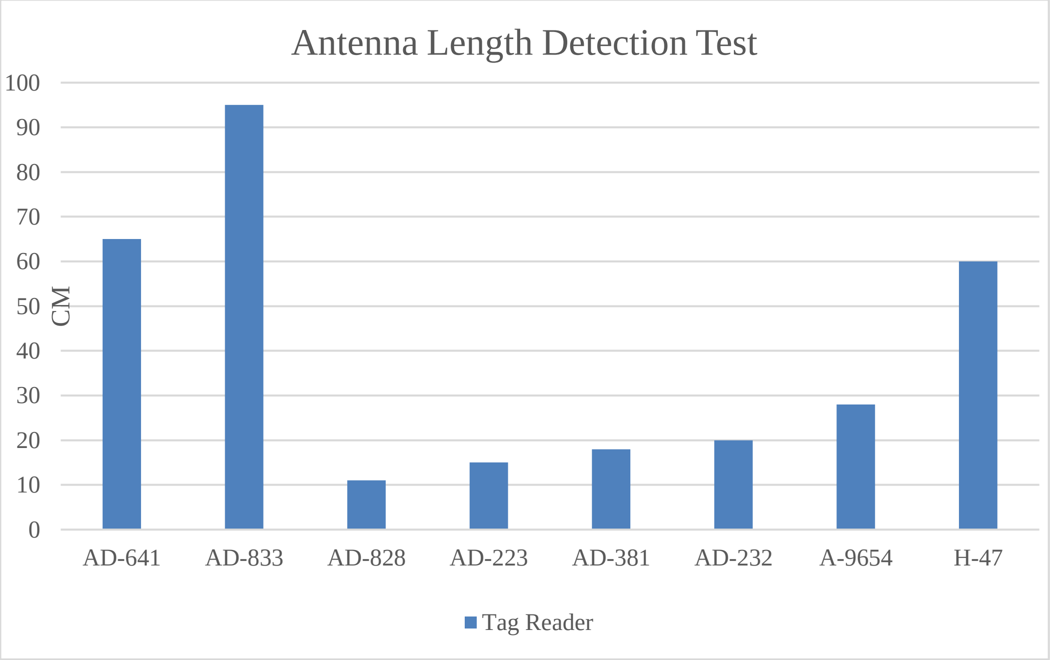


Figure 4.22 Result of Length Detection Performance Test Configuration

4.4.3 UHF RFID Reader Antenna Angle Detection Performance Field Test for Different Tag Types

The antenna angle detection performance field test was carried out to see how the maximum length detection area changed as the antenna reader's angle changed. This investigation also looks into the best antenna angle for capturing data from tags. Figure 4.23 depicts the proper settings for running this test. Then, to carry out this study, five angles were chosen: 30°, 45°, 60°, 75°, and 90°. This investigation also employed tags that produced the longest detection area, hence the AD-833 was chosen.

