A FUNDAMENTAL STUDY ON THE CIRCULAR POLARIZATION ANTENNA FOR RFID UHF READER

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ABSTRACT

A FUNDAMENTAL STUDY ON THE CIRCULAR POLARIZATION ANTENNA FOR RFID UHF READER

(***Keywords: Ultra High Frequency, Voltage Standing Wave Ratio, Radio Frequency Identification, Return Loss***)

A few years after the early investigation on ultra-high frequency (UHF) wireless system, considerable research efforts have been put into the design of UHF antennas for radio frequency identification systems. These UHF antennas are essential for providing wireless communications based on the use of very narrow pulses on the order of nanoseconds, covering a small bandwidth in the frequency domain, and over very short distances at very low power densities. In this project, new models of rectangular, T slotted and angular slot UHF antennas are proposed by studying their parameters of antennas such as return loss, gain, radiation pattern and voltage standing wave ratio. The wideband behavior is due to the fact that the currents along the edges of the slots introduce an additional resonance, which, in conjunction with the resonance of the main patch, produce an overall frequency response characteristic. These antennas are considerable small than others listed in the references, which their sizes are less than a wavelength, compact, and suitable for many RFID applications. The configuration of slots type for both patches and pin feed are considered as a novelty and contribution in this project. The geometry of the antenna implies the current courses and makes it possible to identify active and neutral zones in the antenna, thus it will be possible to fix which elements will act on each characteristic. This project also investigated the ability of slotted UHF antennas to improved read range and gain between tags and UHF RFID Reader within the same field test environment. Inserting a half-wavelength slot structure with additional small patches gap attached have resulted frequency notched band characteristics. The measured return loss, radiation patterns, and phase agree well with the simulated results. The antenna provides a directional pattern with the return loss less than -10 dB and circular in phase.

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ABSTRAK

KAJIAN ASAS BAGI ANTENA BERPOLARISASI MEMBULAT BAGI KEGUNAAN PEMBACA PENGENALAN FREKUENSI RADIO PADA FREKUENSI ULTRA TINGGI

(***Kata Kunci: Frekuensi Ultra Tinggi, Nisbah Voltan Gelombang Berdiri, pengenalan frekuensi radio, hilangan kebalikan***)

Beberapa tahun setelah peneraju asal pada pengenalan frekuensi radio (RFID), sokongan penyelidikan telah ditumpukan pada reka bentuk antena frekuensi ultra tinggi (UHF). Antena UHF ini sangat diperlukan dalam penyediaan komunikasi tanpa wayar berasaskan penggunaan denyut yang sangat sempit dalam kiraan nano saat, meliputi jalur yang sangat lebar dalam domain frekuensi, dan mencakupi jarak yang sangat pendek pada kerapatan tenaga yang sangat rendah. Dalam projek ini, model terbaru antena UHF terselot-segiempat tepat, T dan berasaskan sudut di cadangkan dengan mengkaji antenna performance melalui parameter-parameter bagi antenna seperti nisbah volatan gelombang berdiri, gandaan antenna, gandaan arah, hilangan kebalikan, jalur lebar dan bentuk sinaran radiasi. Perilaku jalur lebar disebabkan pada kenyataan bahawa arus disepanjang tepian selot memperkenalkan satu resonan tambahan, yang mana ianya berkaitan dengan resonan tampal asas, sehingga menghasilkan keseluruhan karakteristik sambutan frekuensi. Antena-antena ini berukuran lebih kecil bila diperbandingkan dengan antena lainnya yang tersenarai dalam rujukan, ukurannya lebih kecil daripada satu panjang gelombang, padat, dan sangat sesuai digunakan untuk pelbagai aplikasi RFID. Konfigurasi jenis selot pada kedua tampal dan jalur suapan adalah novelty dan sebagai kontribusi dalam projek ini. Geometri antena mempengaruhi arah arus dan dengan menentukan zon aktif dan neutral pada antenna, maka elemen yang sesuai dapat ditentukan bagi setiap karakteristik. Projek ini juga mengkaji kemampuan antena meningkatkan kadar bacaan dan gandaan diantara pembaca RFID dan juga tag dalam persekitaran kawasan pengujian yang sama. Kemasukan sebuah struktur selot separuh panjang gelombang dengan penambahan sela tampal yang kecil berjaya menghasilkan karakteristik frekuensi notched band. Sela tampal yang kecil ini digunakan bagi mewakili suatu suis. Keputusan pengujian seperti kehilangan kembali, corak sinaran dan fasa didapati menepati keputusan simulasi. Antena ini memberikan corak sinaran semua arah dengan kehilangan kembali kurang daripada -10 dB dan mempunyai sambutan fasa yang membulat.

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TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENTS **ii**

ABSTRACT **iii**

ABSTRAK **iv**

TABLE OF CONTENT **v**

LIST OF TABLES **xi**

LIST OF FIGURES **xii**

LIST OF SYMBOLS **xvi**

LIST OF ABBREVIATIONS **xvii**

CHAPTER 1 INTRODUCTION **1**

1.1 Background 1

1.2 Introduction to Project 2

1.3 Problem Statement 2

1.4 Objective of Study 4

1.5 Project Scope 4

1.6 Thesis Outline 4

CHAPTER 2 LITERATURE REVIEWS **6**

2.1 Introduction of Antenna 6

2.2 Microstrip Patch Antenna 6

2.2.1 Advantages and Disadvantages of Microstrip Patch Antenna 7

2.3 Feeding Method 8
2.3.1 Microstrip Line Feed 8
2.3.2 Coaxial Feed 9
2.3.3 Proximity Coupled Feed 9
2.3.4 Aperture Couple Feed 10
2.4 Size Reduction Techniques 11
2.4.1 High Dielectric Constant 11
2.4.2 Shorting Post 11
2.4.3 Structural Modification 12
2.4.4 Perturbation and Plate Loading 12
2.5 Antenna Parameter 13
2.5.1 Directivity 13
2.5.2 Gain 13
2.5.3 Bandwidth 14
2.5.4 Axial Ratio 14
2.5.5 Radiation Pattern 14
2.5.6 Polarization 16
2.6 RFID Component 17
2.6.1 Basic Operation Of RFID 17
2.6.2 RFID Tags 17
2.6.3 RFID Reader 18
2.6.4 RFID Antenna 19
2.6.5 RFID Frequency Range 21

