DESIGN AND ANALYSIS OF HEXAGONAL ANTENNA FOR UHF RFID READER

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DESIGN AND ANALYSIS OF HEXAGONAL ANTENNA FOR UHF RFID READER

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ABSTRAK

Tujuan kertas kerja ini adalah untuk membentangkan reka bentuk dan analisis antenna berbentuk tampalan heksagon untuk aplikasi Pembaca Radio Frequency identification (RFID) Ultra High Frequency (UHF) dan untuk menerima faedah yang ditawarkan oleh sistem RFID UHF. Dalam reka bentuk ini, bahan FR-4 digunakan untuk mempunyai struktur sederhana, kos rendah dan berat yang ringan. Antena yang dicadangkan terdiri daripada tampalan antenna heksagon dan bentuk segi empat tepat untuk substrat. Antenna ini bertujuan untuk berfungsi pada julat frekuensi 919 MHz hingga 923 MHz, yang dikhaskan untuk sistem RFID UHF Malaysia. Voltage Standing Wave Ratio (VSWR) sebanyak 1.14 dan keuntungan (Gain) sebanyak 5.87 pada 921 MHz diperolehi mengunakan aplikasi Computer Simulation Technology (CST) studio. Keputusan parameter antenna seperti lebar jalur, kehilangan pulangan dan corak sinaran turut dibincangkan. Akhir sekali, antenna ini akan diuji dengan modul pembaca UHF industri dan boleh membaca id data tag UHF yang dihasilkan oleh Avery Dennison yang mengikut piawaian ISO 16000-C. Semua analisis parameter telah dilaksanakan menggunakan aplikasi CST Microwave Studio 2019.

ABSTRACT

The purpose of this paper is to present a design and analysis of hexagonal antenna for Ultra High Frequency (UHF) Radio Frequency Identification (RFID) Reader Application, to embrace the benefits offered by UHF RFID systems. In this design the FR-4 material is use to have medium, low cost and lightweight structure. The proposed antenna made up of hexagonal antenna patch and rectangular shape for the substrate. The antenna is meant to work on a frequency range of 919 MHz to 923 MHz, which is reserved for Malaysia's UHF RFID system. A voltage standing wave ratio (VSWR) of 1.14 and a gain of 5.87 at 921 MHz was obtained in CST microwave studio. The result of antenna parameter such as bandwidth, return loss and radiation pattern also discussed. Finally, this antenna will be tested with industrial UHF reader module and be able to read UHF tag data id manufactured by Avery Dennison that follow ISO 16000-C standards. All the parameter analysis was executed using CST Microwave Studio 2019 software.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 Constant
fr	Operating Frequency
θ	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
CST	Computer Simulation Technology
PCB	Printed Circuit Board

CHAPTER 1

INTRODUCTION

1.1 Background

Radio Frequency Identification (RFID) has been on the immediate horizon for the last decade, but this exciting technology revolution is only just beginning. RFID is already widely used in industries such as manufacturing, retail, and even healthcare [5]. RFID technologies enable amazing efficiency in these and many other industries while reducing the risk of lost goods and other costly issues.

Radio frequency identification (RFID) is a method that uses electromagnetic radiation or radio waves to identify items wireless. In general, RFID system consists of a tag that stores data attached or embedded into object or something to transmit stored data to the antenna and the reader connected to the antenna and receives data from the RFID tag. Then, data will transmit into the RFID database where it can be stored and evaluated. Now RFID finds many applications in various areas such as vehicle security, animal tracking, access control, retail item management, asset identification and electronic toll collection [1].

Because of their compact size, low cost, and ease of fabrication, microstrip patch antennas are becoming increasingly popular for modern communication systems. There has been a lot of research done on simple microstrip geometries like rectangular, circular, and triangular shapes [2]. Patch antennas have the advantage of radiating with moderately high gain in a direction perpendicular to the substrate and being inexpensive to manufacture [6]. Many factors influence the bandwidth and efficiency of a Microstrip antenna, including patch size, dielectric constant of the substrate, substrate thickness, shape, feed point, type location, and so on. A thick dielectric substrate with a low dielectric constant is preferred for good antenna performance because it allows for better radiation, higher efficiency, and greater bandwidth [3-5]. Rectangular, circular, Square, and polygonal microstrip antennas are the most common, but any continuous shape is possible.

1.2 Introduction to project

This project focus on the designing and analysis small antenna for RFID reader using low-cost substrate material such as FR-4. The frequency range of this project is 919 MHz to 923 MHz that legally used in Malaysia. The structure of microstrip patch antenna consists three main part which is radiation patch (A microstrip or patch antenna operates in a way that when current though a feed line reaches the strip of the antenna, then electromagnetic waves are generated), substrate (dielectrics) are used for improved electrical and mechanical stability, they are used to reduce the size of the antenna (higher permittivity, lower size) and can help to produce displacement current which produces time varying Magnetic Field and ground plane (function as capacitor plate to receive the displacement current and return to ground side) [4].

Figure 1.1 RFID System

1.3 Problem Statement

According to the frequency spectrum in which they operate, RFID systems are frequently categorised. Frequency is a term used to describe the magnitude of radio waves used to communicate between system components. Low frequency (LF), high frequency (HF), and ultra-high frequency (UHF) bands are used by RFID systems all around the world. There are benefits and drawbacks to using each of these frequency bands, and radio waves behave differently at each of these frequencies. Different countries have allotted different parts of the radio spectrum for RFID standardize three main RF bands: low frequency (LF), 125 to 134 kHz, high frequency (HF), 13.56 MHz, and ultrahigh frequency (UHF), 860 to 960 MHz Standard Radio System Plan (SRSP) states Malaysia legal frequency range for RFID and the requirements for the utilisation of the frequency band 919 – 923 MHz for Radio Frequency Identification Device (RFID) systems in Malaysia.

In order to operate efficiently in the electromagnetic spectrum, typical antennas rely on size. The antenna will not be able to broadcast or receive the desired electromagnetic waves effectively if it is not long enough to resonate at the correct frequency. For microstrip antenna if bigger the size of antenna it will become difficult to use because most of the application that used in small device. The bigger the size also will make the cost of fabrication, mass, weight and volume increase. This problem will interrupt the performance of antenna in real life application.

Data transfer between the tag and reader is problematic due to low efficiency (s11). S11, also known as the reflection coefficient (also written as gamma: or return loss), measures the amount of power reflected from the antenna. All power is reflected from the antenna and not radiated if S11 = 0 dB. When 3 dB of power is applied to the antenna, the reflected power is -7 dB if S11=-10 dB. The antenna either "received" or "delivered" the remaining power. This accepted power is lost by the antenna as radiation or absorption.

1.4 Objective of Study

The project objective is to structure and investigate the microstrip patch antenna with hexagonal patch for UHF RFID that's can be operate in Malaysia assigned frequency which are located from 919 MHz – 923 MHz with centre frequency set at 921 MHz or 0.921 GHz which is average value. The FR4 material is used as substrate in design microstrip patch antenna with substrate thickness (h) is 1.6mm and dielectric consistent (εr) = 4.7. Besides that, there are other objectives that we consider in this study includes:

- To design antenna that can operated for UHF RFID systems in Malaysia with frequency given from 919 MHz to 923 MHz

- To develop and implement slot for size reduction of the antenna

- To increase the antenna efficiency by decrease the return loss S11 value.

1.5 Project scope

The scopes of this project are:

- To ensure the microstrip patch antenna operate at 921 MHz of resonance frequency.
- To design and analysis effect of antenna parameter using the CST Microwave Studio 2019.
- To ensure the fabrication process of antenna is completed and tested the antenna using the network analyser

1.6 Thesis outline

- Chapter 1: Focus on project background, project objective, project scope and project summary.
- Chapter 2: This chapter is focus on the previous work that related to microstrip patch antenna. The chapter covers detail of basic antenna parameters and shapes, feeding technique and polarization.
- Chapter 3: Present the research flow and activities to design and develop microstrip patch antenna. The research flow covers about method flow. In the meantime, the research activities describe overall method flow in the research.
- Chapter 4: Focus on the result of antenna testing by simulation and measured to determined antenna performance. In addition, study the effect of antenna performance due to parametric changing.
- Chapter 5: Focus on conclusion of project, future recommendation and impact to society

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction of Antenna

In the 1950s, the microstrip antenna was initially introduced. This concept, however, had to wait roughly 20 years. should be realised following the completion of the printed in the 1970s, circuit board (PCB) technology was at its peak. Since The most prevalent forms of antennas are microstrip antennas. Due to their versatility, antennas have a wide range of uses. Its perceived benefits of conformal simplicity, high mobility, minimal weight and low-profile cheap cost, flat configuration appropriate for arrays with ease-of-use microwave monolithic integrate circuits (MMICs) [7], broadcast radio, direction founding , global positioning system (GPS), Radio-frequency identification (RFID), remote sensing, vehicle collision avoidance system, satellite communications, surveillance systems, multiple-input multiple-output (MIMO) systems, radar systems, mobile systems television, missile guidance, military applications and other civilian have all used them.

2.2 Microstrip Patch Antenna

A microstrip antenna in the context of communications usually made on a printed circuit board using photolithographic methods (PCB). The majority of their usage is in microwave frequencies. An individual microstrip antenna is made up of a ground plane made of metal foil on one side of the printed circuit board and a patch antenna made of metal foil in a variety of shapes on the surface of the PCB [10]. Typically, foil microstrip transmission lines are used to link the antenna to the transmitter or receiver. The antenna and ground plane are where the radio frequency current is applied (or, with receiving antennas, the received signal is created). The microstrip patch antenna has limited transfer impedance speed, low productivity and it suitable for low power application. Other than that, microstrip patch antenna produce poor polarization. For some applications, circular or rectangular microstrip patches have been transformed into different shapes. For a particular frequency, hexagonal form microstrip antennas are lower in size and higher in gain than square and circular microstrip antennas. [5]. The small size is an important requirement for portable communication equipment's.

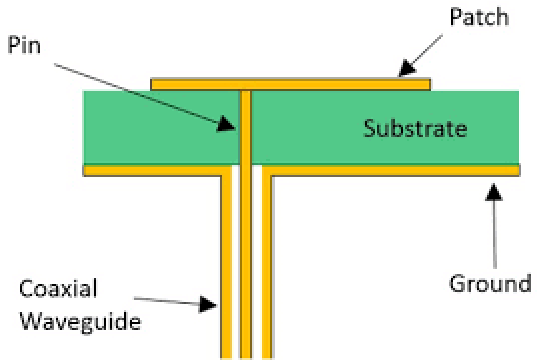


Figure 2.1 Microstrip patch antenna with coaxial feed

2.2.1 Advantages and Disadvantages of Microstrip Patch Antenna

Antenna performance will be improved by using a thicker dielectric material with a lower dielectric constant. It has higher efficiency and radiation, as well as a large operational bandwidth [6].

Advantages:

- Microstrip patches of various shapes, such as square, rectangular, triangular, polygonal and so on, may be etched quickly.
- Cheaper in fabrication and mass production
- Capable of supporting multiple frequency bands (dual, triple)
- Light in weight and support dual polarisation types, namely linear and circular.
- They are light in weight.
- This antenna type has smaller size and hence will provide small size end devices
- Operate at microwave frequencies where traditional antennas are not feasible to be designed.

- Suitable for linear and circular polarizations.

Disadvantages:

- Lower power handling capability.
- Offers lower gain.
- From feeds and other junction points, the microstrip antenna structure radiates.
- Lower impedance bandwidth by default.
- Offers low efficiency due to dielectric losses and conductor losses

2.3 Feeding Method

There are two types for feeding methods. One makes contact, whereas the other doesn't [3]. Coaxial probe, microstrip line, aperture coupled, and proximity coupled are the four different types of feeding techniques.

2.3.1 Microstrip Line Feed

The microstrip patch is directly attached to the conducting microstrip feed line in this feeding approach. The feed line is not the same size as the microstrip patch. It's simple to make and match [3]. Aside from that, it's excellent for usage in a sustaining system for receiving wire exhibits. However, microstrip line feed have a disadvantage in that they have a low data transfer capacity and emit some unwanted radiation.

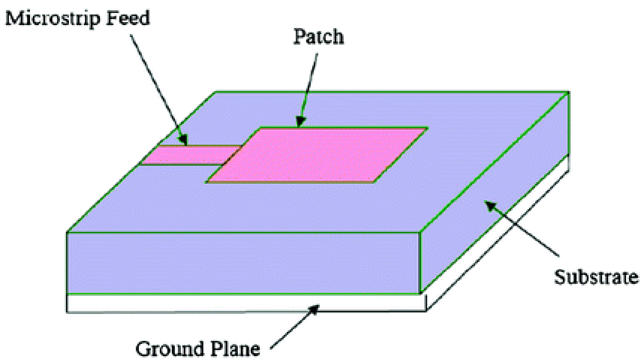


Figure 2.2 Microstrip Line Feed

2.3.2 Coaxial Feed

The inner conductor of a coaxial cable is connected to the antenna's microstrip patch, while the outside conductor is attached to the ground plane [1]. In most cases, the feed networks are isolated from the microstrip patch, but not in this mechanism [6]. The advantages of the coaxial feeding method include reduced spurious radiation, ease of manufacture, and efficient feeding [3]. However, this feed method has several weaknesses which is difficult to fabricate because the antenna needs to be drilled to place the coaxial connecter on the antenna and the connector stand out on the ground plane, and making the thick of substrate not fully planar. In addition, this method produces narrow bandwidth.

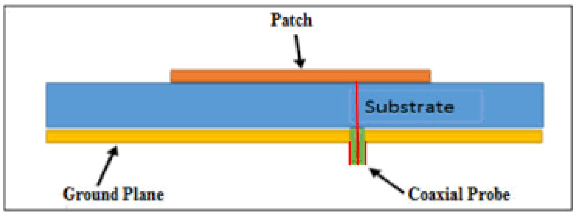


Figure 2.3 Coaxial Feed

2.3.3 Proximity Coupled Feed

The design of this feeding technique is more challenging than previous feeding techniques. Two dielectric substrates are used in this approach. The feed line is between two substrates, and the microstrip patch is on the upper surface of the upper dielectric substrate. It offers the widest bandwidth while avoiding spurious radiation. This feed method has several advantages which is produces 13% of high bandwidth 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 [3].