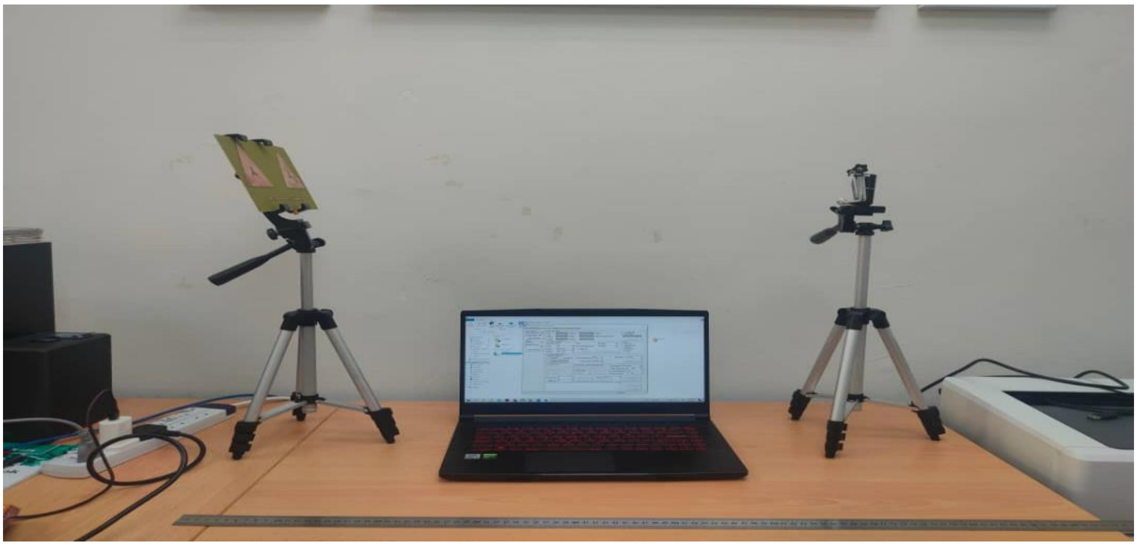


Figure 4.23 Angle Detection Performance Test Configuration

The outcome of this examination is shown in Figure 4.23. With a detection length of 49.3 cm and 30 angles presented, the antenna can gather data from the tag. The antenna was then rotated at a 45-degree angle, with the result that the antenna successfully acquired data from the tag to a detection length of 66.8 cm before losing the signal. When the antenna's angle is set to 60 degrees, the detection length gradually rises from 70.7 to 75.3 cm, allowing the antenna to detect and capture data from the tag. Finally, the antenna angles were changed to 75 and 90 degrees, respectively, resulting in detection lengths of 82 and 95cm. The conclusion can be made after this examination, the design, size and shape of the tag also affect the length detection performance of antenna to track and captured the data from the tags.

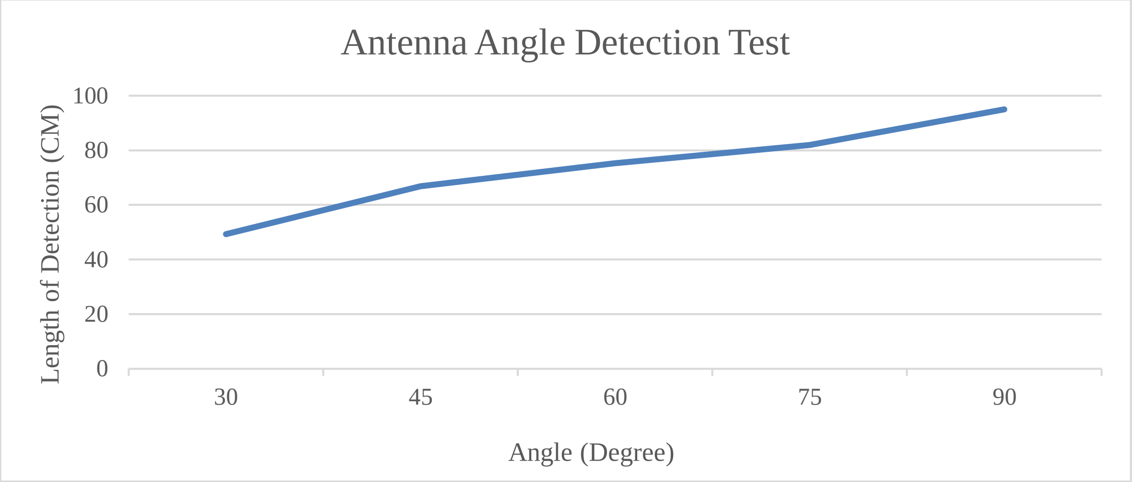


Figure 4.24 Result of Angle Detection Test

4.5 Parametric Study

The effect of modifications in the patch antenna geometric parameter on antenna performance will be investigated in this subchapter. The parametric research looked at the effect of changing the the thickness of substrate, symmetrical slot length, symmetrical slot width, symmetrical height of triangular patch, symmetrical slit height, side equal length equilateral triangular patch and comparison between triangular array antenna and triangular patch antenna. on antenna performance when the operating frequency and return loss were changed (S11). The CST Microwave 2019 programme was used to adjust the parameters of the investigation. Figure 4.25 depicts the antenna parameter structure that will be studied in this subchapter.