CHAPTER 3 METHODOLOGY 22

3.1 Microstrip Patch Antenna Design 22

3.1.1 Antenna Research 23

3.1.2 Antenna Design with CST Microwave Studio 2014 23

3.1.3 Simulation Process 23

3.1.4 Fabrication Process 24

3.1.5 Antenna Testing 24

3.2 Design Specification 25

3.3 Design Procedure 25

3.3.1 Design Simulation 27

3.3.2 Calculation of Patch Dimension 27

3.4 Design Microstrip Patch Antenna Using CST MWS 28

3.5 Fabrication Process 35

3.5.1 Brush Cleaning Machine 305 mm Model RBM300 35

3.5.2 PCB Board Drying Machine 35

3.5.3 Dry Film Photoresist Sheet Laminator 36

3.5.4 UV Double Sided Exposure Units with Vacuum 37

3.5.5 Rota Spray Developer Machine 37

3.5.6 Acid Remover Machine / Etching Machine 38

3.6 Antenna Testing 39

3.6.1 The Vector Network Analyzer 39

3.6.2 UHF RFID Reader Antenna Length Detection Performance Field Test for Difference Tag Types 40

3.6.3 UHF RFID Reader Antenna Angle Detection Performance Field Test for Different Tag Types. 41

CHAPTER 4 MICROSTRIP PATCH ANTENNA WITH ANGULAR SLOT FOR UHF RFID READER 43

4.1 Introduction 43

4.2 The Geometry of Purpose Angular Slot Antenna 43

4.3 Simulation Result 45

4.3.1 Simulation Result of Return Loss 45

4.3.2 Simulation Result of Voltage Standing Wave Ratio (VSWR) 46

4.3.3 Simulation Result of Radiation Pattern 46

4.3.4 Simulation Result of Gain 48

4.4 Result of Antenna Testing 48

4.4.1 Antenna Testing Using Vector Network Analyzer 48

4.4.2 Field Test of Length Detection Performance for Different Tags Type 51

4.4.3 UHF RFID Reader Antenna Angle Detection Performance Field Test for Different Tag Types 54

4.5 Parametric Study 55

4.5.1 Diameter of Patch 56

4.5.2 Radius of Upper and Lower Slot 57

4.5.3 Angle of Upper and Lower Slot 58

4.5.4 Substrate Thickness 59

4.6 Comparison Angular Slot Circular Patch Antenna between Circular Patch Antenna 60

CHAPTER 5 CIRCULAR SHAPED PATHC ANTENNA WITH RECTANGULAR SLOT 62

5.1 Introduction 62

5.2 Final Design of UHF RFID Microstrip Patch Antenna 62

5.2.1 Simulated and Measured Return Losses 62

5.2.2 Simulated Radiation Pattern 64

5.2.3 Simulated VSWR 66

5.2.4 Simulated Gain 66

5.3 Parametric Study 67

5.3.1 Asymmetric Slot Width 68

5.3.2 Asymmetric Slot Length 68

5.3.3 Substrate Permittivity 69

5.3.4 Diameter of Patch 70

5.4 Antenna Testing 71

5.4.1 Antenna Testing with Network Analyzer 71

5.4.2 Field Test of Length Detection Performance for Different Tags Type. 73

5.4.3 Field Test of Angle Detection 74

5.5 Comparison of circular patch antenna with I-slot circular patch 75

CHAPTER 6 MICROSTRIP PATCH ANTENNA WITH T SLOT 77

6.1 Introduction 77

6.2 Final Design of UHF RFID Microstrip Patch Antenna 78

6.2.1 Simulated and Measured Return Losses 78

6.2.2 Simulated Radiation Pattern 79

6.2.3 Simulated VSWR 81

6.2.4 Simulated Gain 82

6.2.5 Parametric Study 83

6.2.6 Antenna Testing 90

CHAPTER 7 CONCLUSION 95

7.1 Introduction 95

7.2 Future work 96

7.3 Impact to Society and Environment 97

REFERENCES **98**

APPENDIX A – LIST OF PUBLICATION **100**

APPENDIX B – PRODUCT SPECIFICATION **116**

APPENDIX C – AWARDS/CERTIFICATE **117**

LIST OF TABLES

TABLE 2.1 RFID FREQUENCY CLASS 21

TABLE 3.1 MICROSTRIP PATCH ANTENNA SPECIFICATION 25

TABLE 3.2 READER SPECIFICATION 41

TABLE 4.1 SPECIFICATION OF ANTENNA DESIGN 45

LIST OF FIGURES

FIGURE 1.1 RFID SYSTEM 2
FIGURE 2.1 MICROSTRIP PATCH ANTENNA DIMENSION 7
FIGURE 2.2 MICROSTRIP LINE FEED 8
FIGURE 2.3 COAXIAL FEED 9
FIGURE 2.4 PROXIMITY COUPLE FEED 10
FIGURE 2.5 APERTURE COUPLE FEED 10
FIGURE 2.6 RECTANGULAR MICROSTRIP ANTENNA LOADED WITH SHORTING POST 11
FIGURE 2.7 PATCH WITH SLOT INSERTED 12
FIGURE 2.8 PERTURBATION AND PLATE LOADING 13
FIGURE 2.9 ANTENNA RADIATION PATTERN 15
FIGURE 2.10 TYPE OF ANTENNA POLARIZATION 16
FIGURE 2.11 RFID SYSTEM 17
FIGURE 2.12 (A) PASSIVE RFID TAG (B) ACTIVE RFID TAG 18
FIGURE 2.13 TYPE OF READER (A) STATIONARY (B) HANDHELD (C) MOUNTED 19
FIGURE 2.14 MICROSTRIP PATCH ANTENNA 20
FIGURE 2.15 RADIATION PATTERN OF ANTENNA 20
FIGURE 2.16 TYPE OF ANTENNA (A) DIPOLE ANTENNA (B) DUAL DIPOLE ANTENNA (C) FOLDED DIPOLE ANTENNA 21
FIGURE 3.1 FLOW CHART OF DESIGNING MICROSTRIP PATCH ANTENNA 22
FIGURE 3.2 ANGULAR SLOT OF CIRCULAR PATCH ANTENNA 26
FIGURE 3.3 RECTANGULAR SLOT OF CIRCULAR PATCH ANTENNA 26
FIGURE 3.4 T SLOT OF CIRCULAR PATCH ANTENNA 27
FIGURE 3.5 CREATING NEW PROJECT 29
FIGURE 3.6 CREATING NEW TEMPLATE 29
FIGURE 3.7 SELECTING WORKFLOW 30
FIGURE 3.8 SELECTING SUITABLE SOLVER FOR WORKFLOW 30
FIGURE 3.9 SELECTING THE SUITABLE UNIT FOR THE PROJECT 31
FIGURE 3.10 SELECTING FREQUENCY, FIELD TO MONITOR AND DEFINE AT 31
FIGURE 3.11 CREATING THE PROJECT TEMPLATE 32
FIGURE 3.12 CST TOOLBAR TO START DESIGNING MICROSTRIP ANTENNA 32
FIGURE 3.13 CREATE THE RADIUS OF ANGLE SLOT 33
FIGURE 3.14 CREATE ANGLE OF SLOT 33
FIGURE 3.15 SELECTING THE MATERIAL 34
FIGURE 3.16 DETERMINE THE DIMENSION OF THE ANTENNA 34
FIGURE 3.17 BRUSH CLEANING MACHINE 35
FIGURE 3.18 PCB BOARD PANEL DRYER MACHINE 36
FIGURE 3.19 DRY FILM PHOTORESIST SHEET LAMINATOR 36
FIGURE 3.20 UV DOUBLE SIDED EXPOSURE UNITS WITH VACUUM 37

FIGURE 3.21 DEVELOPER MACHINE 38
FIGURE 3.22 ACID REMOVER MACHINE 39
FIGURE 3.23 MICROSTRIP PATCH ANTENNA TESTED USING NETWORK ANALYZER 40
FIGURE 3.24 THE ANTENNA AND TAG AT THE SAME POSITION 40
FIGURE 3.25 RFID READER 41
FIGURE 3.26 THE POSITION OF ANTENNA AND TAG 42
FIGURE 4.1 FRONT VIEW OF ANTENNA 44
FIGURE 4.2 BACK VIEW OF ANTENNA 44
FIGURE 4.3 SIMULATION RESULT OF RETURN LOSS (S11) 45
FIGURE 4.4 SIMULATION RESULT OF VSWR 46
FIGURE 4.5 SIMULATION RESULT OF RADIATION PATTERN 47
FIGURE 4.6 E-PLANE 47
FIGURE 4.7 H-PLANE 47
FIGURE 4.8 SIMULATION RESULT OF GAIN 48
FIGURE 4.9 CALIBRATION KIT 49
FIGURE 4.10 CALIBRATION TOOL 49
FIGURE 4.11VECTOR NETWORK ANALYZER CALIBRATION PROCESS 50
FIGURE 4.12 COMPARISON RESULT BETWEEN SIMULATION AND ACTUAL ANTENNA 50
FIGURE 4.13 AD-641 UHF RFID TAG 51
FIGURE 4.14 AD-223 UHF RFID TAG 51
FIGURE 4.15 AD-814 UHF RFID TAG 52
FIGURE 4.16 AD-815 UHF RFID TAG 52
FIGURE 4.17 AD-824 UHF RFID TAG 52
FIGURE 4.18 AD-828 UHF RFID TAG 52
FIGURE 4.19 AD-833 UHF RFID TAG 53
FIGURE 4.20 LENGTH DETECTION PERFORMANCE TEST CONFIGURATION 53
FIGURE 4.21 RESULT OF ANTENNA LENGTH DETECTION TEST 54
FIGURE 4.22 ANGLE DETECTION PERFORMANCE TEST CONFIGURATION 55
FIGURE 4.23 RESULT OF ANTENNA ANGLE DETECTION TEST 55
FIGURE 4.24 ANTENNA PARAMETER 56
FIGURE 4.25 RETURN LOSS AND RESONANT FREQUENCY EFFECT DUE TO CHANGES OF THE DIAMETER OF ANTENNA 57
FIGURE 4.26 RETURN LOSS AND RESONANT FREQUENCY EFFECT DUE TO CHANGES OF UPPER AND LOWER RADIUS. 58
FIGURE 4.27 RETURN LOSS AND RESONANT FREQUENCY EFFECT DUE TO CHANGES OF UPPER AND LOWER SLOT ANGLE 59
FIGURE 4.28 RETURN LOSS AND RESONANT FREQUENCY EFFECT DUE TO CHANGES OF SUBSTRATE THICKNESS 60
FIGURE 4.29 CIRCULAR PATCH ANTENNA 60