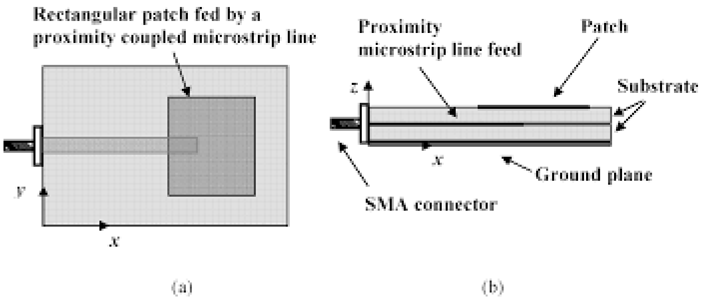


Figure 2.4 Proximity Coupled Feed

2.3.4 Aperture Couple Feed

This feed consists of two substrates that are distinct from one another and separated by a ground plane. The microstrip patch and feed line are connected via a slot in the ground plane in this technique [3]. The aperture coupled feeding approach has the advantages of less interference and pure polarisation. In addition, the slot size such as length and width can improved return loss (S11) and produces wide bandwidth.

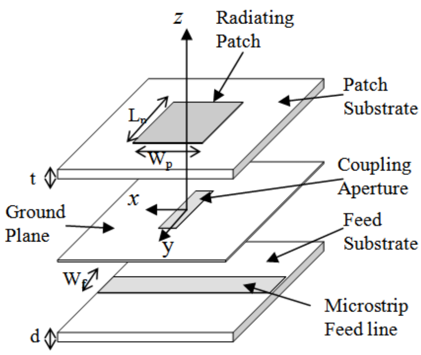


Figure 2.5 Aperture Couple Feed

2.4 Size Reduction Techniques

The majority of microstrip antennas are used for high frequency applications, which are those that have a frequency of 1 GHz or more. At lower frequencies, the antenna's size becomes a critical issue for practical deployment. However, there are a variety of methods for reducing antenna size, including high dielectric constant, shorting post, structural alteration, perturbation, and plate loading [9].

2.4.1 High Dielectric Constant

Using a dielectric constant that is somewhat high is a simple way to reduce the size of a microstrip patch antenna. These materials, on the other hand, are frequently innately lossy and or have a high cost. them. Furthermore, such dielectrics improve the design's sensitivity to minor geometrical changes. antenna's characteristics Superstrates, on the other hand, can be utilized to enhance the effective dielectric constant achieve patch reduction in size. Unfortunately, the patch profile frequently exceeds the acceptable specifications due to the needed superstrate thickness [9]. Another approach is to change the geometry of a planar antenna so that it takes up less space than a rectangular patch. Inserting a shorting pin is one way to accomplish this. However, such a modification comes with a cost in terms of performance, such as a reduction in impedance bandwidth.

2.4.2 Shorting Post

The shorting post technique is a common way to reduce the overall size of a microstrip antenna by removing certain radiating edges using a short circuit (metal clamp or shorting post). The resonance frequency of a short circuited microstrip patch can be altered by changing the position and number of shorting pins [9]. In fact, lowering the resonance frequency of the redesigned patch by reducing the number of shorting posts.

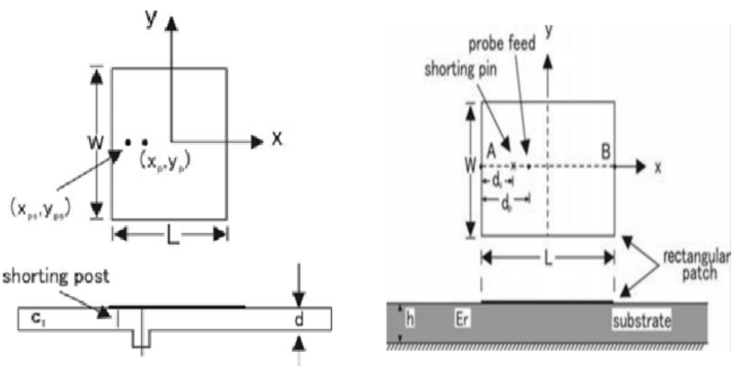


Figure 2.6 Shorting Post

2.4.3 Structural Modification

Another way for reducing the size of a patch antenna is structural modification, which involves adding a slot to the original shape of the radiation patch to reduce meander currents. In general, adjusting the size of the slot, such as length and width, is a good way to reduce the antenna size.

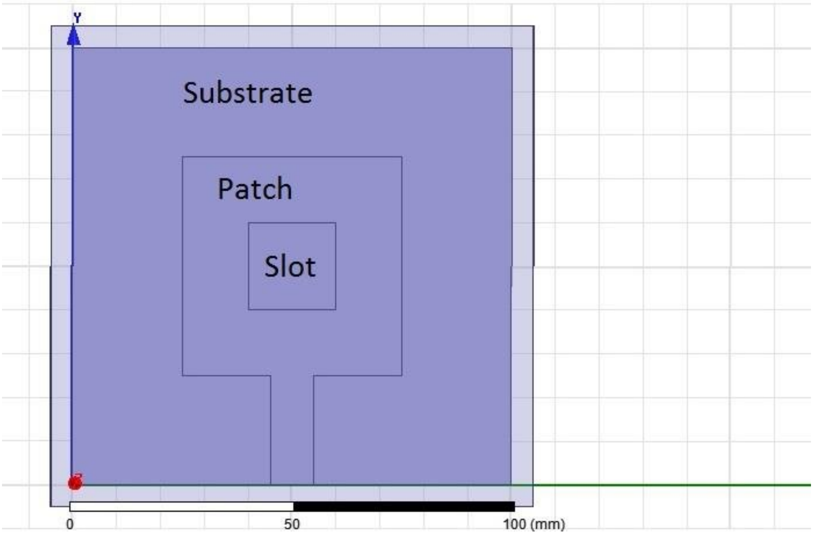


Figure 2.7 Structural Modification

2.4.4 Perturbation and Plate Loading

Another strategy for reducing antenna size is perturbation and plate loading, which is based on the perturbation effect. The magnetic field should be increased, while the overall energy contained in the electric field should be reduced, using this strategy. As a result, the patch will reduce due to the strong electric field, but the ground plane will rise due to the high magnetic field. The current path of the antenna was increased and the resonance frequency was decreased by increasing the number of plates loaded on the antenna. By combining these two technologies, the size of a microstrip patch antenna can be reduced [9].

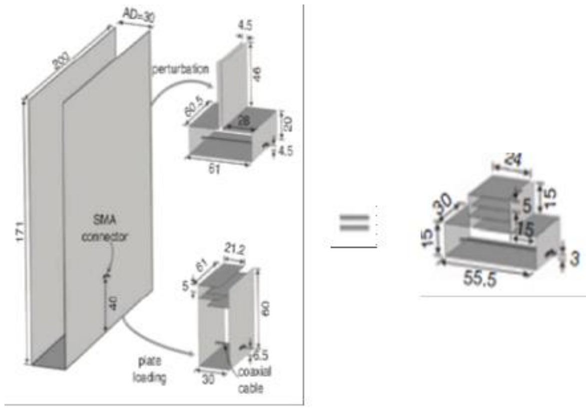


Figure 2.8 Perturbation and Plate Loading

2.5 Antenna Parameter

To determine the antenna performance, several parameter and characteristic of antenna need to be considered such as directivity, gain, bandwidth, axial ratio, radiation pattern, and polarization. The antenna pattern is the response of the antenna to a plane wave incident from a given direction or the relative power density of the wave transmitted by the antenna in a given direction.

2.5.1 Directivity

An antenna's directivity is defined as the ratio of the antenna's radiation intensity in one direction to the antenna's averaged radiation intensity in all directions. The total power radiated by the antenna divided by 4 is the average radiation intensity [8]. Theoretically, the directivity of circular polarization antenna is radiate 360° in any direction while the directivity of linear polarization antenna is radiate 90° in one direction.

2.5.2 Gain

In antenna theory, gain is one of the realised values. Gain typically outperforms directivity. Ohmic and other losses are introduced. It is defined as the ratio of the radiation intensity in a given direction from the antenna to the total input power accepted by the antenna divided by 4π, $G = 4\pi U / Pin$ [5].

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

2.5.3 Bandwidth

The frequency range over which an antenna can function properly is known as bandwidth. If the highest frequency of the band is FH, lowest frequency of the band is FL and the centre frequency of the band is FC, then bandwidth can be defined as, BW = 100 × (FH − FL) / FC Different antennas have their own bandwidth as per its de- sign considerations. [11]

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

2.5.4 Axial Ratio

An antenna's Axial Ratio (AR) is the proportion between the major and minor axes of a circularly polarised antenna pattern. This ratio would be 1 if an antenna had perfect circular polarisation (0 dB). This ratio would be more than 1 (>0 dB) if the antenna had an elliptical polarisation [11].

2.5.5 Radiation Pattern

A radiation pattern is the variation in power radiated by an antenna as a function of its direction away from the antenna. This variation in power as a function of arrival angle is visible in the antenna's far field [11]. Radiation pattern can determine the energy radiated and received by the antenna which can be measured using CST MWS simulation.

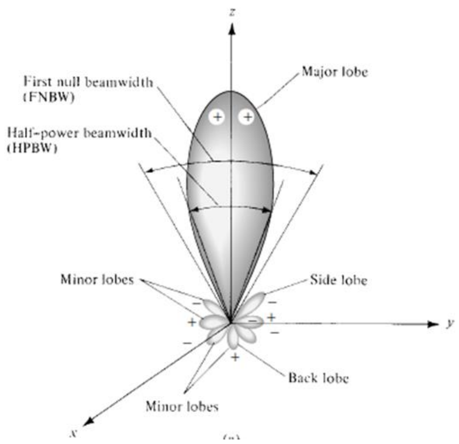


Figure 2.9 Antenna Radiation Pattern

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

- Major/main lobe: major lobe illustrated the lobe that produces by the antenna that contained the maximum radiation energy at certain direction. The direction of major lobe is $\Theta = 0$. The major lobe can be more than one for different antenna types for example split-beam.

- Minor lobe: minor lobe is defined as any lobe that produces by the antenna except major lobe (main beam). The radiation in unwanted direction usually is classified as minor lobe

- 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.

- Back lobe: Back lobe is the lobe that produces by the antenna in opposite direction respect to 180° of the main beams.

2.5.6 Polarization

The direction of the electromagnetic fields created by an antenna when energy radiates away from it is a general definition of an antenna's polarisation [10]. These directional fields determine the direction in which energy is emitted or received by an antenna.

- Linear polarization is the most common polarization.

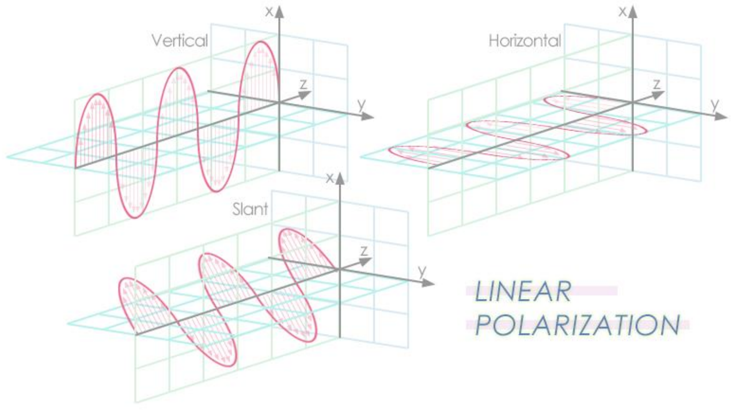


Figure 2.10 Linear Polarization

- The oscillation of an antenna's electrical field on the vertical plane is referred to as vertical polarization, whereas the oscillation on the horizontal plane is referred to as horizontal polarization.

- An electrical field that oscillates at a 45-degree angle to a reference plane is referred to as slant polarization.

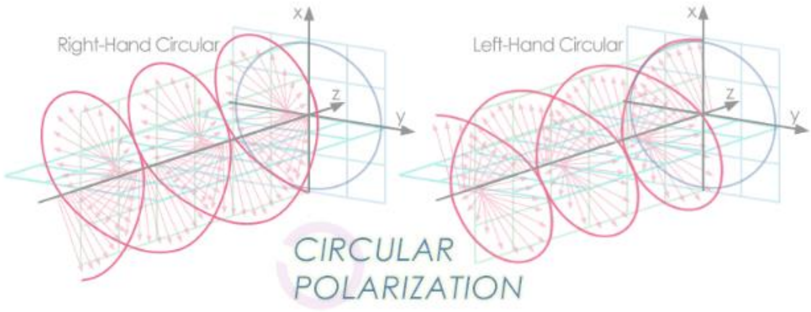


Figure 2.11 Circular Polarization

- A radio wave with circular polarization (CP) rotates as the signal travels. When the polarization rotates to the right, it is known as Right-Hand Circular Polarization (RHCP); when it rotates to the left, it is known as Left-Hand Circular Polarization (LHCP) (LHCP).

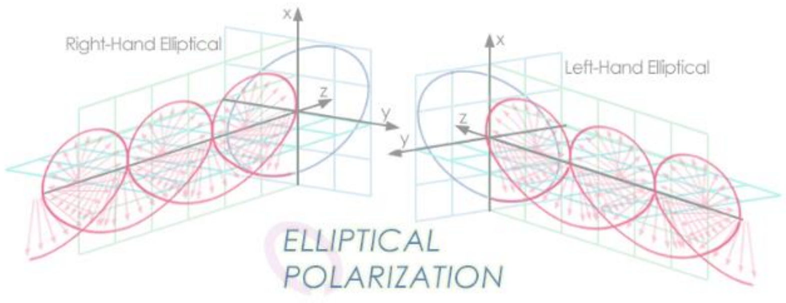


Figure 2.12 Elliptical Polarization

- Ellipsoidal polarization, not to be confused with circular polarization, refers to an electrical field that propagates in an elliptical helix. Elliptical polarization, like circular polarization, can be either right-hand or left-hand

2.5.7 VSWR

Voltage standing wave ratio (VSWR) is the ratio between the standing wave's maximum and minimum values, ideally VSWR is 1:1. If the antenna's and the cable's impedances differ, some of the feeding signal may be partially reflected back. This reflected signal then combines with the feeding signal to form a signal wave known as a standing wave. Which mean the impedance of the antenna and the cable are exactly equal. In real world the VSWR is for example 2:1 meaning, there is a mismatch and some of input signal is reflected back. If it 3:1 there is an even bigger mismatch and so on

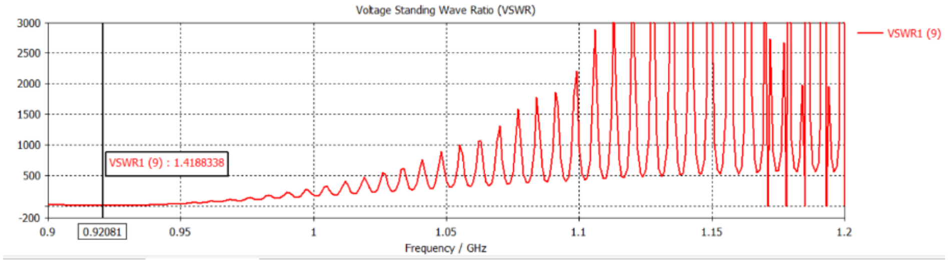


Figure 2.13 Example VSWR Result

2.5.8 Return loss

When a signal enters a transmission line, return loss is the reflection of that signal's power. The proportion of radio waves that arrive at the antenna input that are rejected as opposed to those that are accepted is referred to as the return loss of an antenna. Compared to a short circuit, it is measured in decibels (dB) (100 percent rejection). Portion of input power is reflected from the antenna due to mismatch [2]. For example, if return loss is 30 dB, it means the reflected signal is 30 dB weaker than the input signal (reflected power = input power - RL = -10dBm).