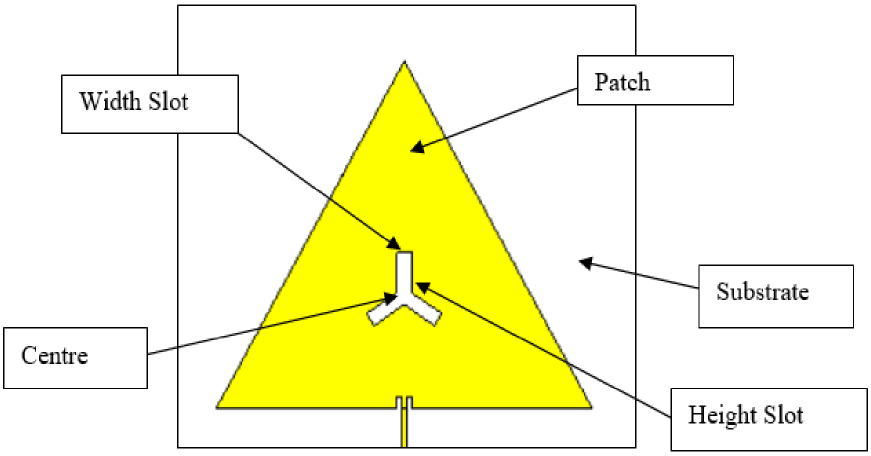


Figure 4.25 Antenna Parameter

4.5.1 Substrate thickness

This examination is the determine effect of antenna performance in term of return loss (S11) and resonant frequency due to changing of substrate thickness. Many PCB that available in market has different thickness of substrate. The 1.6 mm has been used for original design before modification. All parameter such as patch diameter, size of slot and slot diameter is fixed. The thickness of substrate has been used in this examination which is 0.4 mm, 0.8 mm and 1.5 mm. The simulation results as shown in figure 4.26 after changing the thickness of substrate to 0.4 mm, 0.8 mm and 1.5 mm that represent in green line, blue line and orange line generated by CST. By adjusting thickness of substrate to 0.4 mm, the antenna produces 904.74 MHz of working frequency and -9.26 of return loss. In this condition, the antenna cannot function properly because all of microstrip patch antenna start working when the value of return loss is below -10 dB. Then, by increasing the thickness of substrate from 0.4 mm to 1.5 mm, the working frequency is rises up from 904.74 MHz to 916 MHz and it also improved the value of return loss from -9.26 to -20.78 dB. Lastly, the working frequency increasing from 916 MHz to 917.3. MHz when 0.8 mm of substrate thickness was applied. It also improved the return loss from -20.78 dB to -25.78 dB. Based on this examination, by increasing the thickness of substrate will improve the working frequency and return loss (S11) and 1.6 mm of substrate thickness is most suitable for proposed antenna design.

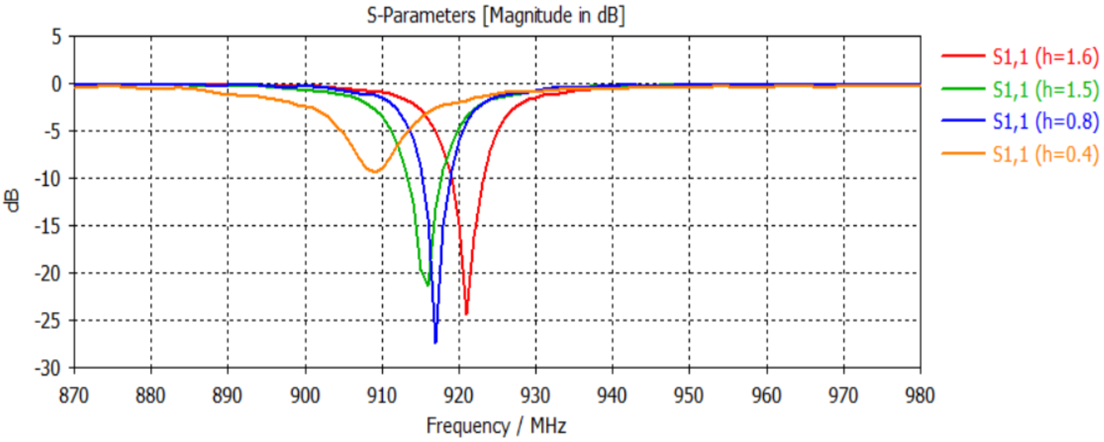


Figure 4.26 Return Loss and Resonant Frequency Effect Due to Changes of Substrate Thickness

4.5.2 Symmetrical Slot Length

This examination was executed to determine the effect of antenna performance due to changing of slot length. By maintaining the other antenna parameter and changing slot length value, the effect of antenna performance can be determined from the changing on working frequency and return loss. Figure 4.27 shows the effect on the proposed microstrip patch antenna due to slot length changes. By decreasing the length of slot to 9.6 mm, the resonant frequency up from 921 MHz to 922 MHz and the value of return loss also improved from -24.08 dB to -23.08 dB respectively. Then, the length of slot changes to 9.4 mm, the resonant frequency up from 920 MHz to 923 MHz and increase the return loss value from -24.08 dB to -22.91 dB. This examination also decreasing the slot length to 9.8 and the result is shows by orange line that it same with the length 10.0 mm. The conclusion can be made is, if the length of slot increase, the value of frequency will be decreasing and the value of S11 will be improved.