FIGURE 4.30 COMPARISON RESULT BETWEEN CIRCULAR PATCH ANTENNA AND ANGULAR SLOT PATCH ANTENNA 61
FIGURE 5.1 FABRICATED MICROSTRIP PATCH ANTENNA 63
FIGURE 5.2 MEASURED AND SIMULATED RETURN LOSS 63
FIGURE 5.3 SIMULATED PATCH ANTENNA RADIATION PATTERN 64
FIGURE 5.4 E-PLANE RADIATION PATTERN 65
FIGURE 5.5 H-PLANE RADIATION PATTERN 65
FIGURE 5.6 VSWR OF THE ANTENNA IS 1.044 66
FIGURE 5.7 POLAR PLOT GRAPH FOR GAIN 67
FIGURE 5.8 ANTENNA DESIGN 67
FIGURE 5.9 EFFECT IN VARIATION OF ANTENNA SLOT WIDTH TO THE RESONANT FREQUENCY AND RETURN LOSSES 68
FIGURE 5.10 EFFECT IN VARIATION OF ANTENNA SLOT LENGTH TO THE RESONANT FREQUENCY AND RETURN LOSSES. 69
FIGURE 5.11 EFFECT IN VARIATION OF SUBSTRATE PERMITTIVITY TO THE RESONANT FREQUENCY AND RETURN LOSSES 70
FIGURE 5.12 EFFECT IN DIAMETER OF PATCH ANTENNA TO THE RESONANT FREQUENCY AND RETURN LOSSES 71
FIGURE 5.13 ANTENNA TESTING WITH NETWORK ANALYZER 72
FIGURE 5.14 COMPARISON BETWEEN MEASURED AND SIMULATED RETURN LOSSES 72
FIGURE 5.15 ANTENNA SETUP FOR TAGS DETECTION LENGTH 73
FIGURE 5.16 EFFECT OF DIFFERENT RFID TAGS TYPE TO THE MAXIMUM DETECTION LENGTH 74
FIGURE 5.17 ANTENNA SETUP FOR EFFECT OF ANTENNA ANGLES 75
FIGURE 5.18 EFFECT OF ANTENNA ANGLES TO THE MAXIMUM DETECTION LENGTH 75
FIGURE 5.19 CIRCULAR PATCH ANTENNA WITHOUT I SLOT 76
FIGURE 5.20 CIRCULAR PATCH ANTENNA VERSUS I-SLOT CIRCULAR PATCH ANTENNA 76
FIGURE 6.1 FABRICATED MICROSTRIP PATCH ANTENNA 78
FIGURE 6.2 MEASURED AND SIMULATED RETURN LOSSES 79
FIGURE 6.3 SIMULATED PATCH ANTENNA RADIATION PATTERN 80
FIGURE 6.4 E-PLANE RADIATION PATTERN 80
FIGURE 6.5 H-PLANE RADIATION PATTERN 81
FIGURE 6.6 SIMULATED VSWR 82
FIGURE 6.7 POLAR PLOT GRAPH FOR GAIN 83
FIGURE 6.8 ANTENNA PARAMETER 84
FIGURE 6.9 EFFECT IN VARIATION OF ANTENNA SLOT WIDTH TO THE RESONANT FREQUENCY AND RETURN LOSSES 85
FIGURE 6.10 EFFECT IN VARIATION OF ANTENNA SLOT LENGTH TO THE RESONANT FREQUENCY AND RETURN LOSSES 86

FIGURE 6.11 EFFECT IN VARIATION OF SUBSTRATE PERMITTIVITY TO THE RESONANT FREQUENCY AND RETURN LOSSES 87
FIGURE 6.12 EFFECT IN VARIATION OF SUBSTRATE PERMITTIVITY TO THE RESONANT FREQUENCY AND RETURN LOSSES 88
FIGURE 6.13 EFFECT IN DIAMETER OF PATCH ANTENNA TO THE RESONANT FREQUENCY AND RETURN LOSSES 89
FIGURE 6.14 EFFECT OF SUBSTRATE THICKNESS TO THE RESONANT FREQUENCY AND RETURN LOSSES 90
FIGURE 6.15 ANTENNA TESTING WITH NETWORK ANALYZER 91
FIGURE 6.16 COMPARISON BETWEEN MEASURED AND SIMULATED RETURN LOSSES 91
FIGURE 6.17 ANTENNA SETUP FOR TAGS DETECTION LENGTH 92
FIGURE 6.18 EFFECT OF DIFFERENT RFID TAGS TYPE TO THE MAXIMUM DETECTION LENGTH 93
FIGURE 6.19 ANTENNA SETUP FOR EFFECT OF ANTENNA ANGLES 94
FIGURE 6.20 EFFECT OF ANTENNA ANGLES TO THE MAXIMUM DETECTION LENGTH 94

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
CAD	Computer Added Drawing
HPBW	Half Power Beam Width
CST	Computer Simulation Technology
PCB	Printed Circuit Board
IC	Integrated Circuit
VNA	Vector Network Analyzer

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, many industries including manufacturing companies, servicing, and logistics companies used Radio Frequency Identification (RFID) to facilitate their work and save more time. 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[1]. The system work based on the alternating electromagnetic fields are mostly made up from two main components which is transceivers (readers) and transponders (tag). The transponders (tags) of RFID consists of a small chip to capture data and antenna for connection medium. The microchip that contained on RFID tags namely as Application Specific Integrated Circuit (ASIC) that connected to an antenna[2]. The small microchip and the antenna used to transmit and receive the radio wave from the transceivers (reader) in the same frequency within same time. The antenna produces radio wave to enable the tag, write and read data. Tag and reader communicate each other using the antenna.

The RFID reader (transceiver) can operate in several frequencies. Each country has their own radio regulatory organization that control radio frequency. Generally, RFID application has several frequencies can be used which is low frequency (LF), High frequency (HF), Ultra High Frequency (UHF) and Microwave. Then, the frequency range for these four is 125-135 kHz for LF, 13.56 MHz for HF, 400-960 MHz for UHF and 2.45 or 5.8 GHz for Microwave. There are two areas of interest in the UHF band, one is around 400 MHz and another one is around 860 to 960 MHz. However, every frequency types and range have their own disadvantages and advantages.

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.

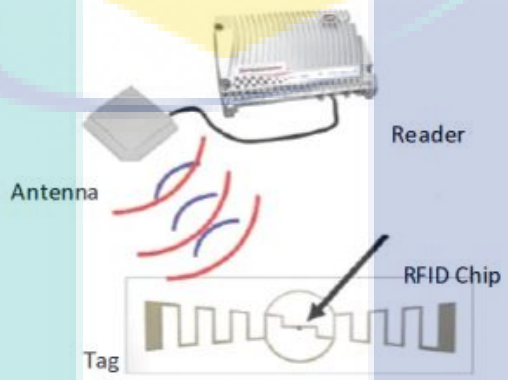

Figure 1.1 RFID System

1.2 Introduction to Project

Recent year, RFID technology is another great achievement in wireless technology and it is based on radio signal to automatically identify without any contact[3]. RFID technology used in many applications in the world such as barcode system, door access control, healthcare industry and transportation. This project focus on to design 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, substrate and ground plane. There are some characteristics of microstrip patch antenna such as light volume and weight, low manufacturing cost and suitable for many RFID applications.

1.3 Problem Statement

In recent years, the main problem to design an UFH RFID antenna is size reduction. The large antenna does not fit into a small area. The reduction size antenna effects the gain. It’s also may affect the read range between RFID reader and antenna. To overcome this problem, the circular patch antenna and coaxial feed line were added in the design to get the small size of UHF RFID antenna reader.

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.

Other than that, most of the circular microstrip antenna produce a circular polarization. The circular polarization produces 360 degree of detection angle. However, circular polarization has a short detection distance compared to linear polarization. In fact, the linear polarization antenna can detect the tag in specific angle and produce a long detection distance.

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.

The other problem in design UHF RFID antenna is narrow bandwidth. 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.

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1.4 Objective of Study

The project objective is to structure and investigate the microstrip patch antenna with angular slot 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 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:

i. To design a low cost and small size of microstrip patch antenna for the UHF RFID Reader.

ii. To get lower than -10 dB of S11 result at centre frequency of 921 MHz for good antenna efficiency.

iii. To verify and validate the design antenna with UHF RFID reader.

1.5 Project Scope

The scopes of this project are:

i. To ensure the microstrip patch antenna operate at 921 MHz of resonance frequency.

ii. To design and analysis effect of antenna parameter using the CST Microwave Studio 2014.

iii. 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

An antenna is device that made from metallic for example wire or rod that can transmit and receive the data via radio wave"[1]. Other than that, antenna and also known as aerial is radiating and receiving devices using radio wave signal by the IEEE[1]. The evolution of microstrip patch antenna began its rapid advancement in late 1970s. In era 1970, the rectangular shape and circular shape become most popular because it's easy to analysis and fabrication. Other than that, the rectangular and circular shape of microstrip antenna have good characteristics of radiation particularly low cross-polarization radiation.

2.2 Microstrip Patch Antenna

The characteristics of microstrip antenna such as low cost, light weight, and easy to fabricate make it so importance in wireless technologies nowadays[4]. Printed circuit board (PCB) is main material to produce low cost microstrip patch antenna. From the figure 2.1 shows the microstrip patch antenna consists of three main layers such as radiation patch, ground plane and substrate as shown in figure 2.1, where the radiation patch on the top of substrate and the ground plane on the bottom of substrate[4]. Where length of patch represented by L, width of patch represented by W, height of substrate represented by h and substrate permittivity represented by $\mathcal{E}$r. represent. Usually, the thick of the patch is ($t << \lambda_O$) and the length is $\lambda_O /3 < L < \lambda_O /2$. The radiation patch usually made from good electric conductor material such as gold or copper. Due to its low cost and compact design, the microstrip antenna become the best attractive antenna structures.

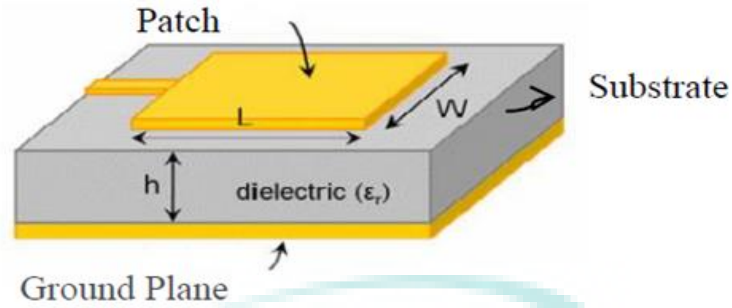


Figure 2.1 Microstrip Patch Antenna Dimension

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. The look into in microstrip patch antenna configuration for the most part spotlights on the best way to conquer these drawbacks[5].