2.6 RFID Component

An object, animal, or human can be individually identified using RFID (radio frequency identification), a sort of wireless communication that uses electromagnetic or electrostatic coupling in the radio frequency region of the electromagnetic spectrum.

2.6.1 Basic Operation Of RFID

An RFID system is made up of three parts: a scanning antenna, a transceiver, and a transponder. An RFID reader, also known as an interrogator, is a device that combines the scanning antenna and the transceiver. Data is first stored on an RFID tag in read-only or read-write format. The tag can be battery-powered or passive [1]. When a tag is close to a scanning antenna, electromagnetic (EM) radiation triggers the tag to start broadcasting data in the form of radio waves. These radio waves are picked up by the antenna and transmitted as digital information to the reader.

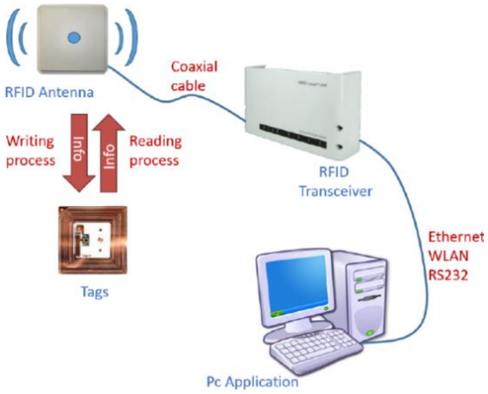


Figure 2.14 RFID System

2.6.2 RFID Tags

The transponder is already built within the RFID tag. RFID reader type, RFID frequency, tag type, and interference from the outside or from other RFID tags and readers all affect how far an RFID tag can be read. RFID tags are made up of an integrated circuit (IC), an antenna, and a substrate; tags with a more potent power source also have a greater read range. The area of an RFID tag where the identification data is stored is called the inlay [1]. There are two main types of RFID tags:

- RFID that's active A battery is frequently the power source for an active RFID tag.
- RFID passive. The reading antenna's electromagnetic wave causes a current in the RFID tag's antenna, giving the passive RFID tag its power.

There are also semi-passive RFID tags, meaning a battery runs the circuitry while communication is powered by the RFID reader. the most importance characteristic of tags in tag range. Tag range means the maximum distance where RFID readers can read or write information on the tag.

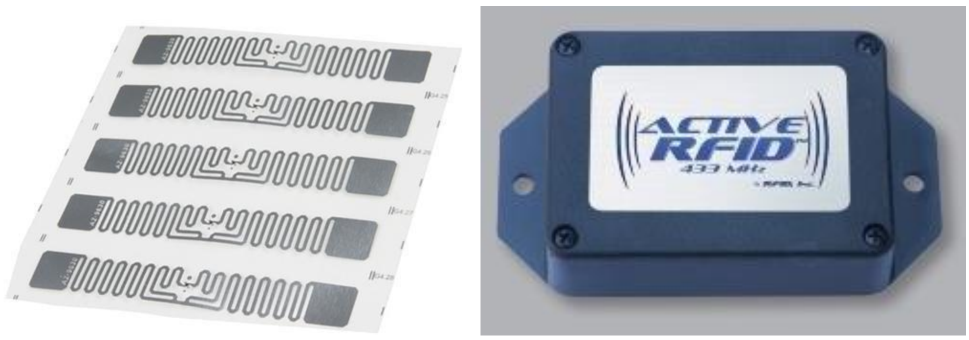


Figure 2.15 Passive RFID Tag and Active RFID Tag

2.6.3 RFID Reader

A device called an RFID reader is used to read radio frequency identification (RFID) tags, which are used to track specific objects. Radio waves are used to transmit data from the tag to the reader. Fixed readers and mobile readers are the two categories into which RFID readers fall. Network-connected RFID readers can be either fixed or portable. It uses radio waves to transmit signals that activate the tag [1]. When the tag is engaged, it transmits a wave back to the antenna, which the antenna then turns into data.

Figure 2.16 Fixed readers and mobile readers

2.6.4 RFID Antenna

The RFID reader antenna uses radio waves to transfer data. Before transmitting, the information must first be converted to radio wave. The Figure 19 shows the example of RFID reader and tags. While Figure 18 illustrates the radiation pattern has been transmit by antenna through radio wave. The antenna transmits an electrical field of radiation pattern, and the wave travels in opposite directions, known as polarization, which can be linear or circular [6].

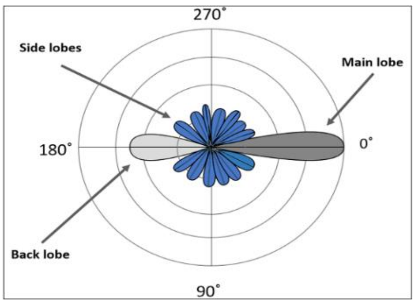


Figure 2.17 Radiation Pattern Antenna

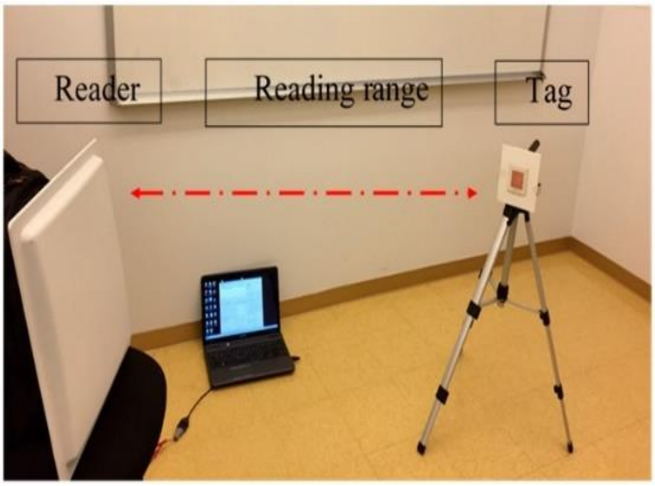


Figure 2.18 Reader and tag

The antenna tag, on the other hand, receives the radio wave transmitted by the antenna reader and converts it into an electrical signal. The dipole, dual dipole, and folded dipole antennas are the three types of UHF microwave antennas.

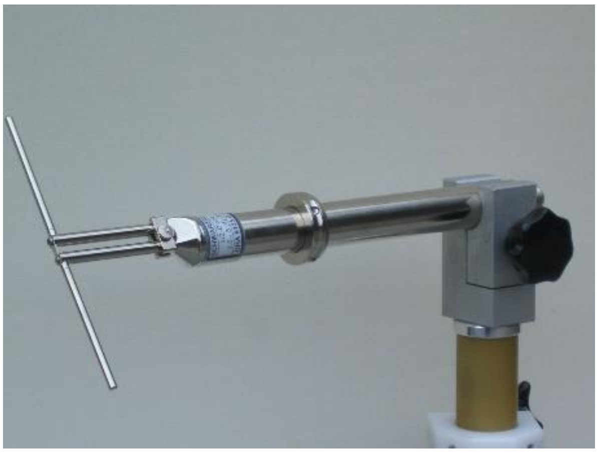


Figure 2.19 Dipole Antenna

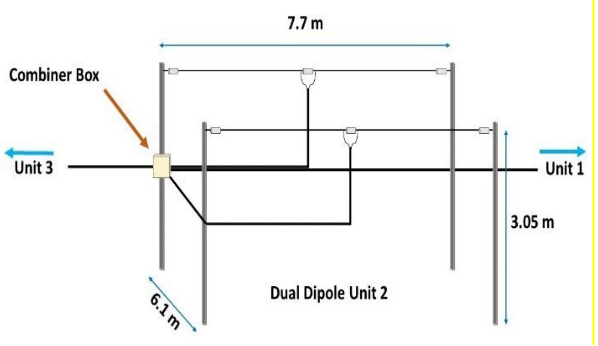


Figure 2.20 Dual Dipole Antenna

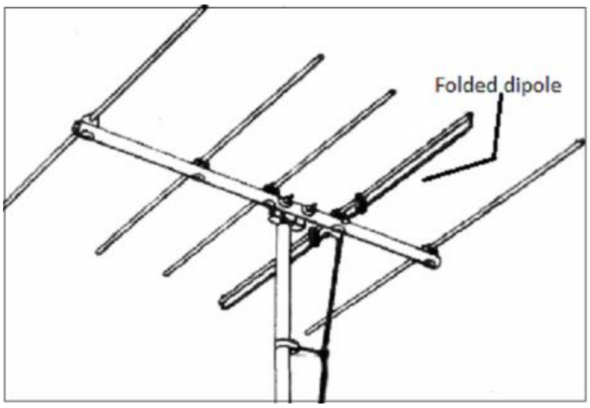


Figure 2.21 Folded Dipole Antenna

2.6.5 RFID Frequency Range

The three main types of RFID systems are low frequency (LF), high frequency (HF), and ultra-high frequency (UHF) (UHF). A microwave RFID option is also available. Depending on the nation and area, radio broadcast frequency varies greatly [7].

- RFID systems that operate at a low frequency. The frequencies span from 30 to 500 kHz, with 125 kHz being the most common. The transmission ranges of LF RFID are limited, ranging from a few inches to less than six feet.

- RFID system with a high frequency These frequencies vary from 3 to 30 MHz, with 13.56 MHz being the most common HF frequency. The typical measurement range is a few inches to many feet.

- RFID systems that operate at ultrahigh frequencies. These may be read from a distance of 25 feet or more and range in frequency from 300 to 960 MHz, with 433 MHz being the most common.

- RFID systems that use microwaves These operate at 2.45 GHz and may be read from a distance of more than 30 feet.

Table 1 RFID Frequency Class

Frequency classes	Low	High	Ultra	Microwave
Frequency Range (Hz)	9 k – 135 k	13.553M – 13.567M	860M – 930M	2.4G – 2.4835G and 5.8G
Detection Range	0.508 meter	1 meter	4-5 meter	10 meters
RFID Application	vehicle immobilizer	Library Items, laundry	Stock chain, entry control	Safety control, work tracking

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 four main tasks including antenna research, antenna design, simulation of antenna and antenna parameter. Figure 3.3 shows the procedure to design the microstrip antenna

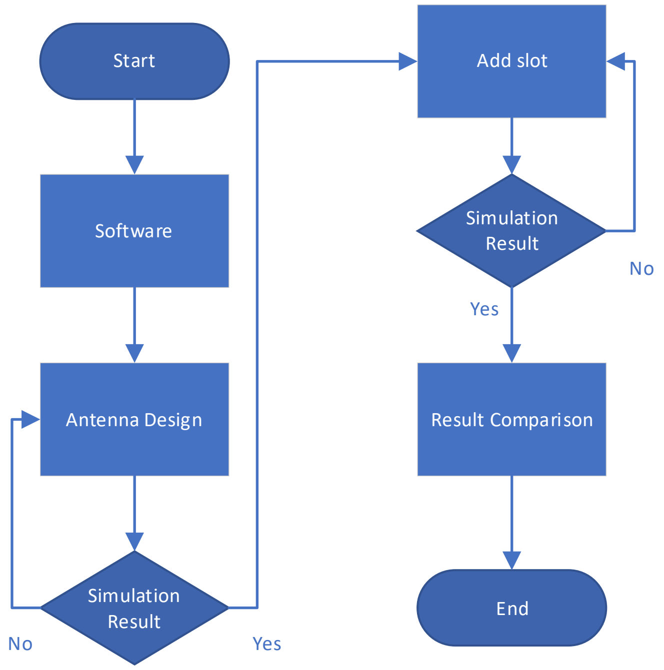


FIGURE 3.1 FLOWCHART OF DESIGNING ANTENNA

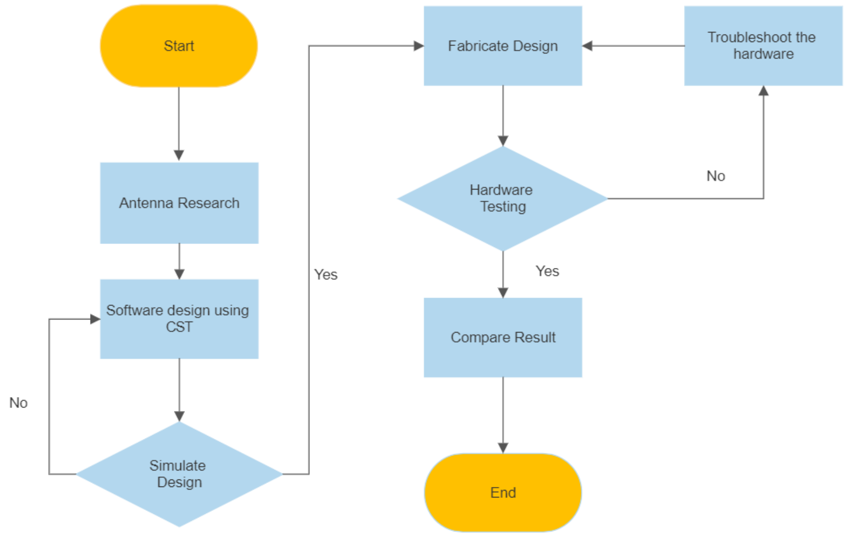


FIGURE 3.2 FLOWCHART OF OVERALL PROJECT

Because of 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 the most frequent antennas used in industry. Although it can be mounted on the same substrate, the antenna is appropriate for direct integration with microstrip circuits. However, this project will require the creation of hexagonal microstrips antenna. Before beginning to design the antenna, numerous parameters must be examined. operating frequency (fo), dielectric constant of substrate microstrip patch antenna (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 with FR-4 substrate material is 4.7 (loss-free). The height of the substrate (h) must be considered in order to achieve optimum or maximal antenna performance. The antenna in this project was designed using the height of substrate value specified using FR-4 substrate material, which is 1.6mm.

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 emphasised 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 microwave Studio

CST Microwave Studio was used to create the microstrip patch antenna design. This programme is a three-dimensional electromagnetic simulation tool for high-frequency components. CST MWS enables the analysis of high-frequency devices, particularly antenna devices, in a quick and precise manner. CST MWS provides an analysis result of EM behaviour for antenna devices quickly and with excellent ease of use. CST MWS 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 in order to simulate an antenna utilising CST MWS. The CST simulation will display accurate antenna performance study results such as 1D results, s-parameter (S11), gain, radiation pattern, efficiency, directivity, bandwidth, and antenna polarisation plots, as well as a rectangular diagram. The s-parameter (S11) analysis result will indicate if the antenna is effective or not. To work efficiently at a given frequency, the S-parameter must be less than -10 dB. Right Hand Circular Polarization (RHCP) and Lefthand Circular Polarization (LHCP) can be used to repeat the estimation of radiation design and polarisation for antenna tests, as well as the Voltage Standing Wave Ratio (VSWR).