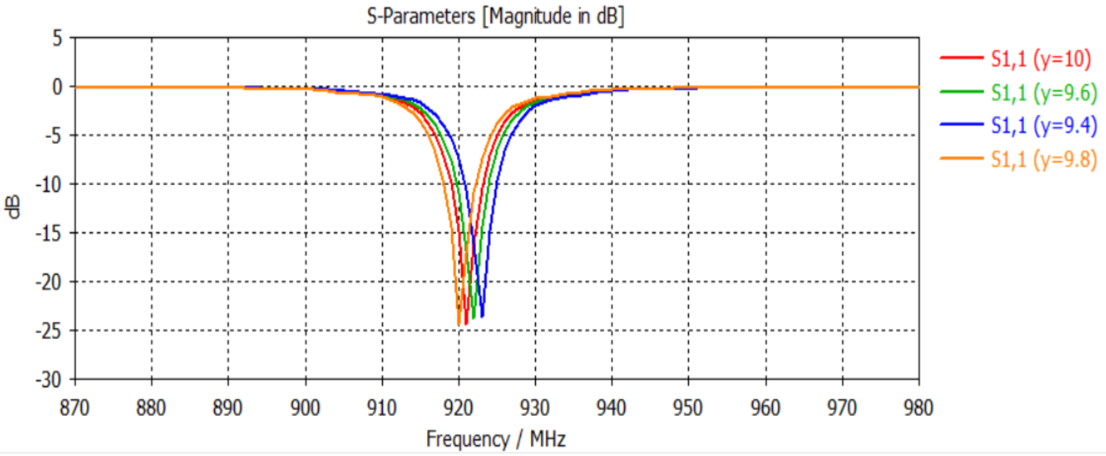


Figure 4.27 Return Loss and Resonant Frequency Effect Due to change of Length of Slot

4.5.3 Symmetrical Slot Width

This examination was executed to determine the effect of antenna performance due to changing of slot width. By maintaining the other antenna parameter and changing slot width value, the effect of antenna performance can be determined from the changing on working frequency and return loss. Figure 4.28 shows the effect on the proposed microstrip patch antenna due to slot width changes. By decreasing the width of slot from 2.0 to 1.8 mm, the resonant frequency rises from 921 MHz to 922 MHz and the value of return loss also improved from -24.44 dB to -24.84 dB respectively. Then, by increasing the width of slot to 2.2 mm, the resonant frequency drops from 921 MHz to 920 MHz and drop the return loss value from -24.44 dB to -21.31 dB. This examination also decreasing the width of slot to 1.6mm and the result is shows by blue line. The conclusion can be made is, if the width of slot antenna increases, the value of frequency will be decreasing and the value of S11 will be improved depend on size of width used.

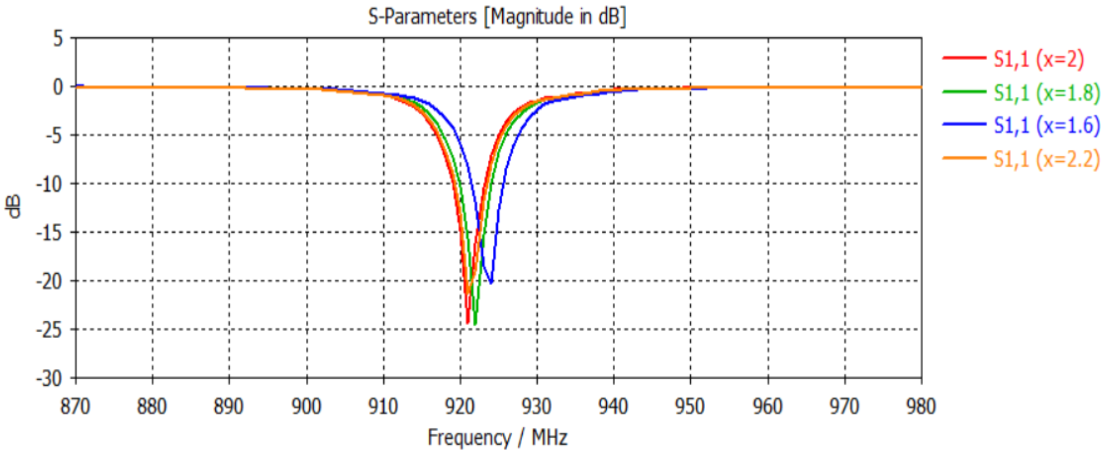


Figure 4.28 Return Loss and Resonant Frequency Effect Due to Changes of Width of Slot

4.5.4 Symmetrical Height of Triangular

This examination was executed to determine the effect of antenna performance due to changing of height of patch. By maintaining the other antenna parameter and changing patch diameter value, the effect of antenna performance can be determined from the changing on working frequency and return loss. Figure 4.29 shows the effect on the proposed microstrip patch antenna due to height of patch changes. By decreasing the height of patch to 86.4 mm, the resonant frequency rises up from 921 MHz to 922 MHz and the value of return loss also improved from -24.44 dB to -24.59 dB respectively. Then, by increasing the height of patch to 86.6mm, the resonant frequency drops off from 921 MHz to 920 MHz but improved the return loss value from -24.44 dB to -22.53 dB. This examination also decreasing the patch height by 89.3 mm and the result is shows by orange line that the frequency and return loss increase. The conclusion can be made is, if the height of the patch antenna deccreases, the value of frequency will be increase and the value of S11 will be improved.