2.2.1 Advantages and Disadvantages of Microstrip Patch Antenna

The popularity of microstrip patch antenna is rise up in wireless industries cause by its low-level structure. Microstrip patch antenna usually used in wireless device such as mobile phone, barcodes technology. The major advantages and disadvantages of microstrip patch antenna are:

Advantages:

- Low fabrication cost.
- Able to fabricate feed line.
- Light weight and low volume.
- Suitable for linear and circular polarizations.
- Compact and slim.
- Reconfiguration appearances can easily be obtained.
- Support single, dual and triple operating frequency.
- Conformable to planar and nonplanar surfaces.

- Adopted in different types of frequency bands that may have varied specifications[6].

Disadvantages:

- Narrow bandwidth.
- Low gain.
- Support for low power application.
- Lack of efficiency of polarization.

However, RFID applications not require large bandwidth. Then, the antenna will reject all frequency or signal that are out of band and consequently increases the quality factor.

2.3 Feeding Method

2.3.1 Microstrip Line Feed

The patch is fed by a microstrip line on an indistinguishable plane from the patch for microstrip feeds. The feeding line and patch frame on same structure. By comparing to the other feeding method of microstrip patch antenna, this feeding method is easier to fabricate. Other than that, it suitable for use in receiving wire exhibit sustaining system. however, microstrip line feed have some weakness which is limited capacity data transfer and produce some undesired radiation.

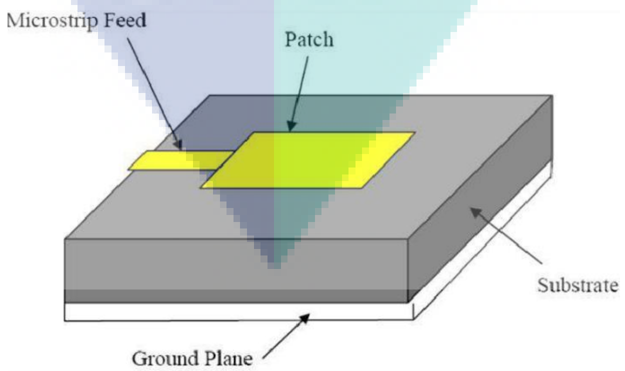


Figure 2.2 Microstrip Line Feed

2.3.2 Coaxial Feed

This feed technique is common feeding technique for microstrip patch antenna. This method also known as probe feed. The ground plane of microstrip antenna is soldered to the outer conductor of coaxial connecter, while the radiating patch of microstrip antenna is soldered to the inner conductor of coaxial connector. The advantages of coaxial feed method are the connecter can be soldered at any desired position inside the radiation patch to match with input impedance. 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.

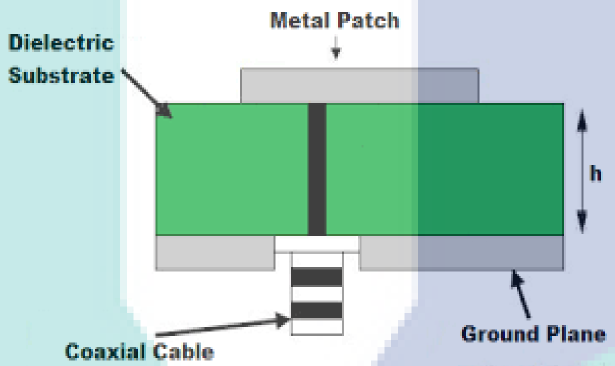


Figure 2.3 Coaxial Feed

2.3.3 Proximity Coupled Feed

Proximity couple feed method is feed method that used two dielectric substrate and the feed line is placed between two of dielectric substrate, where the patch is place on top substrate. This method also known as the electromagnetic coupling scheme. This feed method has several advantages which is produces 13% of high bandwidth and it's also eliminates 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.

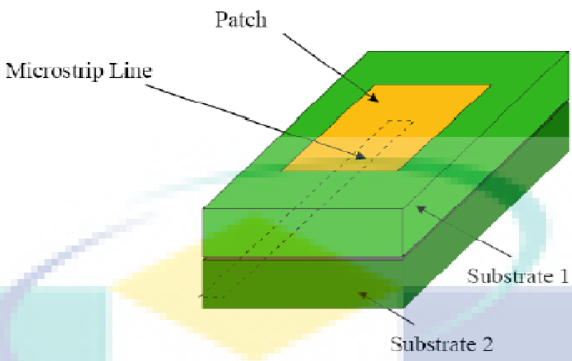


Figure 2.4 Proximity Couple Feed

2.3.4 Aperture Couple Feed

By applying this feed method, the ground plane separates between feed line and the radiation patch. The slot or also knows as aperture in the ground plane has been used to made coupling between the patch and the feed line. In addition, the slot size such as length and width can improved return loss (S11) and produces wide bandwidth[7]. Usually, the position of slot or aperture in the middle under the radiation patch. Besides that, spurious radiation can be minimized by applying this feed method.

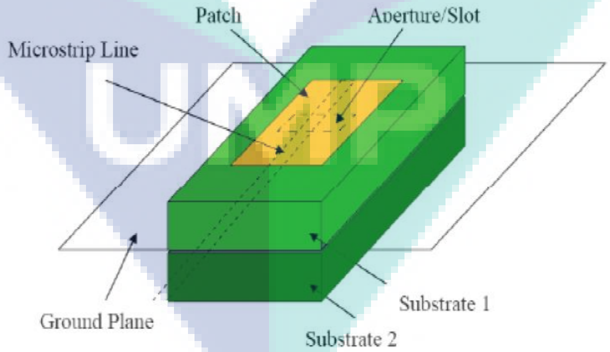


Figure 2.5 Aperture Couple Feed

2.4 Size Reduction Techniques

Generally, most of microstrip antenna for high frequency application which is application that have 1 GHz of frequency and above. The size of the antenna becomes a serious problem for practical deployment at lower frequencies. However, for reduction the size of antenna there are various method, such as high dielectric constant, shorting post, structural modification, and perturbation and plate loading[8].

2.4.1 High Dielectric Constant

High dielectric constant technique used high dielectric constant material to reducing the size of the antenna. However, the radiation efficiency and bandwidth will reduce via this technique. In additional, this technique also increasing weight of the antenna.

2.4.2 Shorting Post

Shorting post technique is the common technique to decreasing the overall microstrip antenna size by applying a short circuit (metal clamp or shorting post) to eliminate some radiating edge. The resonance frequency of the short circuited microstrip patch has been shown to be adjustable by modified the position of shorting posts and number of shorting posts. In facts, by decreasing the number of shorting posts affected the resonance frequency of modified patch to become lower.

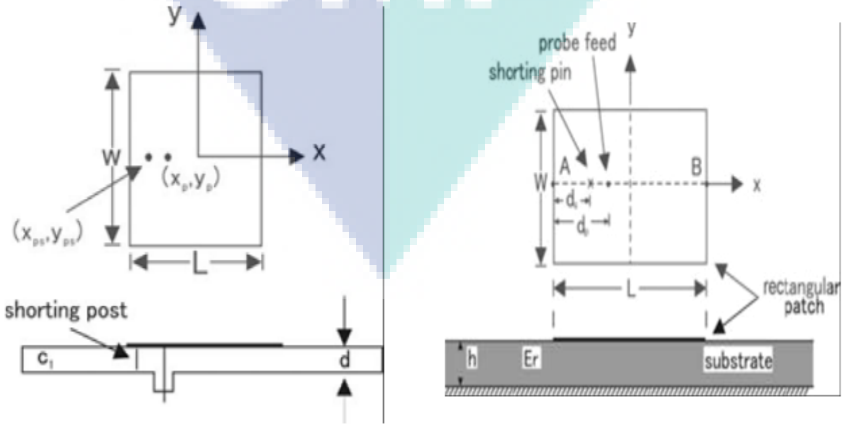


Figure 2.6 Rectangular Microstrip Antenna Loaded with Shorting Post

2.4.3 Structural Modification

Structural modification is another technique to decrease the size of patch antenna by applying some slot for modified the original shape of radiation patch to meander currents. Generally, this technique is effective to decrease the antenna size by changing the size of slot such as length and width.