3.2 Design specification

First of all, 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 2 Antenna Parameter

Operating Frequency, f_0	921 MHz
Dielectric Substrate	FR-4
Dielectric Constant, ε_r	4.7
Loss Tangent, θ	0.019
Substrate Height, h	0.16 cm
Patch Thickness, t	0.035 cm

The operating frequency, s-parameter (S11), radiation pattern, directivity, and gain are all theoretically used to define antenna performance. The performance of an antenna is also influenced by the appropriate feeding technique and accurate physical measurement. The UHF frequency range is 300 MHz to 3 GHz, and this project uses UHF RFID frequencies ranging from 919 MHz to 923 MHz. The microstrip patch antenna should be capable of operating across many frequency bands. The dielectric constant has an impact on antenna size. Aside from that, the dielectric constant affects the antenna's radiated power, efficiency, and bandwidth.

3.3 Design procedure

The goal of this part is to explain how to construct a circular microstrip patch antenna correctly. The patch antenna concept is outlined as a circular patch. For this design, a 50-surface mount connector will be utilised to connect the feedline to the coaxial link, and the feedline value will be 50. The feedline is installed from below on the ground surface.

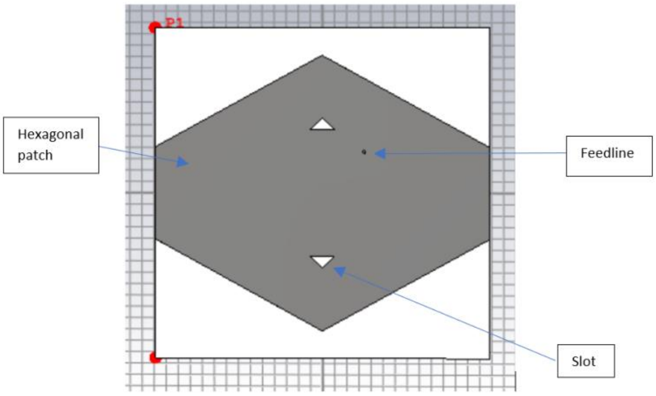


FIGURE 3.3 HEXAGONAL ANTENNA

3.3.1 Design simulation

The software for this project is CST MWS, which is used to simulate the antenna design. CST MWS is capable of simulating antenna designs with precise analytical results. As a high-frequency device (HF), it is user-friendly and simple to use, and it includes a solver module for a certain technology. Operating frequency, dielectric substrate, dielectric constant (Er), substrate height (h), loss tangent (), and patch thickness must all be taken into account (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 Calculation of Designing Hexagonal Antenna

The Hexagonal patch antenna was chosen for design and analysis in order to predict antenna performance. The Hexagonal patch antenna must operate at 921 MHz with an input impedance of 50, a substrate (h) of 1.6 mm, and a dielectric constant of 4.7 [5]. The mathematical expression for calculating the patch antenna's length and width:

- The width of patch antenna is given by equation:

$$W_p = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{3.1}$$

- Calculation of Effective dielectric constant (εreff gives the effective dielectric constant as:): The following equation:

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}} \tag{3.2}$$

- Calculation of the length extension (ΔL): The following equation gives the length extension as:

$$\Delta L = \frac{h}{\sqrt{\varepsilon_r}} \tag{3.3}$$

- Calculation of actual length of patch (L): The actual length is obtained by the following equation

$$L_p = \frac{c}{2f_r\sqrt{\varepsilon_{re}}} - 2\Delta L \tag{3.4}$$

- Formula for point to design Hexagon

$$\text{Point 1: } u = 0 \quad v = \frac{w_p}{2} \tag{3.5}$$

$$\text{Point 2: } u = \frac{L_p}{2}: \quad v = \frac{1}{3} \times \frac{W_p}{2} \tag{3.6}$$

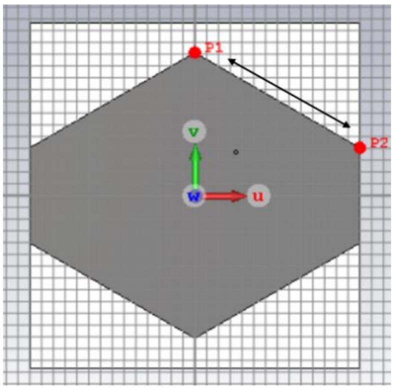


FIGURE 3.4 POINT TO DESIGN HEXAGON

- Calculation of the ground plane dimensions (Lg and Wg ground plane is assumed of infinite size): Ideally the in length and width but it is practically

$$L_g = L_p \tag{3.7}$$

$$W_g = W_p + 6h \tag{3.8}$$

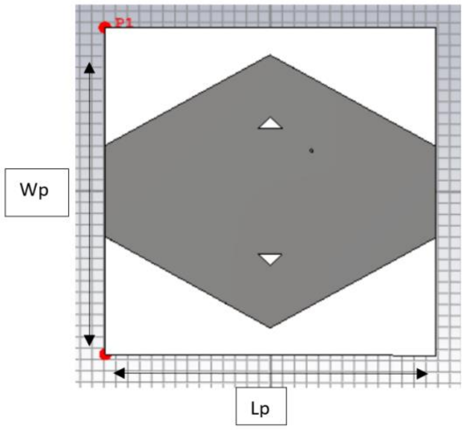


FIGURE 3.5 WIDTH PATCH AND LENGTH PATCH

3.4 Design microstrip patch antenna

CST MWS 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 MWS software is very popular software for modelling several types of antenna for example RF, Optical, EMC/EMI and etc.

STEP 1: Run CST MWS software > Click New and Recent > Click New Template

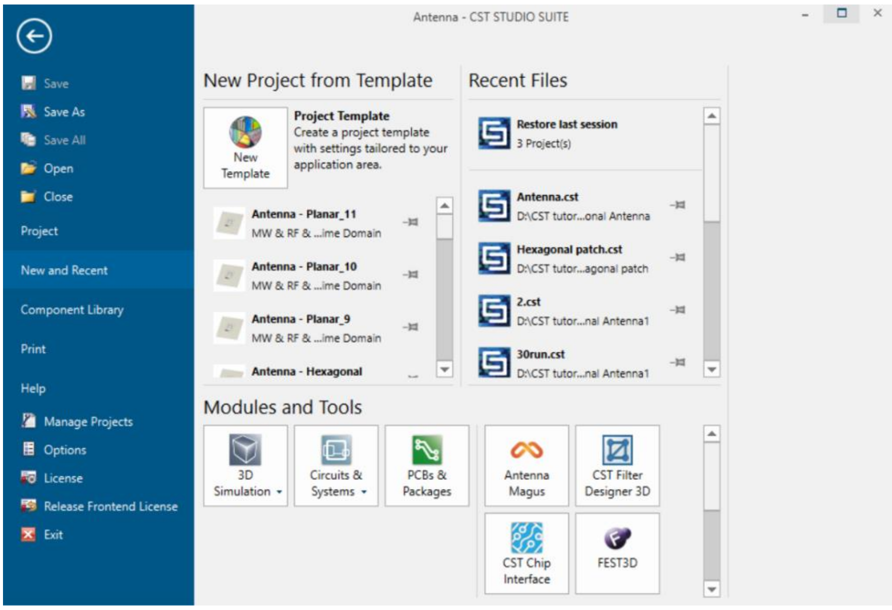


FIGURE 3.6 CREATING NEW PROJECT

STEP 2: Click MW & RF & OPTICAL > Click Antenna > Click Next

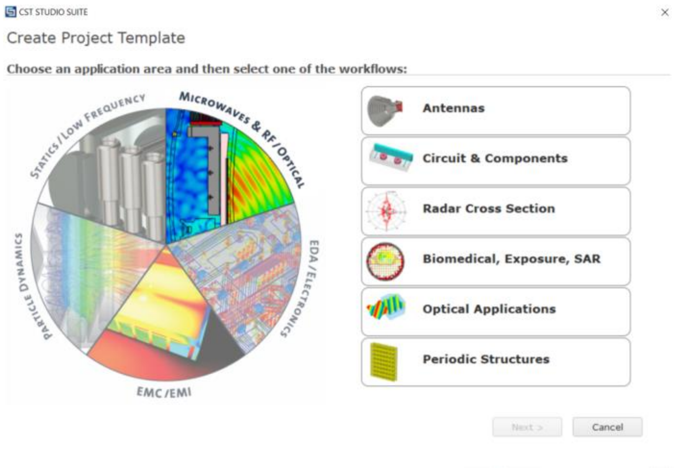


FIGURE 3.7 CREATING NEW TEMPLATE

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

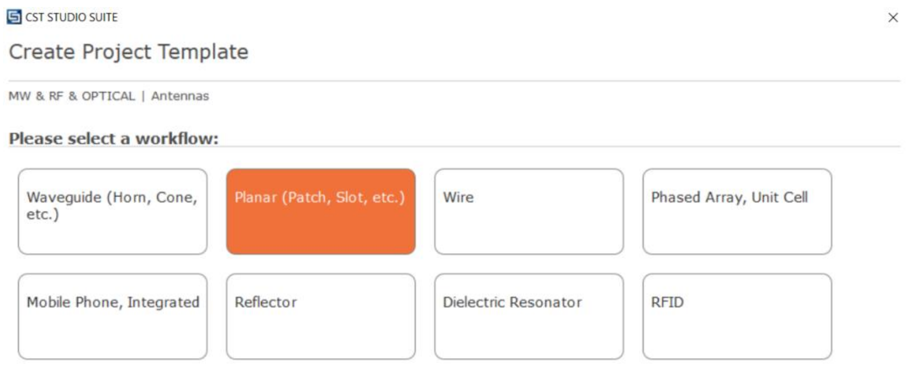


FIGURE 3.8 SELECTING WORKFLOW

STEP 4: Click Time Domain > Click Next

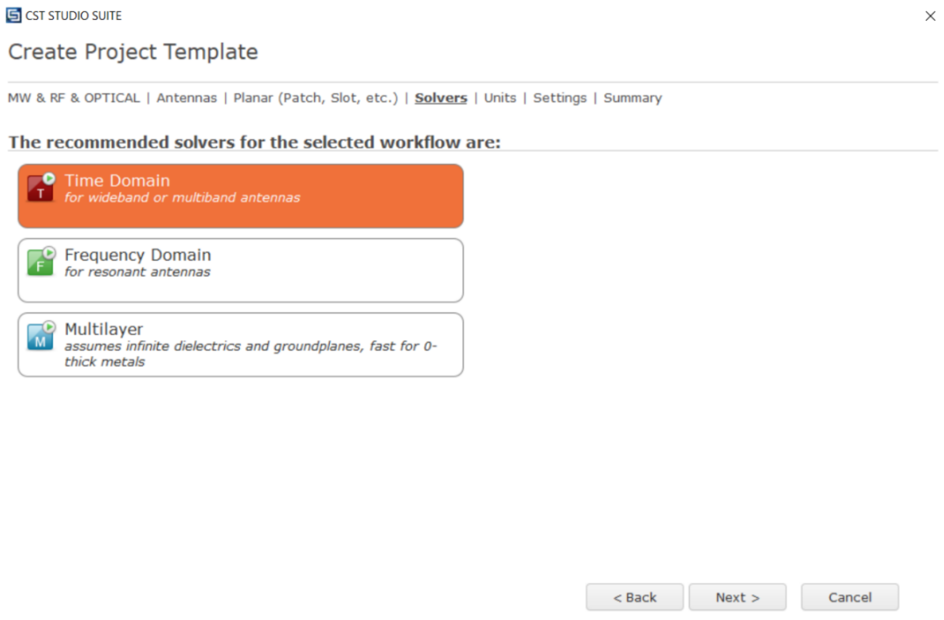


FIGURE 3.9 SELECTING SUITABLE SOLVER FOR WORKFLOW

STEP 5: Select the unit > Click Next

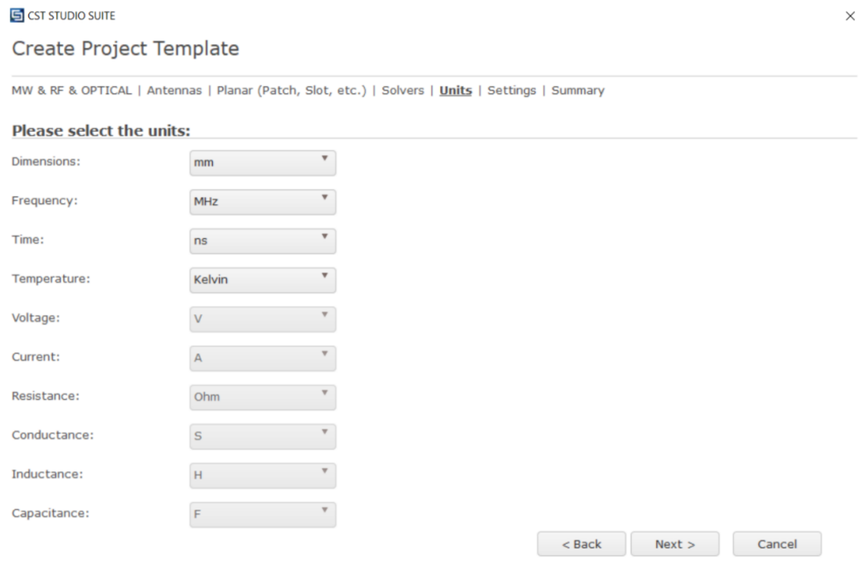


FIGURE 3.10 SELECTING THE SUITABLE UNIT FOR THE PROJECT

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

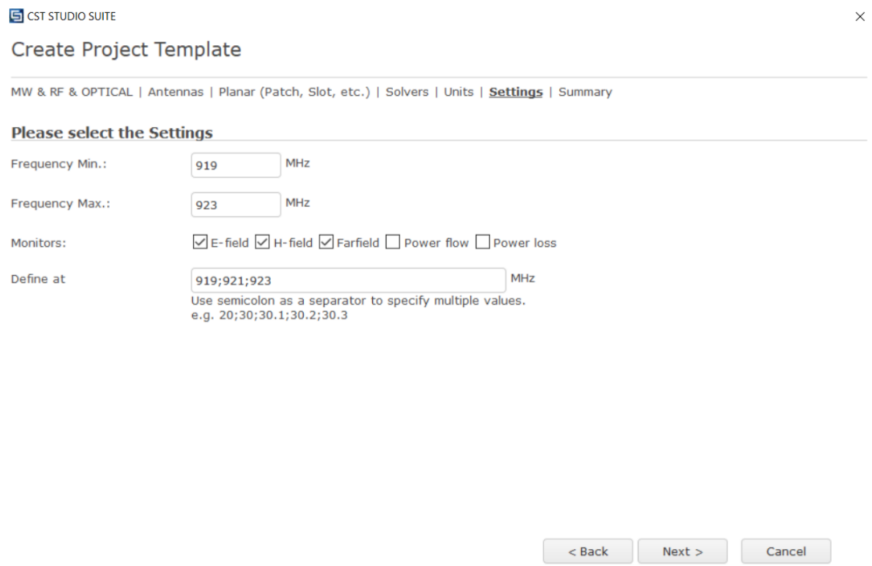


Figure 3.11 Selecting Frequency, Field to Monitor

STEP 7: Click Finish

Note: Make sure all information of the project is correct before clicking Finish.