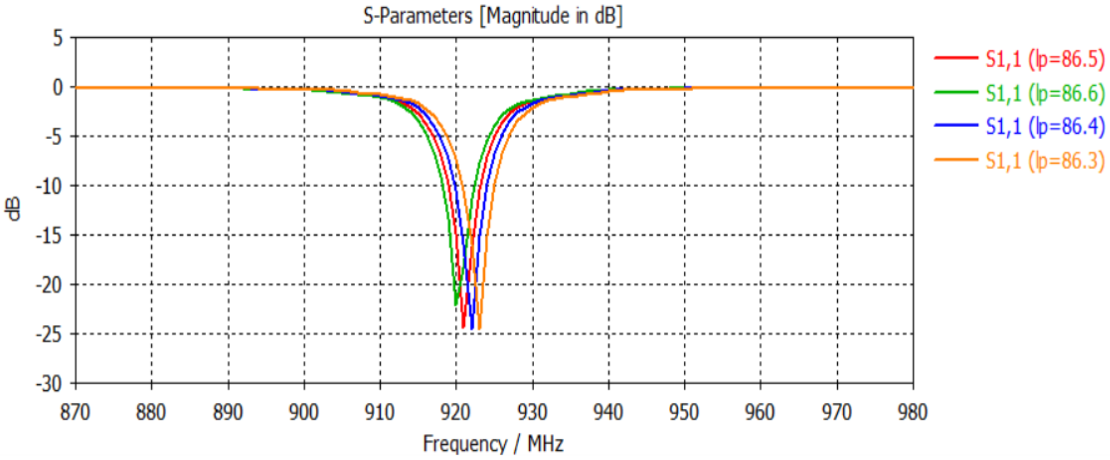


Figure 4.29 Return Loss and Resonant Frequency Effect Due to Changes of Height of Triangular Patch

4.5.5 Symmetrical slit height

This examination was executed to determine the effect of antenna performance due to changing of slit height. By maintaining the other antenna parameter and changing patch diameter value, the effect of antenna performance can be determined from the changing on working frequency and return loss. Figure 4.30 shows the effect on the proposed microstrip patch antenna due to slit height changes. By decreasing the height of slit from 3.0 mm to 2.8 cm, the resonant frequency does not change but the return loss improved from -24.44 dB to -23.69 dB respectively. Then, by increasing the height of slit to 3.4mm and 3.2 mm, the resonant frequency moves a little bit but drop off the return loss value from -24.44 dB to -25.03 dB. The conclusion can be made is, if the height of slit antenna increases, the value of frequency will be decreasing and the value of S11 will be improved but depend on the size of slit.

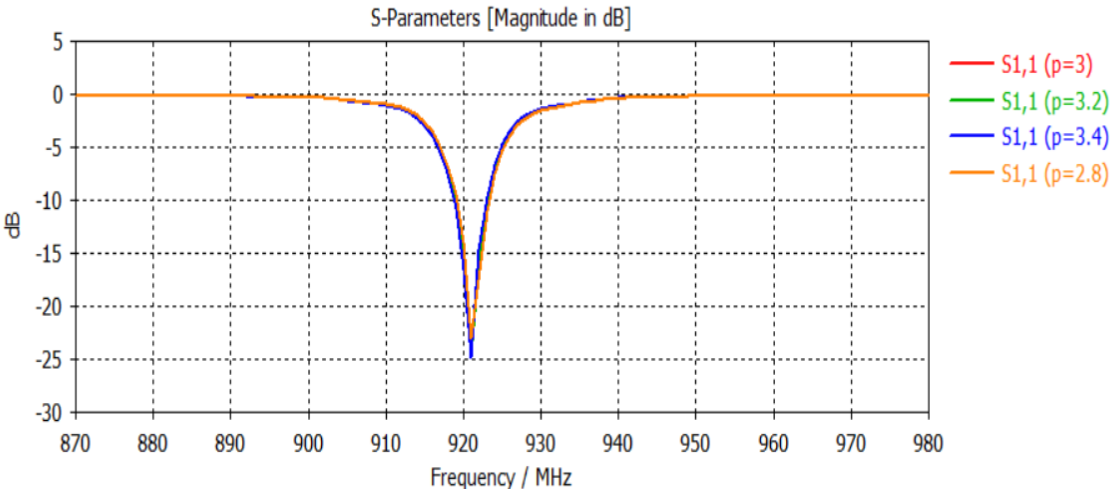


Figure 4.30 Return Loss and Resonant Frequency Effect Due to Changes of Slit Height