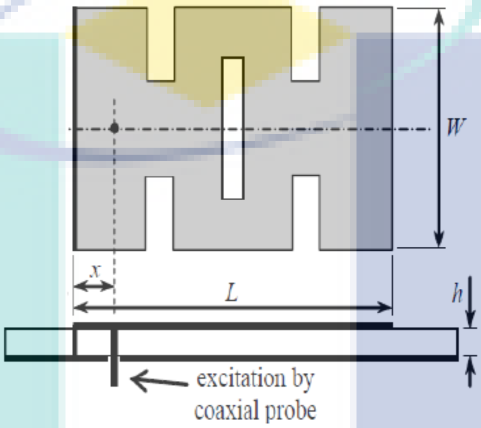


Figure 2.7 Patch with Slot Inserted

2.4.4 Perturbation and Plate Loading

Perturbation and plate loading are another technique based on perturbation effect to reducing size of the antenna by this technique, the magnetic field should be increase and the total energy that contained in the electric field should be decrease. Therefore, the patch will decrease because it has a strong electric field there and the ground plane will be increase because it has a strong magnetic field there. By increased the number of plates loaded on antenna, it increased the current path of antenna and decreased the resonant frequency. The reducing size of microstrip patch antenna will be achieved by using combining these two methods.

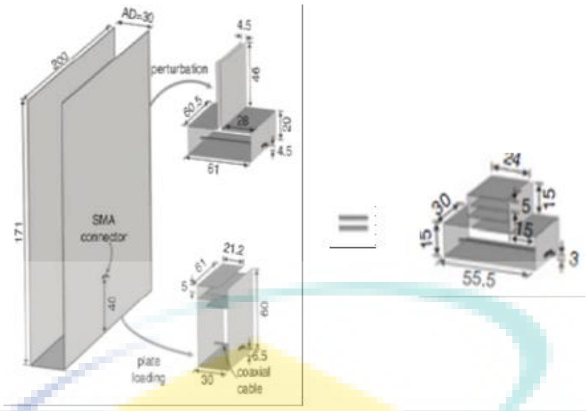


Figure 2.8 Perturbation and Plate Loading

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.

2.5.1 Directivity

The directivity value that produces by standard microstrip patch antenna is around 6-7 dBi[9]. The antenna's directivity is illustrates the ratio of the radiation intensity in a specific direction from the antenna to the radiation intensity averaged over all directions[1]. In other word, the antenna directivity shows how good the antenna radiation in a several directions. From the maximum radiation of antenna, directivity can be measured same as gain which is in fixed direction. 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

The antenna radiation energy in specific direction can be determined by gain when the antenna connected to power sources. It shows potential of the antenna can radiate the assumed power into space in specific direction for a transmitting antenna. then, its shows potential of the antenna transforms the received electromagnetic waves into electric power. Generally, efficiency and directivity contained in gain of antenna.

The gain is simply calculated in dB, which indicates the direction of maximum radiation and based on equation 2.1, the gain can be calculated.

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

Where the antenna efficiency represented by η and the antenna directivity represented by D.

2.5.3 Bandwidth

The bandwidth of antenna is illustrated as the frequency range within which the performance of antenna complies with a specified standard with respect to some characteristics[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:

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

2.5.4 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 circular polarization antenna can be better when the value of axial ratio approximates nearest to 0 dB in order to declare it's as circular polarization.

2.5.5 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[1]. 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[1]. Radiation pattern can determine the energy radiated and received by the antenna which can be measured using

CST MWS simulation. The typical radiation pattern of an antenna illustrates by figure 2.3.

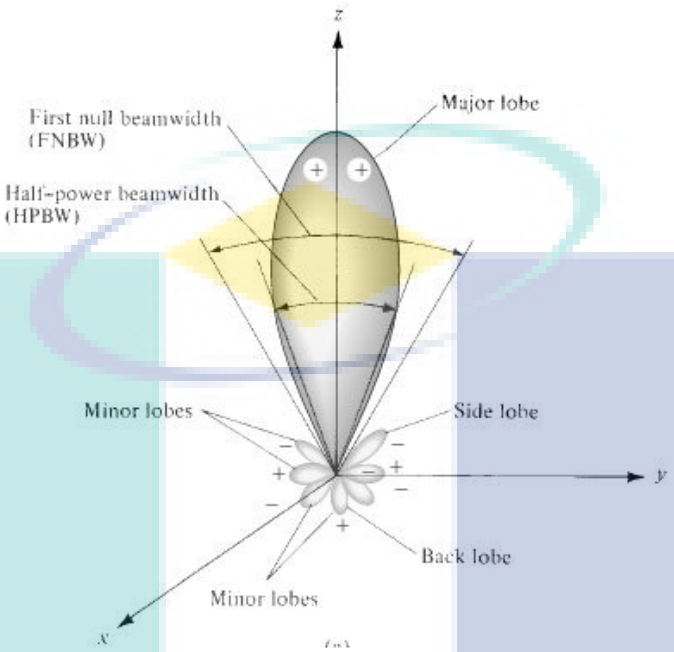


Figure 2.9 Antenna Radiation Pattern

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.

i. 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 Θ = 0. The major lobe can be more than one for different antenna types for example split-beam.

ii. 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

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

2.5.6 Polarization

Polarization illustrated the wave polarization that radiated by the antenna in specific direction[1]. By coordinated the transmitting and receiving polarization, the antenna gain can be improved. 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, circular 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.

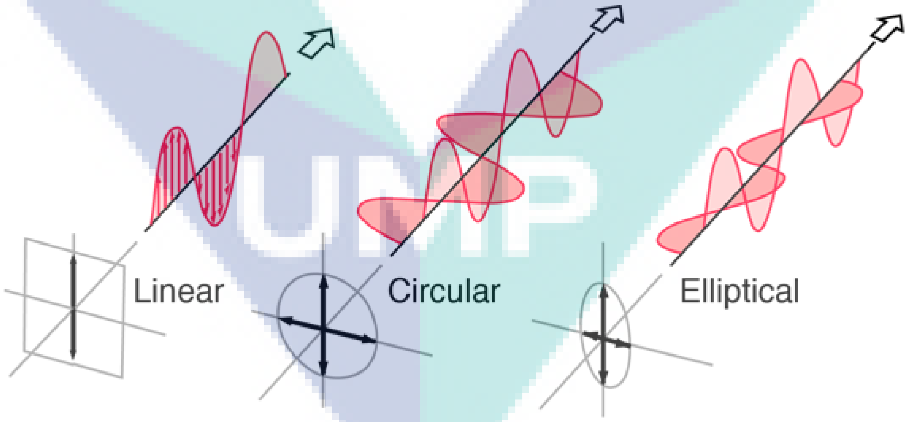


Figure 2.10 Type of Antenna Polarization

2.6 RFID Component

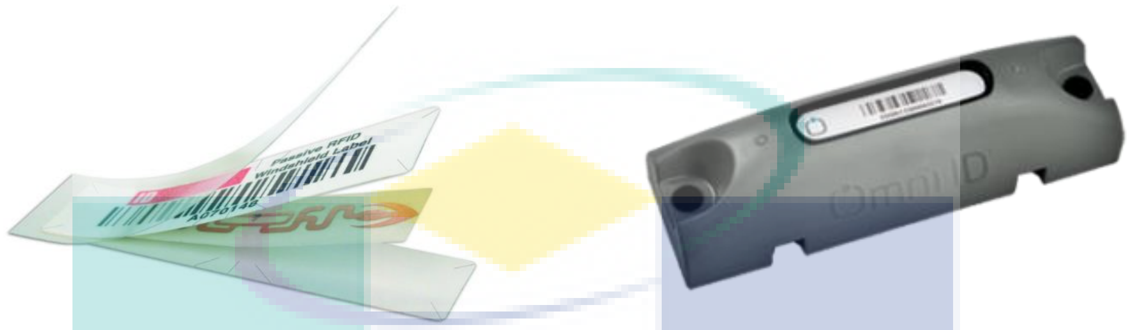
2.6.1 Basic Operation Of RFID

The RFID is a system comprises of three main components namely reader, tag (passive or active), and Information management system (IMS)[10]. 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 transponder (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 2.11 RFID System

2.6.2 RFID Tags

A tag of RFID is electronic devices that has ability to identify and trace object using radio frequency. It exchanges information thought the radio wave with an RFID reader. RFID consists two major part which is antenna and integrated circuit (IC). The antenna act as a receiver to receive the radio wave and integrated circuit (IC) perform to process and store the data. RFID tags divided into two major types which is active tag and passive tag[11]. Active tag need power supply or integrated battery to working. Active tags are impractical in many applications because high cost, unsuitable size and lack of lifetime. Another one is passive tags, many RFID application using passive tags because the tag don't require integrated batteries. The tags also have indefinite lifetime and small to fit in many RFID application. 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.



(a) (b)

Figure 2.12 (a) Passive RFID Tag (b) Active RFID Tag

2.6.3 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's 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, UHF RFID readers communication protocol exposed with strong interference signals due to antenna reflection and transmit leakage[12]. Besides that, the receiver sensitivity, reading range of reader, and overall reader performance will be affected due to high level of distraction. The interference can be minimized by separating the receiver and transmit antenna, but this method will increased the cost and size of the reader[12].

RFID reader can be classified into three types which is stationary reader, mounted reader and handheld reader. Stationary RFID readers require power efficiency as well as high output power since the power amplifier consumes the highest power in the transmitter[13]. 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 is a mobile reader and required power supply to operate. Other than that, handheld radio frequency identification (RFID) reader units with adoption of passive ultra-high frequency (UHF) system become important equipment for warehouse and retail management used. 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)

(b)

(c)

Figure 2.13 Type of lheld (c) Mounted

2.6.4 RFID Antenna

The RFID reader antenna transmit information using radio wave. The information needs to change first to radio eave before transmit. The Figure 2.6 shows the example of RFID reader known as patch antenna. While Figure 2.6 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.