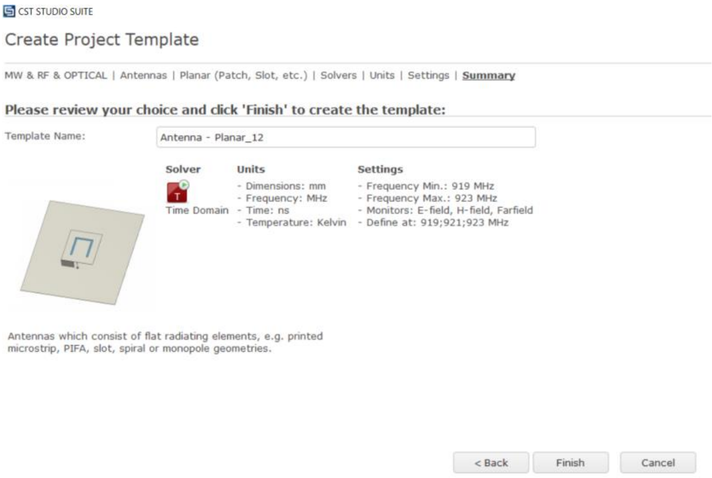


Figure 3.12 Creating the Project Template

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

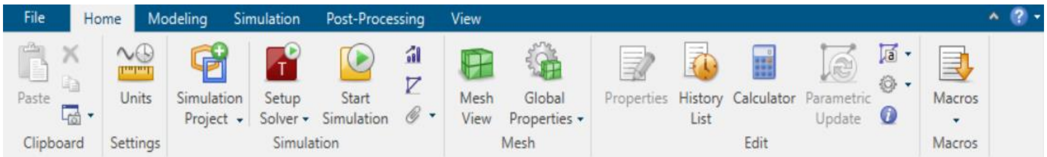


Figure 3.13 CST Toolbar to Start Designing Microstrip Antenna

STEP 9: Click Component at navigation tree > Select Antenna > Select Patch > Select Define brick > Enter the value.

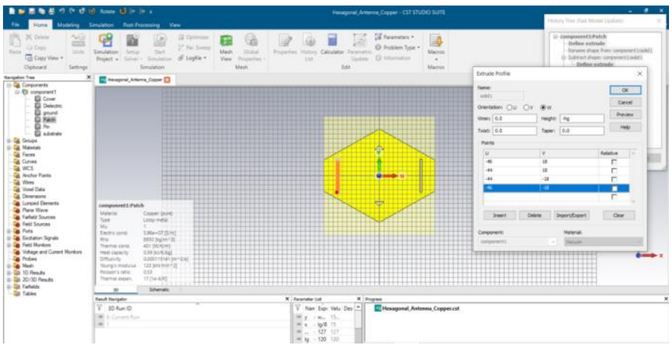


Figure 3.14 Creating the rectangular slot Antenna

STEP 10: Click Component at navigation tree > Select Antenna > Select Patch > Select Define brick > Enter the value.

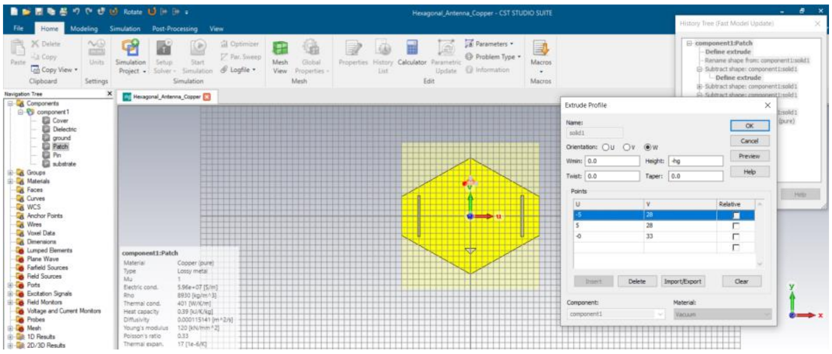


Figure 3.15 Create isosceles triangle

STEP 11: Select Pick > Pick the first point > Pick the second point

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

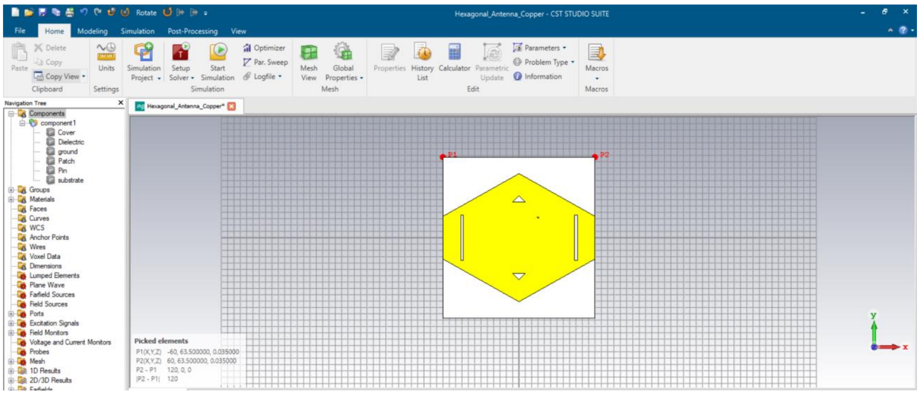


Figure 3.16 Determine the Dimension of The Antenna

3.5 Fabrication Process

3.5.1 Brush Cleaning Machine 305 mm Model RBM300

Figure 3.17 depicts a brush cleaning machine that is suitable for use in small industries and laboratories. The main purpose of this machine is to clean PCB boards and other metal surfaces to ensure that the surface of the material is free of dust and dirt before beginning another process. This machine is also capable of removing the oxide layer from the PCB board. The machine can be fitted with a variety of brushes to allow for the finishing of PCBs before lamination as well as minimal deburring after drilling. Aside from that, this machine is operated automatically via 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 until the cleaning process is complete.

Figure 3.17 Brush Cleaning Machine

3.5.2 PCB Board Drying Machine

The PCB board panel dryer machine, as shown in figure 3.18, was used to dry the PCB board after it had been cleaned. This unit chassis is made of high-quality stainless steel and has special features that remove and eliminate water from the PCB board after cleaning to avoid problems during the fabrication process. The stainless-steel bench top printed circuit board drying equipment uses a set of squeegees towelling rollers and a heated hot air knife to dry wet circuit boards. The device consists of four pairs of squeegee towel rollers: the first pair rotates in a shallow water tank with a water level detector, helping to capillary water trapped in the drilled holes; the second and third pairs of towel rollers remove extra moisture before the circuit board enters the heat zone, where the high output hot air blower removes additional moisture from both the surfaces of the circuit board and inside the holes; and the fourth pair of towel rollers restore moisture to the circuit board. When the board leaves the last set of rollers, it is then dried.

Figure 3.18 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 suitable for use in small laboratories. This unit includes a small control panel where the user can set the appropriate temperature and roller speed for applying dry film to the PCB board. The selection of temperature and roller speed is critical in the lamination process to avoid burning the dry film. To avoid problems during the etching process, ensure that the dry film and PCB board stick together without any bubbles after the lamination process. Before the film reaches the heated rollers, the laminator removes the polyofin cover sheet; these rollers then combine with heat and pressure the photo emulsion on both sides of the material. The rear cold pressure rollers continue to roll and attach the photo emulsion onto the material. The most important part that need to considered is room lighting. Philips TL 65 W 16 strip lights are ideal for room lighting as their spectrum has no effect on most photoresists.

Figure 3.19 Dry Film Photoresist Sheet Laminator

3.5.4 UV Double Sided Exposure Units with Vacuum

Figure 3.20 Vacuum UV Exposure Units are used for exposure photo sensitive material such as front plates, photo sensitive films, base materials or printed plates depicts. UV double-sided exposure units also suitable for double-sided PCB panels. This unit also had a small control panel and a digital display where the user could set the process time. The UV exposure units have been set at 30 seconds for this process to transfer the antenna layout on PCB film to the PCB board using a UV beam. Furthermore, this process must be carried out in a dark room to protect the dry film from damage prior to the etching process.

Figure 3.20 UV Double Sided Exposure Units with Vacuum

3.5.5 Rota Spray Developer Machine

In the developer process, the Rota spray developer machine (shown in figure 3.21) was used. The developer process must be carried out in order to remove the unwanted dry film that had covered the etching area on the PCB board. To avoid any accidents, use hand gloves and a face mask while carrying out this process. The step below explained the correct procedure to used developer machine:

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 has been removed.

Figure 3.21 Developer Machine

3.5.6 Acid Remover Machine / Etching Machine

As shown in figure 3.22, an acid remover machine, also known as an etching machine, was used for the etching process to remove unwanted copper on the PCB board that was not covered by dry film in order to form the angular slot. This machine contained acid capable of easily removing the copper layer on the PCB board. To reduce the possibility of an accident occurring during the process, personal protective equipment (PPE) such as hand gloves and face masks should always be managed to wear. The step below explained the correct procedure to used developer machine:

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 3.22 Acid Remover Machine

3.6 Antenna Testing

3.6.1 The Vector Network Analyzer

A vector network analyzer is a device that measures the frequency response of a component or a network made up of many components that can be passive or active. After the fabrication process is completed, the network analyzer depicted in Figure 3.23 will be used to evaluate the performance of the microstrip patch antenna. If the desired results cannot be obtained, the microstrip patch antenna must be redesigned using CST Microwave Studio 2019. This phase is critical for identifying potential discrepancies between the simulated structure, fabrication errors, and the effect of lead used to connect the PCB layer to the feed joint. The antenna must then be redesigned until all requirements for the desired antenna are met.

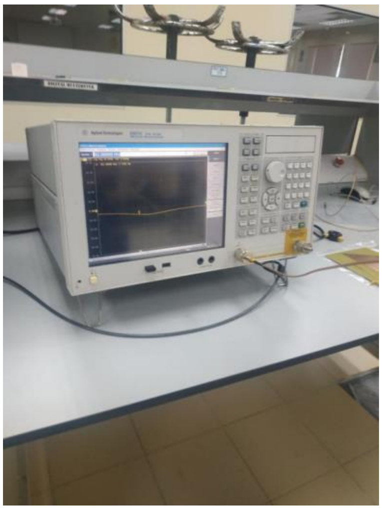


Figure 3.23 Microstrip Patch Antenna Tested Using Network Analyzer

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

The microstrip patch antenna was designed to detect a variable length passive tag. Then, run this test to determine the maximum recognition length between the antenna reader and the RFID tags. RFID labels the antenna reader and passive RFID tag were both placed at the same height, as shown in figure 3.24, and the maximum recognition length was tested and recorded. Then, repeat the procedure until all scope designs for different RFID tags have been recorded.

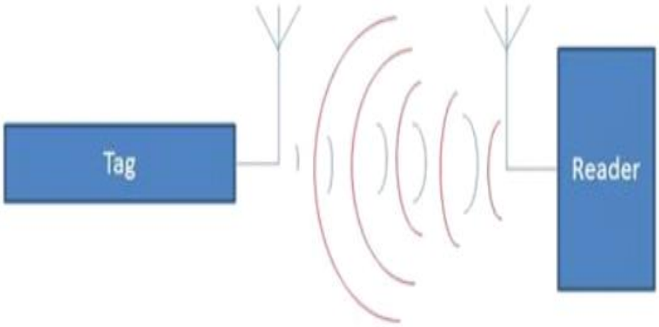


Figure 3.24 The Antenna and Tag at the Same Position

Figure 3.25 depicts the antenna reader that we used to conduct the antenna testing and its suitability for ultra-high frequency (UHF) coordination. The RFID reader is a device that tracks RFID tag data using radio waves. RFID systems are more advanced than barcode scanner systems. The RFID tag does not require a visible pathway to the reader and does not require a specific part to be detected. To be detected, the tag must be within the radio wave range.

Figure 3.25 RFID Reader

Table 3 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 Different Tag Types.

To investigate the antenna performance when the position of the tag changes in various angles, the antenna angle detection test must be performed. The angles to be tested in this test are 15°, 30°, 45°, 60°, 75° and 90°, with the tag placed on the field. We used one tag in this investigation that demonstrated the longest distance in length detection test we've ever done. Figure 3.26 depicts how the antenna angle test is carried out.

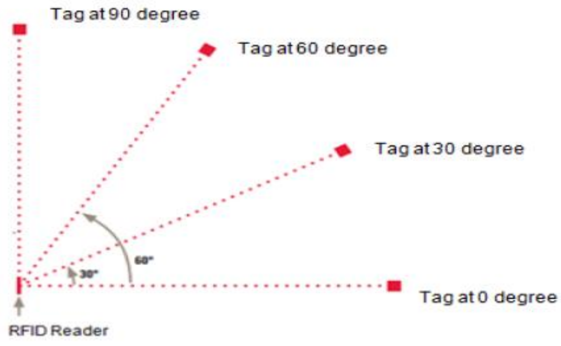


Figure 3.26 The Position of Antenna and Tag

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will discuss the performance of the proposed antenna in order to compare simulation, measured losses and s-parameters (S11). Operating frequency of 921 MHz and s-parameter (S11) is less than -10dB in simulation result also being proposed. This chapter also includes a voltage simulation result, the proposed antenna's standing wave ratio (VSWR) and gain. To ensure that the antenna can operate, the VSWR simulation result must be less than 2. In terms of detection range, the gain of the microstrip patch antenna is critical. It also plays an important role in the parametric study to determine the performance of the antenna in various antenna parameters. The design of patch antenna discussed the development and analysis of the antenna reader work carried out on the basic hexagonal patch antenna to produce linear polarization antenna.

4.2 The pattern of hexagonal Antenna

The figure 4.1 and figure 4.2 show the pattern of symmetrical rectangular slot antenna and symmetrical isosceles triangular slot antenna. The slot of antenna is fabricated from a single patch on top and ground patch is full covered with copper layer at the lower back. Table 4 is described full design dimension specification of antenna to work at the required resonant frequency of 921 MHz. All antenna parameter plays a big role in achieving the excellent efficient radiation pattern with adequate gain and directivity based on the working frequency. The equipment that available inside CST 2019 has been used to perform design of the antenna. Then, the fabricate antenna will be tested using Vector Network Analyzer (VNA) to figure out the antenna performance.