4.5.6 Side Equal length equilateral Triangular patch

This examination was executed to determine the effect of antenna performance due to changing of side equal length of equilateral triangular patch. By maintaining the other antenna parameter and changing side equal length value, the effect of antenna performance can be determined from the changing on working frequency and return loss. Figure 4.31 shows the effect on the proposed microstrip patch antenna due to side equal length changes. By decreasing the length of side from 100.5mm to 100.4mm, the resonant frequency drops off from 921 MHz to 917 MHz and the value of return loss also decrease from -24.44 dB to -22.35 dB respectively. Then, by increasing the diameter of patch to 100.6 mm, the resonant frequency drops off from 921 MHz to 916 MHz but improved the return loss value from -24.44 dB to -25.10 dB. This examination also decreasing the length of side equal triangular by 100.6mm and the result is shows by green line. The conclusion can be made is, if the length of the side triangular patch decreases, the value of frequency will be increasing and the value of S11 will be improved.

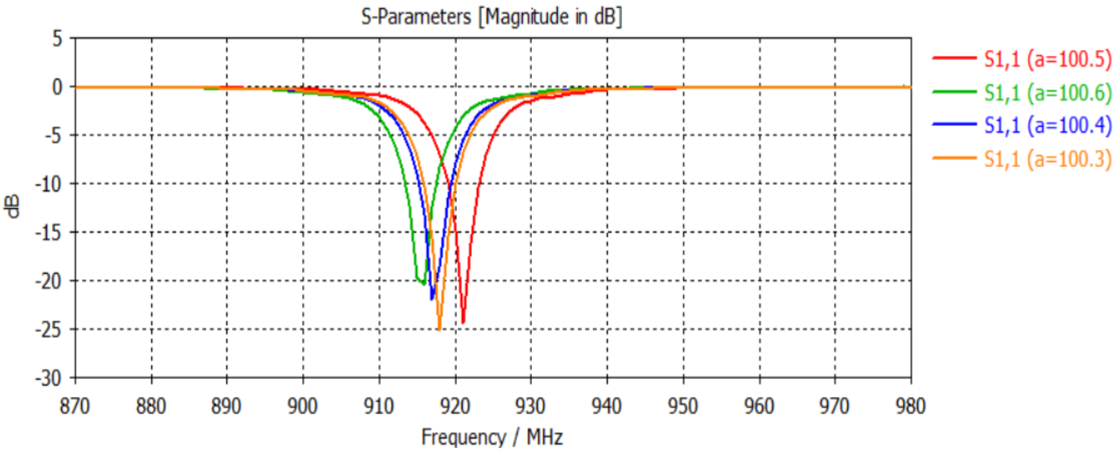
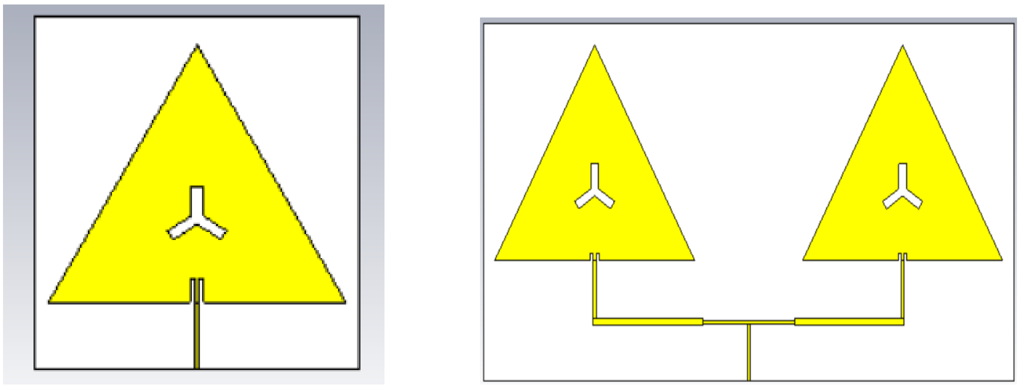