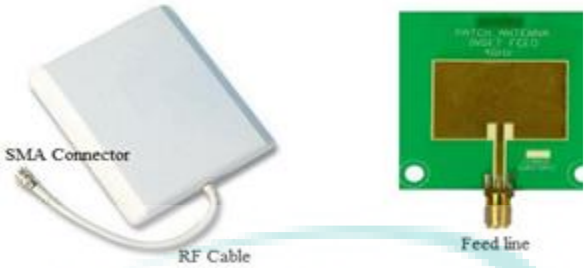


Figure 2.14 Microstrip Patch Antenna

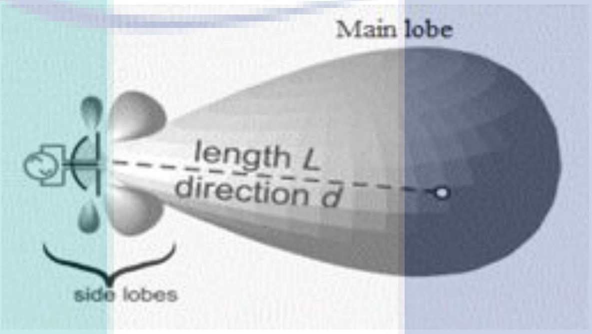
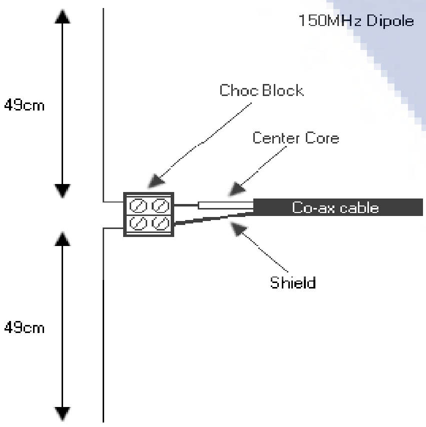
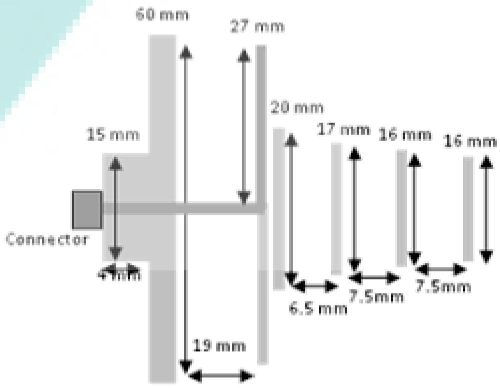


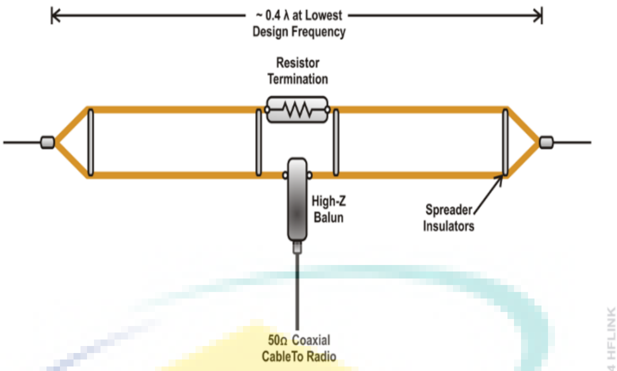
Figure 2.15 Radiation Pattern of Antenna

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.





(b) (a)



(c)

Figure 2.16 Type of Antenna (a) Dipole Antenna (b) Dual Dipole Antenna (c) Folded Dipole Antenna

2.6.5 RFID Frequency Range

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

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 meter
RFID Application	vehicle immobilizer	Library Items, laundry	Stock chain, entry control	Safety control, work tracking

Table 2.1 RFID Frequency Class

CHAPTER 3

METHODOLOGY

3.1 Microstrip Patch Antenna Design

The main purpose of this chapter is covered the procedure required to design and fabricate the propose 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.

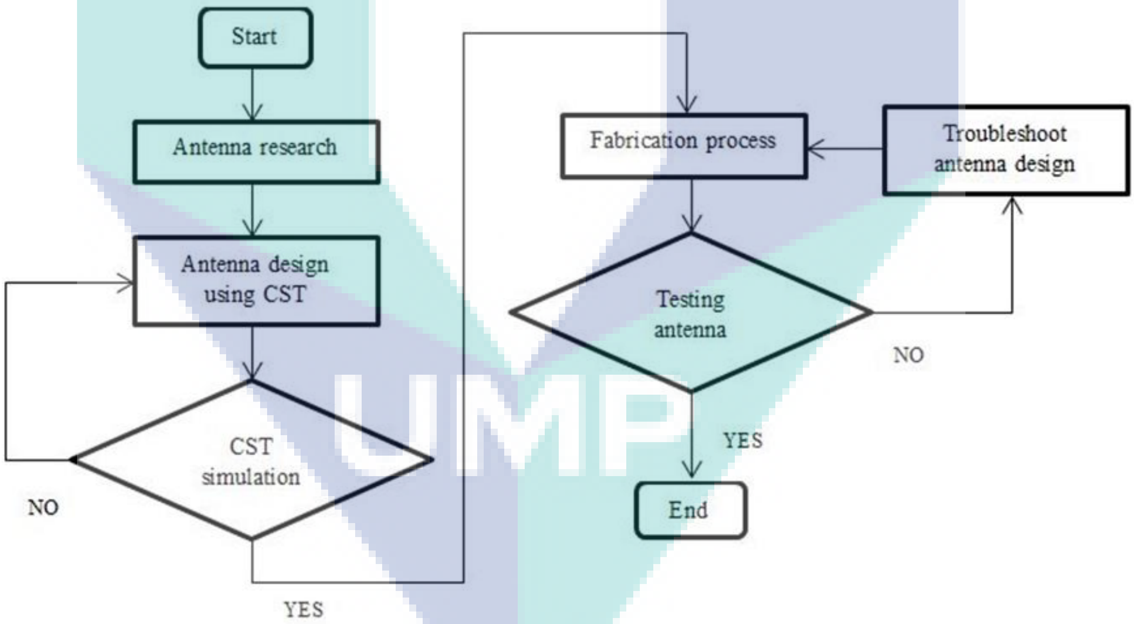


Figure 3.1 Flow Chart of Designing Microstrip Patch Antenna

Microstrip antenna, also known as patch antenna are very famous antennas in microwave industries because of their compatibility and simplicity with integrated microchip technologies. The common antenna used in industry is rectangular patch antenna because the antenna is suitable for direct integration with microstrip circuit, although it can be fixed on the same substrate. However, this project needs to design circular microstrip antenna and several parameters need to be considered before start designing such as operating frequency *(fo)*, dielectric constant of substrate (εr) and height of substrate (h).

Operating frequency is very important part of antenna requirements which means the antenna need to be perform is certain frequency. The operating frequency for this project is 921 MHz which is legally used in Malaysia. Other than that, the value of dielectric constant plays a big role on the designing and performance of the antenna. The dielectric constant value that specified with FR-4 substrate material is 4.7 (loss-free) used for designing the antenna. In order to get optimum or maximum performance of the antenna, the height of substrate (h) need to be consider. The height of substrate value that specified with FR-4 substrate material is 1.6mm used for designing the antenna in this project.

3.1.1 Antenna Research

The writing of microstrip patch antenna research has been investigated in all aspect such as articles, conferences paper, books, journals, and latest sites in the research area. It also focused on improvement of wireless innovation. In this part, RFID innovation has been chosen to be explored deeply. In this study, a lot of appropriate framework related to the project has been compared worldwide.

3.1.2 Antenna Design with CST Microwave Studio 2014

In order to design the microstrip patch antenna, CST Microwave Studio has been used. This software is a 3D EM simulation tool for high frequency components. CST MWS allows rapid and precise investigation of high-frequency devices especially antenna devices. With exceptional ease of use, CST MWS rapidly gives analysis result of EM behaviour for the antenna devices. CST MWS offered time domain solver and frequency domain solve for helping user to design the antenna.

3.1.3 Simulation Process

In order to execute simulation of antenna using CST MWS, the design of microstrip patch antenna need to be done. CST simulation will show the analysis result of antenna performance such as 1D result, s-parameter (S11), gain, radiation pattern, efficiency, directivity, bandwidth and antenna polarization of antenna plot and also rectangular diagram. Analysis result from s-parameter (S11) will determine whether the antenna is effective or not. S-parameter need to be less than -10 dB to for antenna work effectively at certain frequency. Other than that, Voltage Standing Wave Ratio (VSWR) value can be carried out in this process.

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 MWS. Before starting the printing procedure, exported the latest simulated design from CST MWS 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 MWS. 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 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.