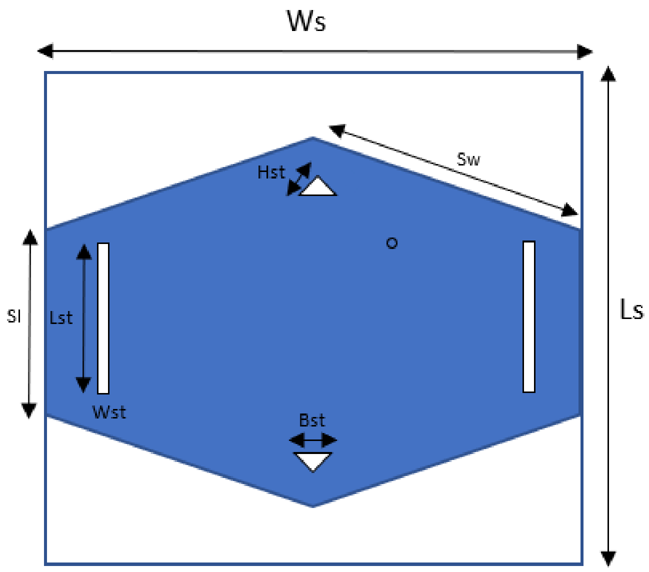


Figure 4.1 Front View of Antenna

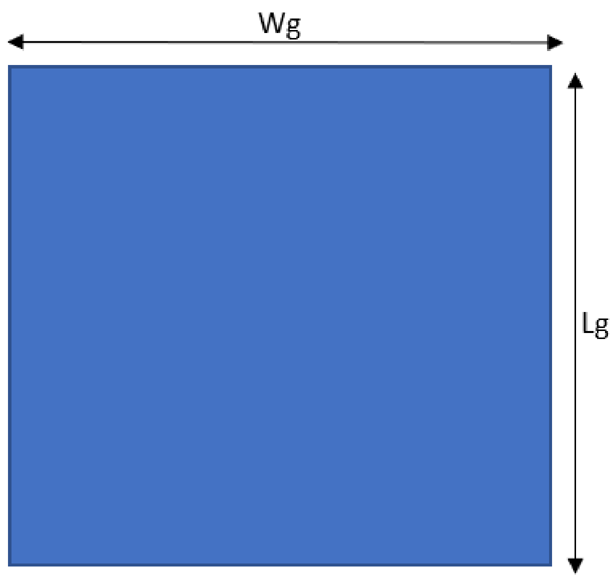


Figure 4.2 Back View of Antenna

Table 4 Specification of Antenna Design

Parameter		Label	Dimension(mm)
Patch	Length	Sl	33.67
	Width	Sw	68.80
Ground	Length	Lg	127
	Width	Wg	120
Rectangular Slot	Length	Lst	36
	Width	Wst	2
Triangular Slot	High	Hst	7.07
	Base	Bst	10
Substrate FR-4	Length	Ls	127
	Width	Ws	120
	Thickness	St	1.6
	Dielectric Constant	ε_r	4.7
SMA	Impedance	Ω	50

4.3 Simulation Result

4.3.1 Simulation Result of Return Loss

The power level of the antenna is reflected as a result of return loss (S11). It is also known as the reflection coefficient. When the return loss at a specific frequency is less than -10 dB, the antenna can operate. Aside from that, the antenna may be unable to operate when the return loss exceeds -10 db. The total radiated power to the antenna can be calculated using the results of the return loss (S11) simulation. Figure 4.3 shows the antenna operating at 921 MHz and -33 dB.

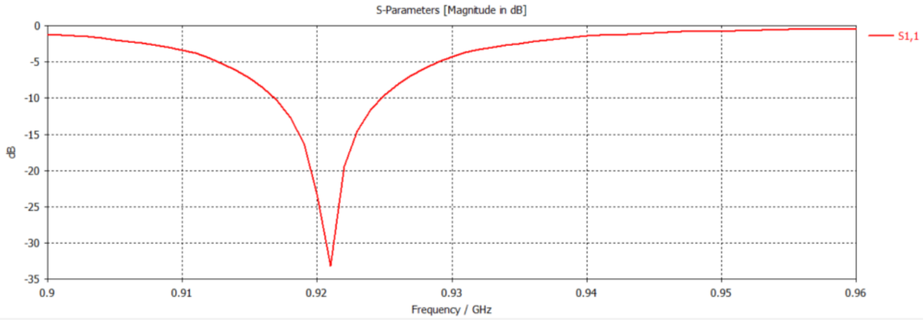


Figure 4.3 Simulation Result of Return Loss (S11)

4.3.2 Simulation Result of Voltage Standing Wave Ratio (VSWR)

The voltage standing wave ratio (VSWR) is the result of a relationship between a transmission line and a patch antenna. The VSWR value for a microstrip patch antenna must be less than 2 [5]. Aside from that, the VSWR value indicates how much power the antenna has in terms of reflection coefficient. It also indicates the maximum amount of power that can be delivered to the antenna. In general, the VSWR value must be less than 2 in order to produce a good-performing antenna. The figure below depicts the simulation result for this project's antenna design using CST MWS. It demonstrates that the value of VSWR is less than 2 at the frequency 921 MHz, which is considered a good result.

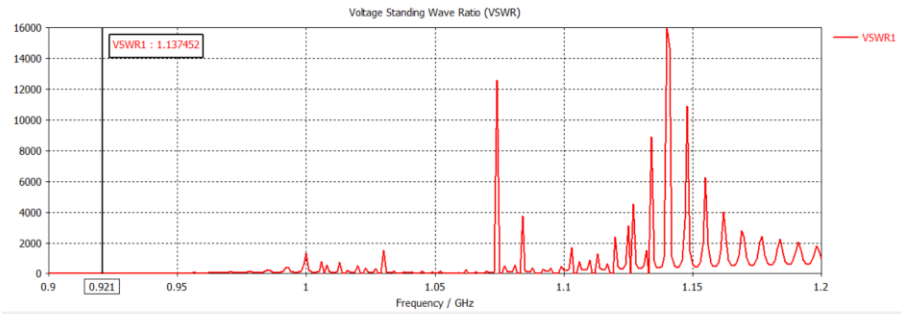


Figure 4.4 Simulation Result of VSWR

4.3.3 Simulation Result of Radiation Pattern

The simulation result of a radiation pattern can be used to determine information about radiated energy. In general, the radiation pattern of an antenna in polar form is 360 degrees [4]. The radiation pattern's red area indicates a good detection area for a long detection range. Based on the positive value of gain, the antenna can be detected in all directions. Figure 4.5 show the 3D radiation pattern with a patch antenna design that achieves 5.87 dBi at 921 MHz.

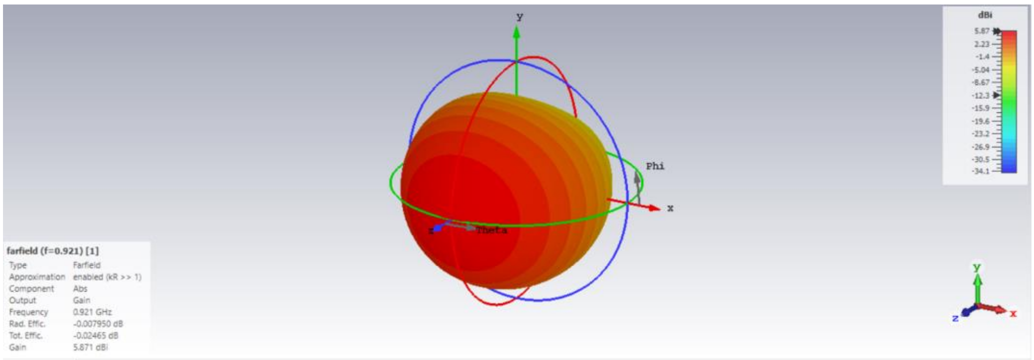


Figure 4.5 Simulation Result of Radiation Pattern

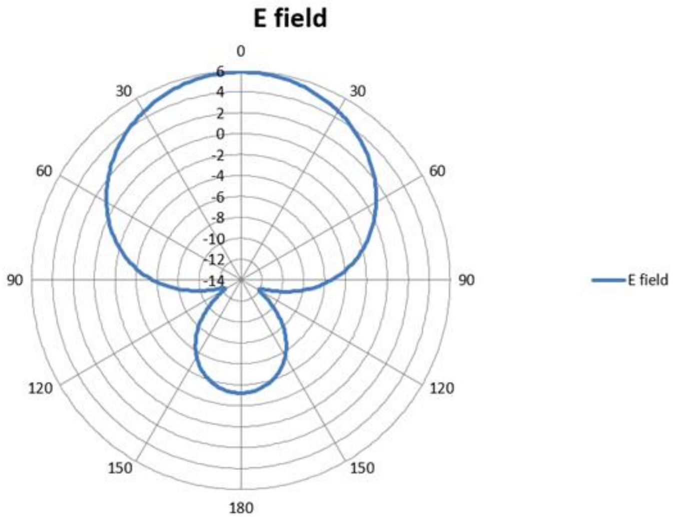


Figure 4.6 E-Plane

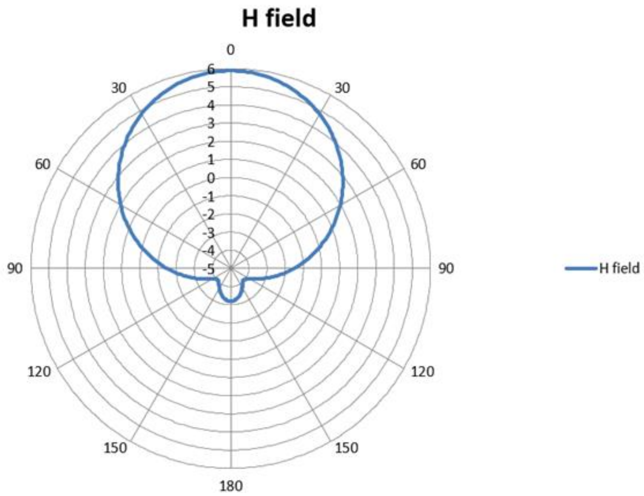


Figure 4.7 H-Plane

4.3.4 Simulation Result of Gain

This simulation result is also important for describing the performance of the antenna, whether it is operational or not. According to the simulation results, when connected to a power source, the antenna gain is capable of transmitting power in a specific direction. If the gain value is high and the assumed power can be transmitted into space at a specific angle or direction, the antenna could be powerful.

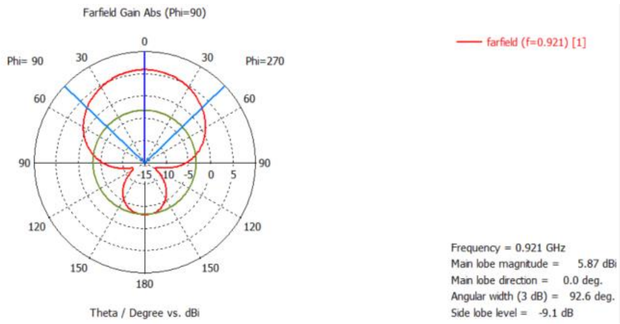


Figure 4.8 Simulation Result of Gain

4.4 Result of Antenna Testing

In this subchapter, the fabrication antenna will be tested to determine the antenna performance and efficiency. The test that will be execute such as antenna testing using vector network analyser, Antenna Length Detection Performance Field Test, and Antenna Angle Detection Performance Field Test. Then, the result will be discussed to determine the proposed antenna design performance.

4.4.1 Antenna Testing Using Vector Network Analyzer

In this examination, vector network analyser Agilent E5071C that available at ICOE lab in UMP will be used to determine the performance of actual antenna. This instrument is can support any antenna that perform at frequency 9 kHz to 8.5 GHz, then it suitable used for this examination. The main focus of this examination is to compared the simulation antenna performance and actual antenna performance in term of return loss (S11) value. Before this examination start, the vector network analyser needs to be calibrated first to make sure the reading from this instrument is accurate and avoid any loss occurred. Figure 4.9 and figure 4.10 shown the calibration kit and calibration tools has been used to calibrated the vector network analyser. The calibration process needs to be done by following the correct procedure as shown in figure 4.11 to make sure the vector network analyser works properly during antenna testing. After done the calibration process, the vector network analyser is ready to be used.

Figure 4.9 Calibration kit

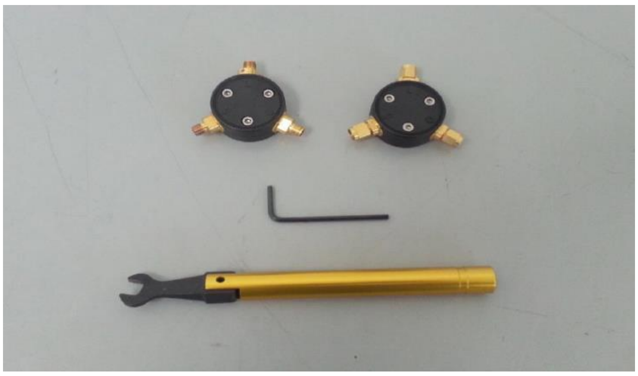


Figure 4.10 Calibration tool

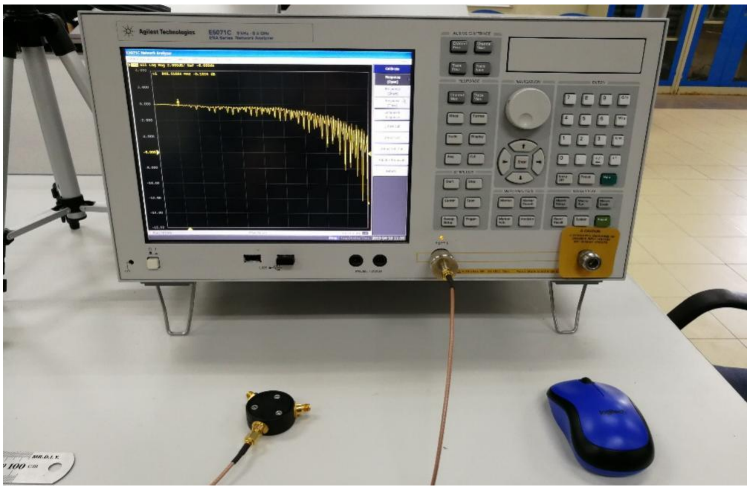


Figure 4.11 Vector Network Analyzer Calibration Process

After finish the antenna testing using vector network analyzer, figure 4.12 shown the comparison between simulation antenna result (CST) and actual antenna result (VNA) in term of return loss (S11) value. The actual antenna result is more lowers which is -23.71 dB compared to simulation antenna result which is -33.14 dB respectively at resonant frequency of 921 MHz.