Figure 4.31 Return Loss and Resonant Frequency Effect Due to Changes of Side Equal Length Equilateral Triangular patch

4.5.7 Comparison between Triangular Array Antenna and Triangular Patch Antenna

This comparison has been done to study the impact of triangular array antenna against triangular patch antenna in term of antenna performance. The triangular patch antenna as shown in figure 4.32 has been set to operate at the same working frequency of 921 MHz and used the same material as triangular array antenna. It also used 4.7 of substrate permittivity (Ɛr). The dimension of triangular array antenna is 266.2 mm x 143.6 mm x 1.6mm mm, while 110.5 mm x 119.8 mm x 1.6mm of triangular patch antenna. The CST MWS 2019 has been used in this comparison test to generated the simulation result for these two types of antenna.



(a)

(b)

Figure 4.32 Triangular Patch Antenna: (a) Single element (b) Array

The comparison results between triangular array antenna and triangular patch antenna as shown in figure 4.31. By referring from the result, the tringular array antenna produces a good value of return loss (S11) which is -24.44 dB at 921 MHz of working frequency compared to the return loss that produces by triangular patch antenna which is -9.89 dB. By using the CST MWS 2019, another antenna parameter for both design such as gain, directivity, radiation pattern, and vswr can be measured. The conclusion can be made after doing this comparison, array antenna gave high impact to return loss (S11). Other than that, the size of antenna will be decreased by applying slot on it and it produces a good return loss (S11) at 921 MHz.

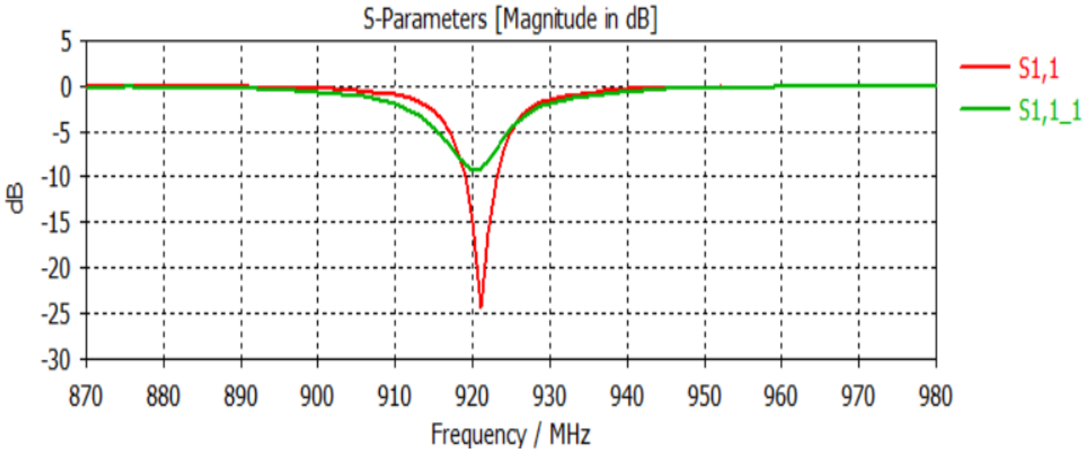


Figure 4.33 Comparison Result Between Triangular Array Antenna (Red) and Triangular Patch Antenna(green)

CHAPTER 5

CONCLUSION

5.1 Introduction

On FR-4 with a substrate thickness of 1.6 mm and a dielectric constant of 4.7, an efficient triangle shaped antenna with array method has been created. The antenna's total dimensions are 14.36 cm x 26.62 cm x 0.16 cm. The 50 SMA connection is used to pin feed this design. The many modifications of geometric dimensions on the triangular patch and array method of the provided antenna have been investigated to study the antenna reflection coefficient of S11. After analysing the results of all simulations, we can conclude that the developed antenna structure is linear polarised and may be used in a UHF RFID system in Malaysia with frequency bands ranging from 919 to 923 MHz with return losses of less than -10 dB.

5.2 Future Work

This microstrip patch antenna with array technique need more attention as there are many more important things need to be study at the frequency of 921 MHz. As a recommendation, the next study can explore deeper in UHF RFID. Others can investigate the configurations antenna of UHF RFID reader from this review. For this project, circular polarization can be suggested. Different kind of energize either circular or linear polarization can be found in the antenna. The triangular patch can be changed for single feed square polarization in form of square patch. There are many types of technique can be used to determine the antenna performance by keeping optimized parameter in action. In this study, the quality of the substrate has been changed. Low cost types of substrate were chosen for this research. We need to replace the high-quality substrate to obtain more precise and high efficiency result. A better result of antenna testing can be achieved by using the new high precision machine to fabricate the antenna. The efficiency and enhancing the impedance can be focused from different design. The microstrip patch antenna has many designs such as circle and polygonal circle. It can be applied and examined to give a solid execution of patch antenna with linear polarization and energizes more after this study. For this study, low-cost substrates were used. To get a more exact and high-efficiency outcome, we must change the high-quality substrate. Using the new high-precision machine to fabricate the antenna will result in a better antenna test result. Different designs might be focused on increasing efficiency and decreasing impedance. Microstrip patch antennas come in a variety of shapes and sizes, including circles and polygonal circles. It can be used and tested to produce a solid patch antenna with linear polarisation that energises more after this research.

5.3 Impact to Society and Environment

Nowadays, microstrip antenna had been used in various applications that can run at certain frequency. If the antenna match with their specification, it can operate either low or high range frequency. If the frequency is too high like an UHF frequency range and MF frequency range, the antenna will be light and small. These antenna applications are capable to operate and integrated on form of linear or planar arrays. It can be used to generate an antenna in pattern of linear, circular and elliptical polarization of electro-magnetic radiation. These antenna specifications are already well known for its performance and extent usage. The research and development of microstrip antenna should be continued. It is expected that it can replacing the conventional antenna for many other applications in this world. Some upgraded application antenna gave a huge impact to the people, society and environment. This can be seen in remote sensing system, satellite in communication system and direct broadcast television system.

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Use a reference manager such as *Mendeley* or *EndNote* to generate your list of references here.

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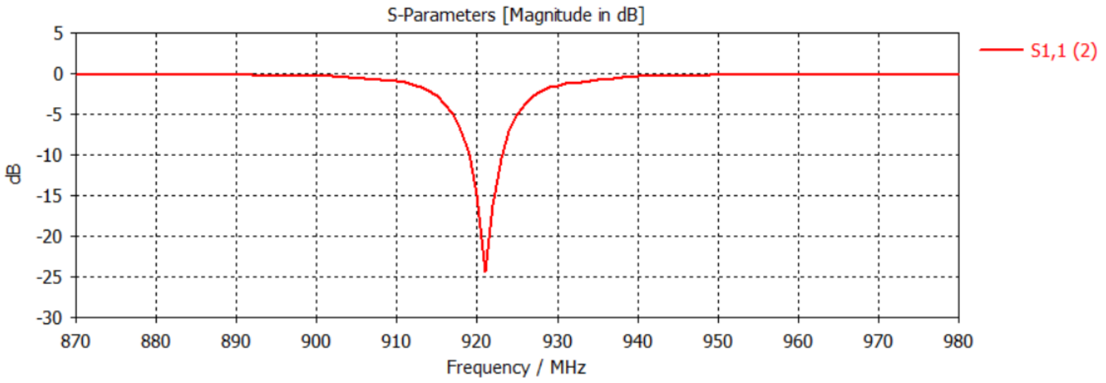
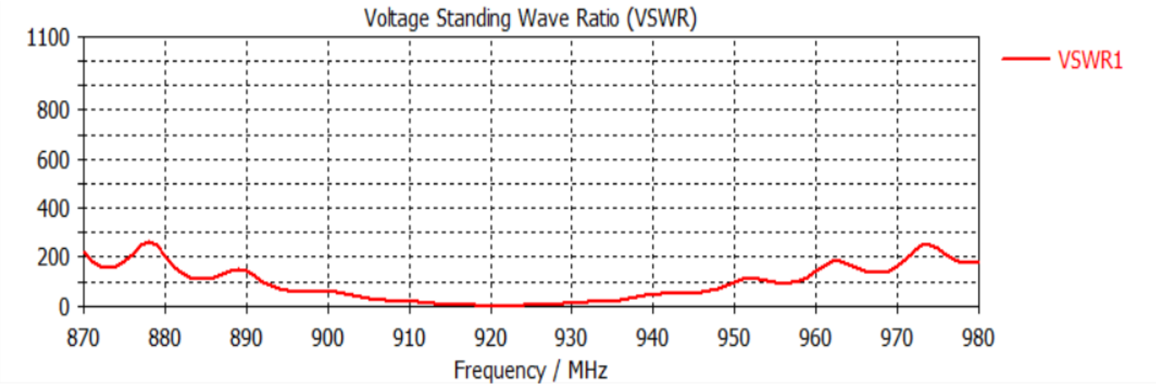
APPENDIX A
SAMPLE APPENDIX 1



a) Triangular Array Antenna S-Parameter (S11) Simulation Result



a) Traingular Array Antenna VSWR Simulation Result