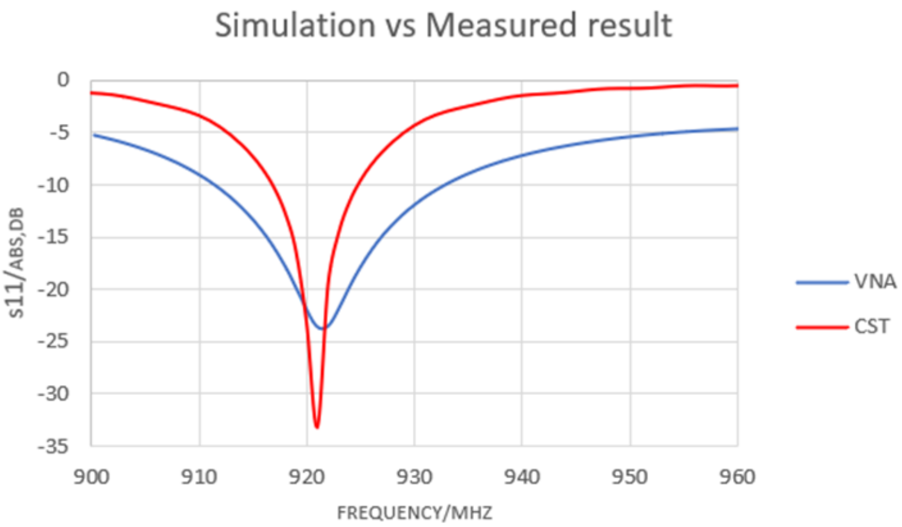


Figure 4.12 Comparison Result Between Simulation and Actual Antenna

4.4.2 Field Test of Length Detection Performance for Different Tags Type

Basically, there are many various of RFID tags that available in the industry. It also has different characteristics in tern of capacity of memory, frequency, detection length and size of tag. This examination will used eight different RFID tag which is AD-641, AD-833, AD-828, AD-223, AD-381, AD-232, A-9654 and H-47 as shown in the figure below. The purposed of this examination is to determine the distance of the tag can be track by antenna before losing the signal strength. By using the RFID system, the tag can be track and detect via radio wave. The figure 4.21 shows the correct configuration to execute this examination.

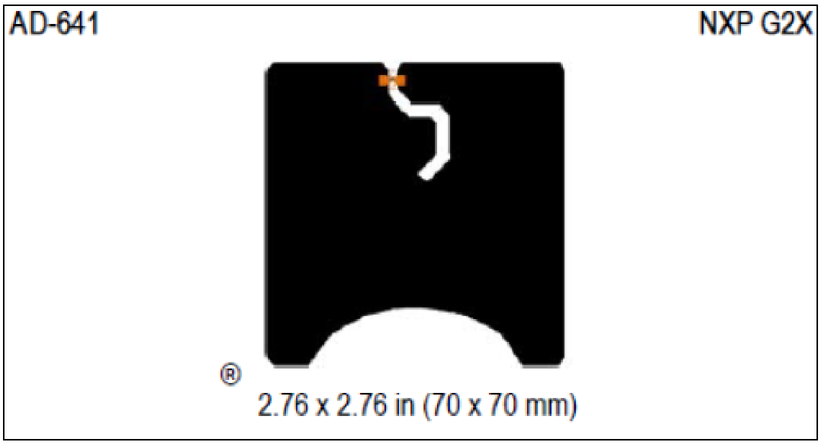


Figure 4.13 AD-641 UHF RFID Tag

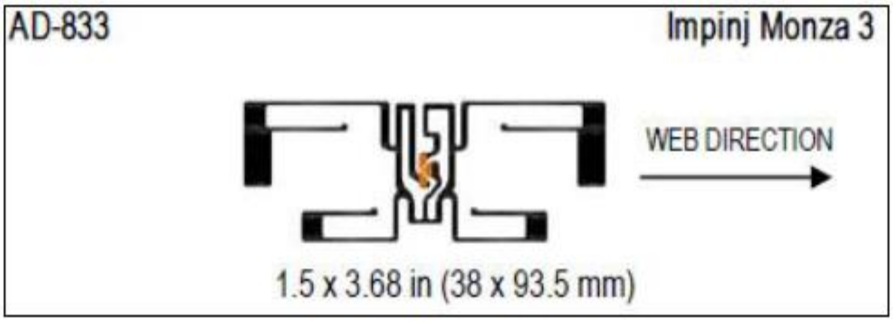


Figure 4.14 AD-833 UHF RFID Tag

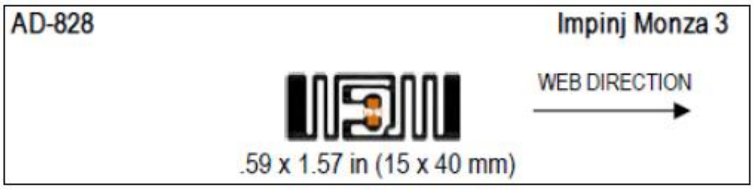


Figure 4.15 AD-828 UHF RFID Tag

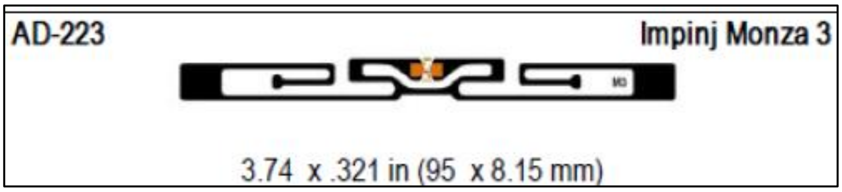


Figure 4.16 AD-223 UHF RFID Tag

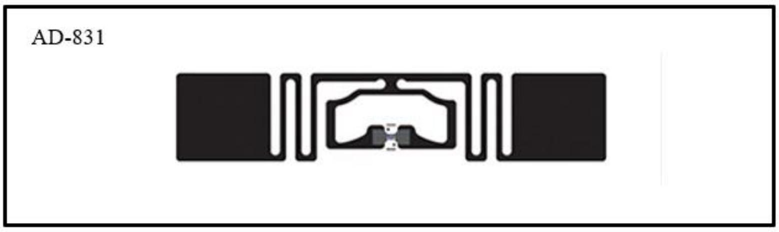


Figure 4.17 AD-831 UHF RFID Tag

Figure 4.18 AD-232 UHF RFID Tag

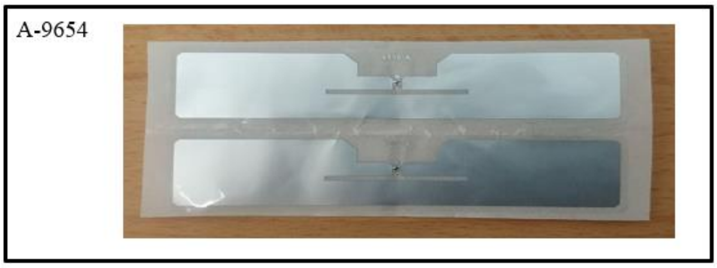


Figure 4.19 A-9654 UHF RFID Tag

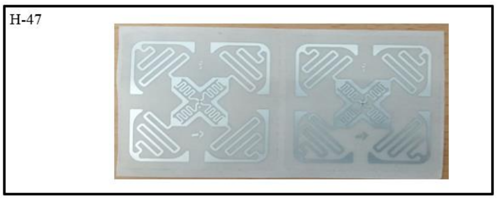


Figure 4.20 H-47 UHF RFID Tag

Figure 4.22 shows the result for all eight different tags after execute this examination. H-47 produces longest length of detection compared to other tags, and AD-232 produces shortest length of detection. The H-47 tag recorded 95 cm of length detection area followed by A-9654 with 89 cm and AD-833 with 82 cm of length detection area. Then, AD- 641 and AD-381 is 30 and 44 respectively. Lastly, AD-232 tag produces the shortest length detection area with 17 cm followed by AD-828 with 22 cm and AD-223 with 28 cm of length detection area. 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 4.21 Length Detection Performance Test Configuration

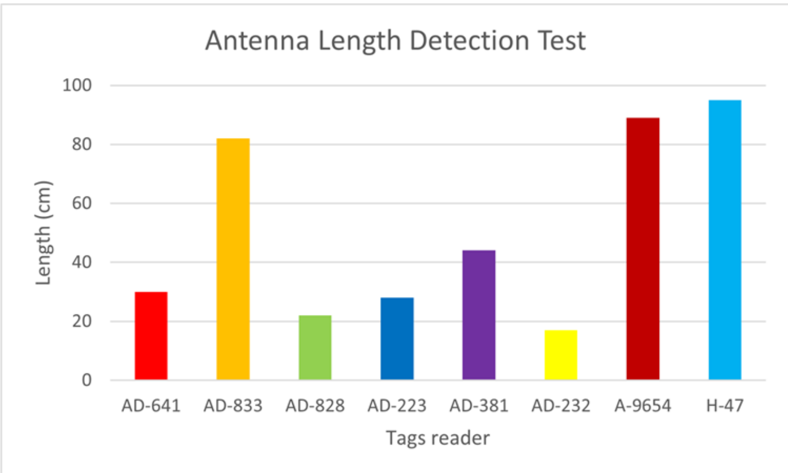


Figure 4.22 Result of Antenna Length Detection Test

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

The antenna angle detection performance field test was executed to determine the change of maximum length detection area when the angle of antenna reader changes. This examination also studies the effective angle of antenna to capturing data from tags. The figure 4.23 shows the correct configuration to execute this examination. Then, six angles have been picked to executed this examination which is 15°, 30°, 45°,60°, 75° and 90°. This examination also used tags that produces longest length detection area, then the H-47 has been selected.

Figure 4.23 shows the result after this examination finished.

At 15 and 30 angles shown the antenna can captured the data from the tag with 75cm and 80 cm respectively of detection length. Then, the angle of antenna was change to 45 angle and the result shows the antenna successful to captured the data from tag at 83 cm of detection length before losing the data signal. When the angle of antenna was adjusted to 60 angles, the length of detection increases slowly from 83 cm to 89 cm for antenna to detect and captured data from tag. Lastly, the antenna angle was change to 75 and 90 and the result of detection length is rises up to 92 cm and 103 cm respectively. The conclusion can be made is, 90 angles of antenna produce impressive detection length because the position tag and antenna are directly perpendicular to make the antenna easier to detect and captured the data from the tag.

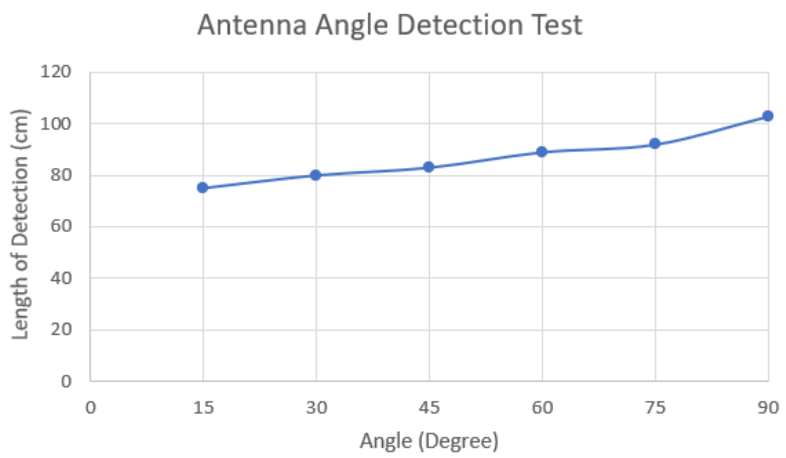


Figure 4.24 Result of Antenna Angle Detection Test

4.5 Parametric Study

In this subchapter will be study about the effect of antenna performance due to changes of the patch antenna geometric parameter. The parametric study was covered the change of length of antenna patch, rectangular slot, triangular slot, and substrate thickness to determine the effect of antenna performance depends on change of working frequency and return loss (S11). The change of the parameter study was carried out using the CST Microwave 2019 software. The structure of antenna parameter that will study on this subchapter as shown in figure 4.25.

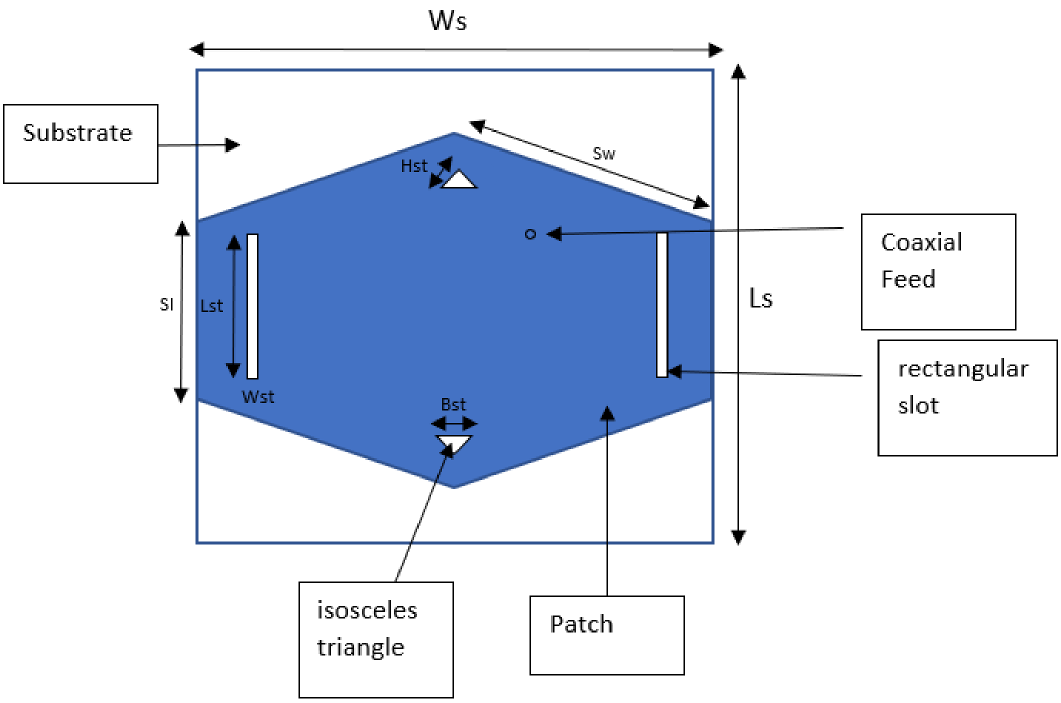


Figure 4.25 Antenna Parameter

4.5.1 Length of Patch

This examination was executed to determine the effect of antenna performance due to changing of patch length. By maintaining the other antenna parameter and changing patch length value, the effect of antenna performance can be determined from the changing on working frequency and return loss. Figure 4.25 shows the effect on the proposed microstrip patch antenna due length of patch changes. By decreasing the length of patch to 100mm, the resonant frequency rises up from 921 MHz to 929 MHz and the value of return loss also improved from -33.14 dB to –43.58 dB respectively. Then, by increasing the diameter of patch to 102 mm, the resonant frequency drops off from 921 MHz to 913 MHz but improved the return loss value from -33.14 dB to -33.32 dB. This examination also decreasing and increasing the patch diameter by 99 mm and 103 mm and the result is shows by blue (99 mm) and purple (103 mm) line. The conclusion can be made is, if the length of the patch antenna increases, the value of frequency will be decreasing and the value of S11 will be improved.

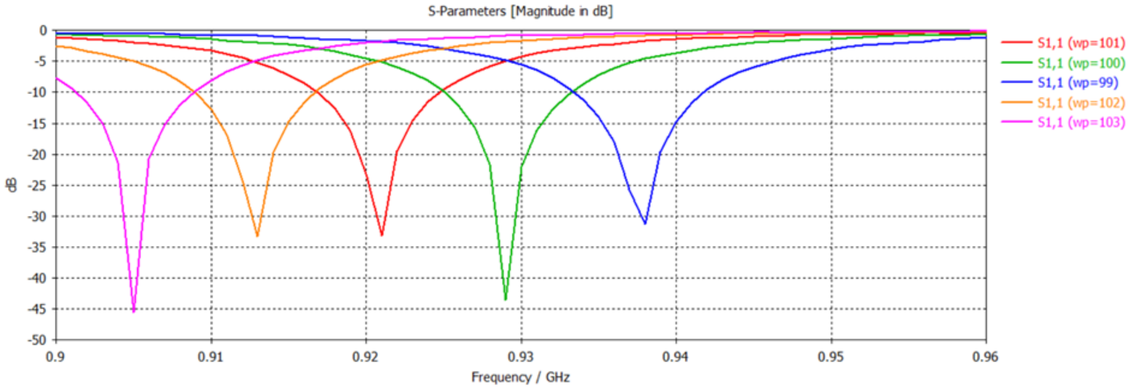


Figure 4.26 Return Loss and Resonant Frequency Effect Due to Changes the length of patch Antenna

4.5.2 Isosceles triangular Slot

Figure 4.27 shows the effect of antenna performance due to changing of base isosceles triangle. In this examination, all parameter such as diameter of patch, thickness of substrate, and rectangular slot are fixed. Originally, the base of isosceles triangle is 10mm and the result of the return loss and working frequency shows at figure below is red line (S1,1). By decreasing the length slot to 9 mm, the resonant frequency remains the same (921MHz) and the return loss (S11) value change from -33.14 dB to -27.93 dB. Then, by increasing to 11 mm, the resonant frequency also maintains 921 MHz. It also decreases the value of return loss (S11) from -33.14 dB to -29.53 dB. This examination also decreasing and increasing the base 8 mm and 12 mm and the result is shows by green (8 mm) and purple (12 mm) line. In conclusion, the antenna produced high working frequency and improved their return loss (S11) at base equal to 10mm.

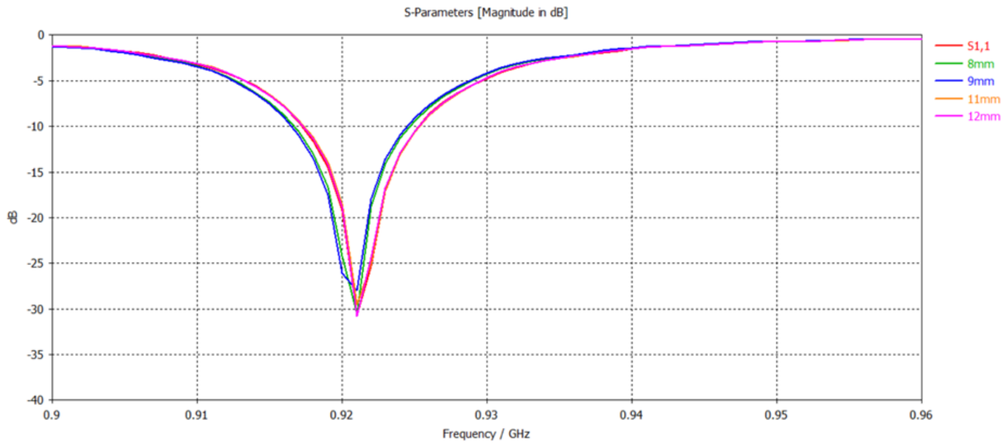


Figure 4.27 length of base for isosceles triangle slot vs s11

4.5.3 Rectangular Slot length

Figure 4.28 illustrate the effect of antenna performance due to changing slot length for rectangular slot. The changing of resonant frequency and return loss (S11) is the main factor to determine the antenna performance. In this examination, all parameter such as diameter of patch, thickness of substrate, and isosceles triangular slot are fixed. the original and the simulation result shows at figure below that represent in red line (S1,1). By decreasing the length to 35mm the resonant frequency remains the same 921 MHz, but the return loss (S11) changes from -33.14 dB to -30.70 dB. Then, by increasing length to 37 mm, the resonant frequency also maintains 921 MHz. It also changes the value of return loss (S11) from -33.14 dB to -31.45 dB. This examination also increasing and 34 mm and 38 mm, the result represents in purple and yellow line respectively. The conclusion can be made after this examination is by increasing the rectangular slot length, resonant frequency maintain 921 MHz until length change to 38 mm (920 MHz) and the antenna performance has the best return loss (S11) at 36mm.

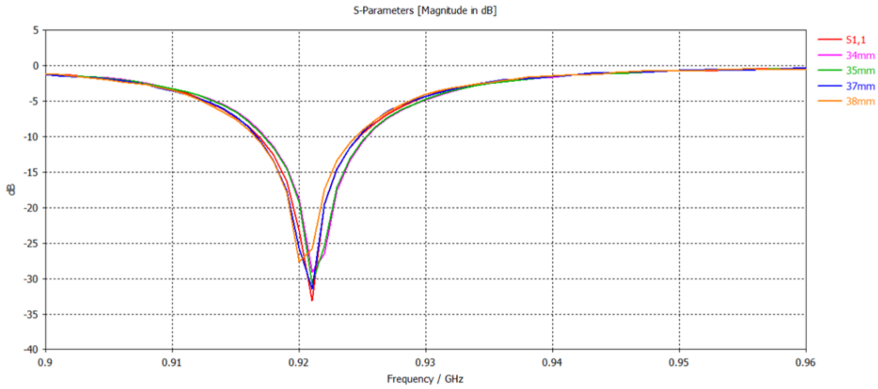


Figure 4.28 Symmetrical slot length of rectangular slot vs s11

4.5.4 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, triangular isosceles and rectangular slot is fixed. The thickness of substrate has been used in this examination which is 1.5 mm, 0.8 mm and 0.4 mm. The simulation results as shown in figure 4.28 after changing the thickness of substrate to 1.5 mm, 0.8 mm and 0.4 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 930 MHz of working frequency and -7.69 dB of return loss. In this condition, the antenna cannot function properly because all of microstrip patch antenna start working properly when the value of return loss is below -10 dB and in industry the passes value for S11 is below than -8 dB. Then, by increasing the thickness of substrate from 0.4 mm to 0.8 mm, the working frequency drop from 930 MHz to 927 MHz and it's improved the value of return loss from -7.69 to -18.33 dB. Lastly, at 1.5 mm of thickness substrate the working frequency drop from 927 MHz to 922 MHz which is near to average ultra-high frequency for Malaysia (921 MHz). It also improved the return loss from -18.33 dB to -36.98 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 this proposed antenna design.

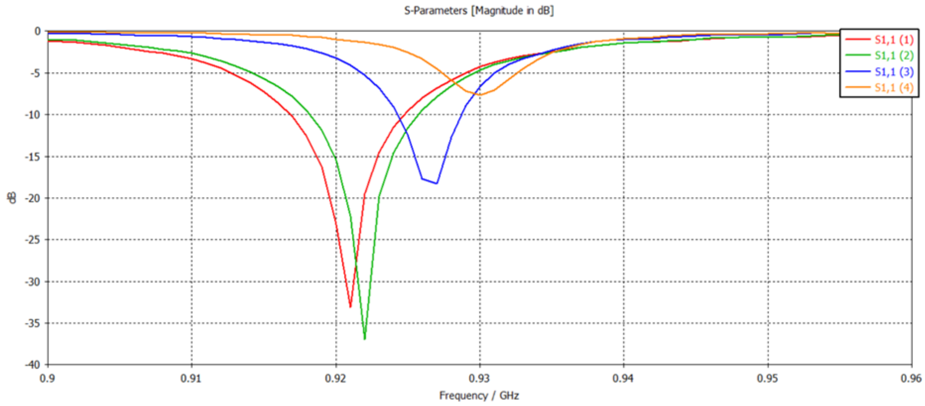
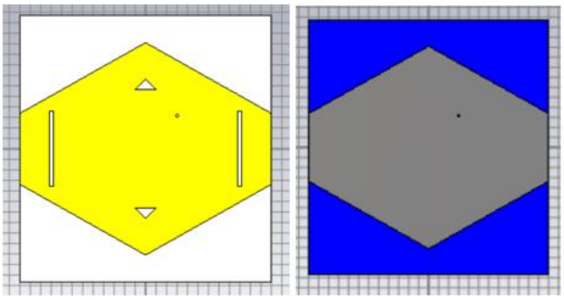


Figure 4.29 Return Loss and Resonant Frequency Effect Due to Changes of Substrate Thickness

4.6 Comparison Hexagonal Antenna with slot and without slot



(a) (b)

Figure 4.30 Hexagonal Antenna: (a) with slot and (b) without slot

The comparison results between Hexagonal Antenna with slot and without slot as shown in figure 4.30. By referring from the result, the slot patch antenna produces a good value of return loss (S11) which is -33.14 dB at 921 MHz of working frequency compared to the return loss that produces by Hexagonal Antenna without slot is -23.83 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, slot give high impact to return loss (S11). Other than that, the size of hexagonal patch antenna will be decreased by applying slot on it and produces a good return loss (S11) at 921 MHz.

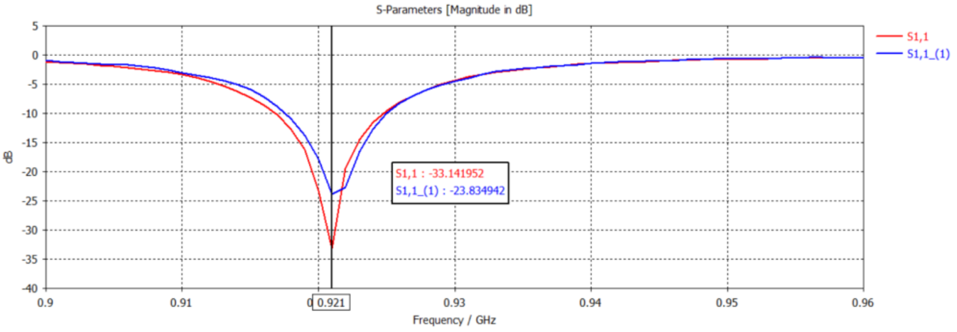


Figure 4.31 Comparison Result Between Hexagonal Patch Antenna without slot and with slot

CHAPTER 5

CONCLUSION

5.1 Introduction

Nowadays, there is a lot of application that use RFID and there is a lot of research have been in design and develop microstrip antenna. One of the reasons, why the cost of this application rising is the growing popularity of wireless applications used for a wide variety of business purposes. The main function of this antenna system in terms of item identification it works to mark animals, objects, and people with its passive transponder (tag) and to consume little power in wireless sensor networks. The two types of microstrip patch antennas, on the other hand, can be powered in either circular or linear polarisation. In this study, a microstrip patch antenna with hexagonal patch and linear polarisation was designed, stimulated, fabricated, and tested. The antenna design was created using CST Studio Suite 2019. Throughout the project, all of the positive and negative aspects of the microstrip patch antenna had been discussed in detail.

The objectives to develop and implement slot for size reduction of the antenna design and use small size of antenna in RFID application had been achieved. The same achievement also proved in reducing the budget of the antenna design by using FR-4 substrate. The project was successful design a microstrip patch antenna with hexagonal patch for UHF RFID that's can be operate in Malaysia assigned frequency which are located from 919 MHz – 923 MHz with centre frequency set at 921 MHz or 0.921 GHz in average value and effectively energize the linear polarization. The low-cost material which is FR-4 has been used with 4.7 of dielectric constant, 0.0019 of loss tangent and high that equal to 0.16 cm. The overall size of the antenna is designed with dimensions of 12.0 cm x 12.7 cm x 0.16 cm. This design is coaxial feed by 50 Ω SMA connector. Simulation Result of Return Loss (S11) before adding slot = -23.83 dB and after adding slot = -33.14 dB. The gain after adding slot also increase to 5.87 dBi from 5.39 dBi

5.2 Future work

This microstrip patch antenna with hexagonal patch 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 and in size reduction method. Others can investigate the configurations antenna of UHF RFID reader from this review. For this project, linear polarization was obtained. Different kind of energize either circular or linear polarization can be found in the antenna. The hexagonal patch can be changed for single feed square polarization in form of square patch and also can change the feeding method to analyse the different. 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. To achieve a more precise and efficient result, we must replace the high-quality substrate. A better antenna testing result can be obtained by fabricating the antenna on the new high precision machine. Different designs can be focused on increasing efficiency and decreasing impedance. There are numerous designs for microstrip patch antennas, including square, triangular and polygonal. After this study, it can be applied and examined to provide a solid execution of patch antenna with linear polarisation and energises more.

5.3 Impact to Society and Environment

Microstrip antennas are now used in a variety of applications that operate at a specific frequency. If the antenna meets their specifications, it can operate at either a low or high frequency range. The antenna will be light and small if the frequency is too high, such as in the UHF and MF frequency ranges. These antenna applications can operate and be integrated as linear or planar arrays. It can be used to generate an antenna with polarisation patterns of linear, circular, and elliptical electromagnetic radiation. These antenna specifications are already well known for their performance and range of application. Microstrip antenna research and development should be continued.

It is expected that it will replace traditional antennas in many other applications around the world. Some upgraded application antennas had a significant impact on people, society, and the environment. This is visible in remote sensing systems, satellite communications systems, and direct broadcast television systems. To function effectively in the electromagnetic spectrum, typical antennas rely on size. If the antenna is not long enough to resonate at the desired frequency, it will be unable to transmit or receive electromagnetic waves efficiently. When it comes to military and consumer electronics, smaller is often better.

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APPENDIX A
SAMPLE APPENDIX 1

APPENDIX B
SAMPLE APPENDIX 2