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

Table 3.1 Microstrip Patch Antenna Specification

Theoretically, the operating frequency, s-parameter (S11), radiation pattern, directivity, and gain describe about antenna performance. The suitable feeding technique and accurate physical measurement also effect 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 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 circular microstrip patch antenna. A circular 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 coaxial link, the value of feedline will be a 50 Ω feedline. The feedline is placed on the ground surface from below. Figure 3.2 shows the structure of circular patch antenna with angular slot.

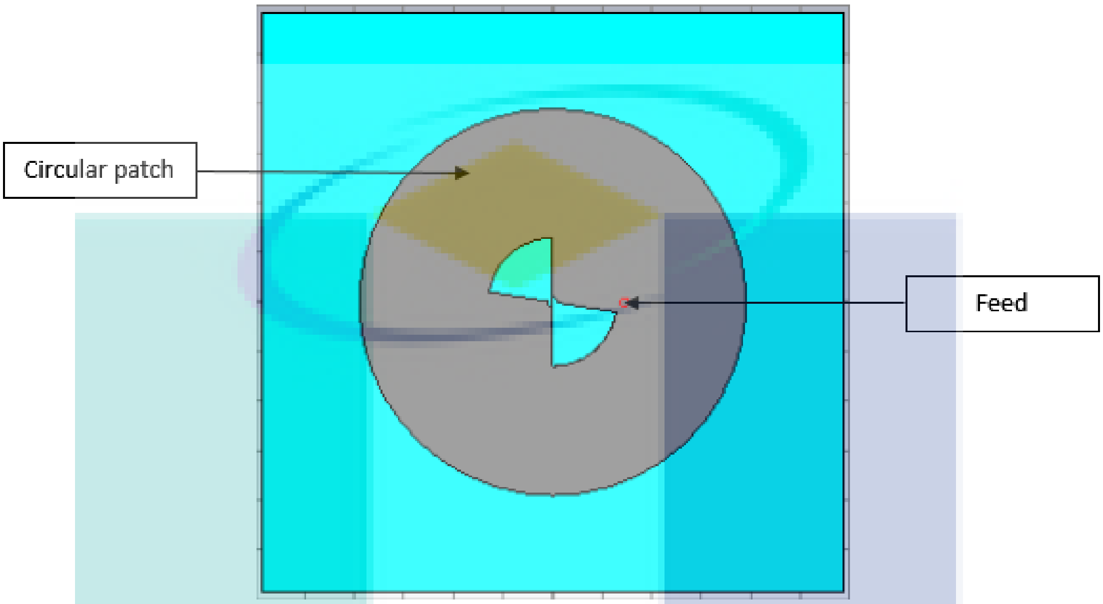


Figure 3.2 Angular Slot of Circular Patch Antenna (Linear Polarization)

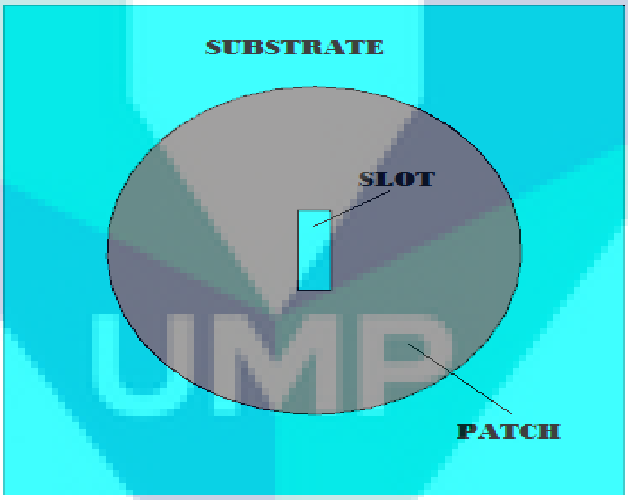


Figure 3.3 Rectangular Slot of Circular Patch Antenna (Linear Polarization)

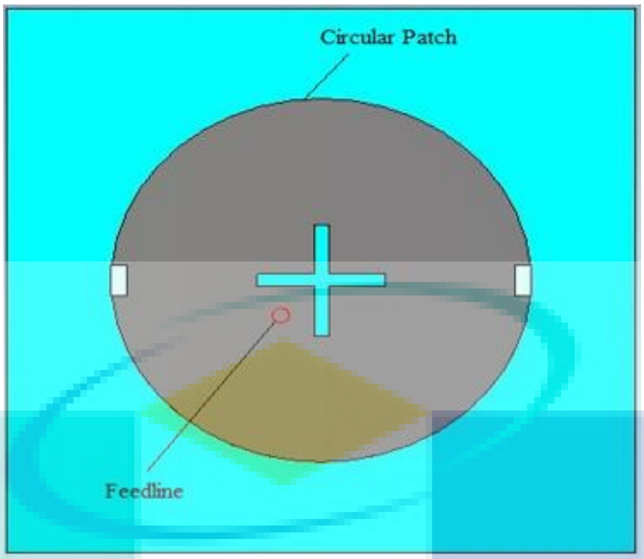


Figure 3.4 T Slot of Circular Patch Antenna (Circular Polarization)

3.3.1 Design Simulation

CST MWS is main software for this project in order to simulate the antenna design. CST MWS able to simulate the antenna design with accurate result of analysis. It is user-friendly and easy to use as a high-frequency devices (HF) and contains a solver module for a particular technology. Several parameters need to be considered such as operating frequency, dielectric substrate, dielectric constant ($\mathcal{E}r$), substrate height (h), loss tangent (Θ), and thickness of the patch (t). it is because all parameter value influent the result of the antenna whether it effective or not. The effectiveness of antenna is depending on simulation result in term of s-parameter (S11), VSWR, gain and radiation pattern.

3.3.2 Calculation of Patch Dimension

The circular patch antenna has been chosen to be design and analysis to predict the performance of antenna. The circular 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 radius of the patch antenna (*a*):

$$radius,\ a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad (3.1)$$

where;

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \tag{3.2}$$

The mathematical expression above not considering fringing effect. The fringing effect will make the patch electrically bigger and after considering the fringing effect of the patch, the mathematical expression is:

$$effective\ radius, a_e = a\left\{1 + \frac{2h}{\pi\varepsilon_r a}\left[ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \tag{3.3}$$

.

3.4 Design Microstrip Patch Antenna Using CST MWS

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. After finish designing the proposed antenna design, the antenna is ready to start simulation process using CST MWS 2014 to determine the antenna performance depends on several parameter such as s-parameter (S11), resonant frequency, radiation pattern, gain, directivity and etc.

The step below shows the right ways to design the antenna using CST MWS describe from figure 3.3 until figure 3.16:

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

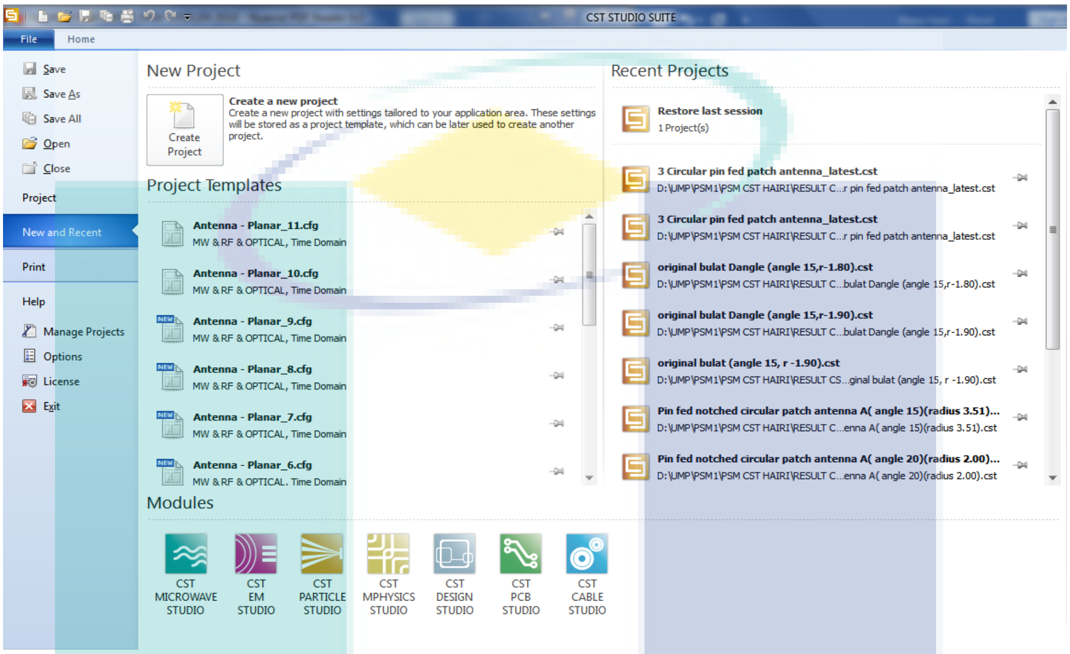


Figure 3.5 Creating New Project

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

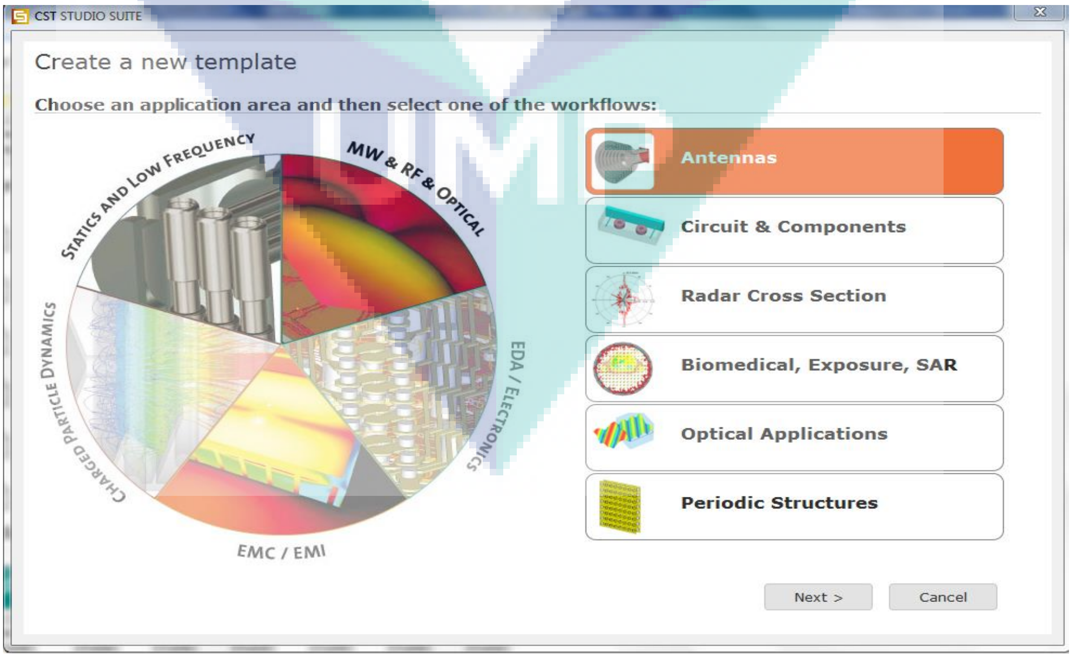


Figure 3.6 Creating New Template

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

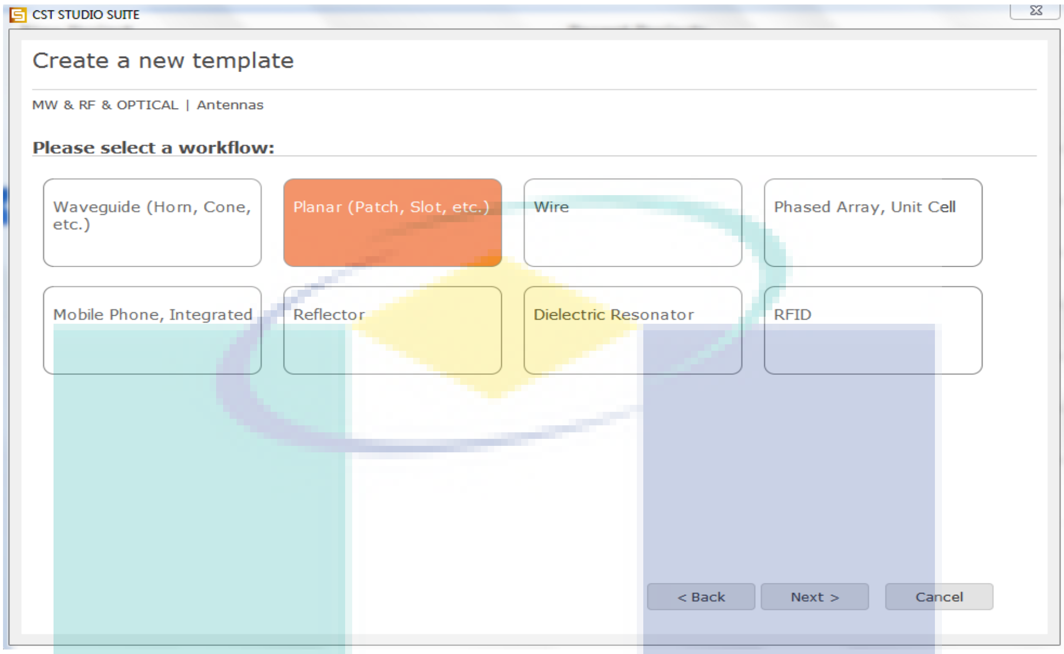


Figure 3.7 Selecting Workflow

STEP 4: Click Time Domain > Click Next

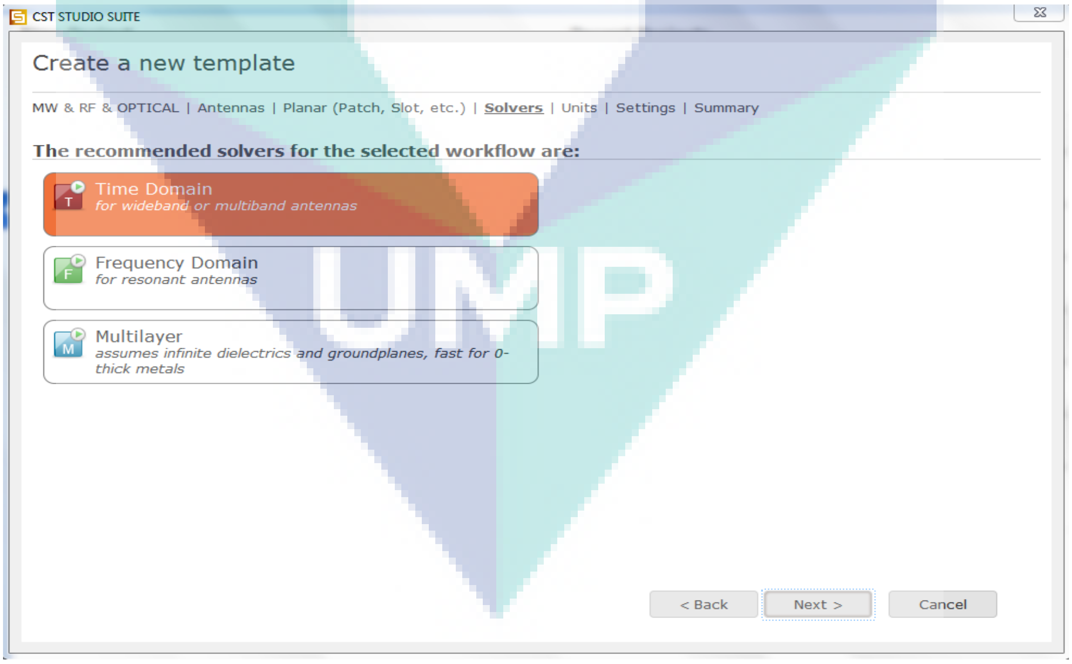


Figure 3.8 Selecting Suitable Solver for Workflow

STEP 5: Select the unit > Click Next

Note: Select the suitable unit for the project.

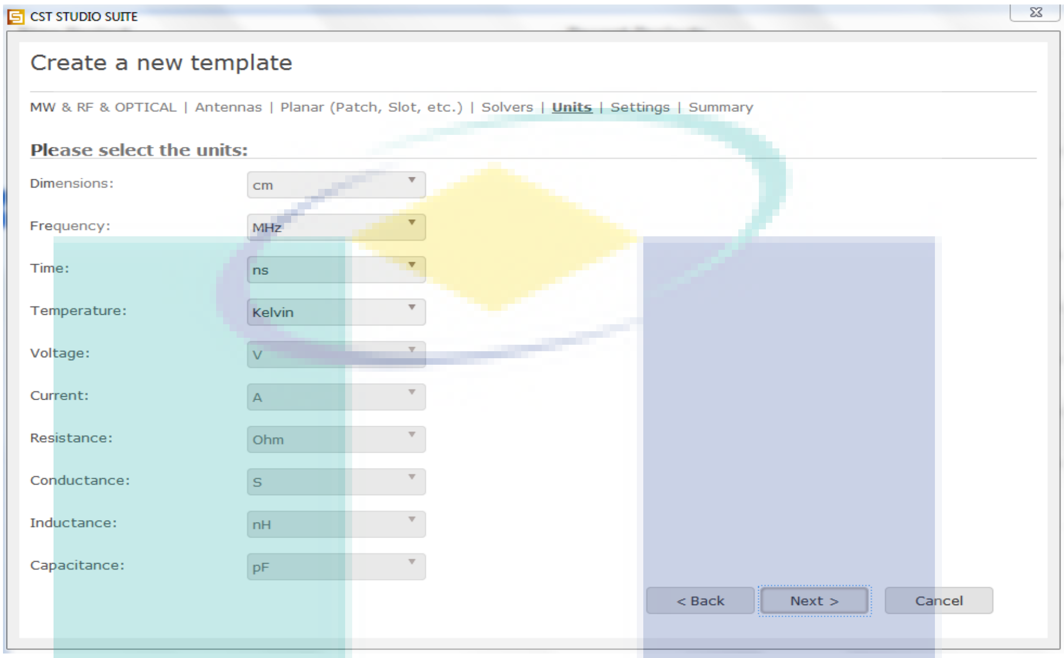


Figure 3.9 Selecting the Suitable Unit for The Project

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

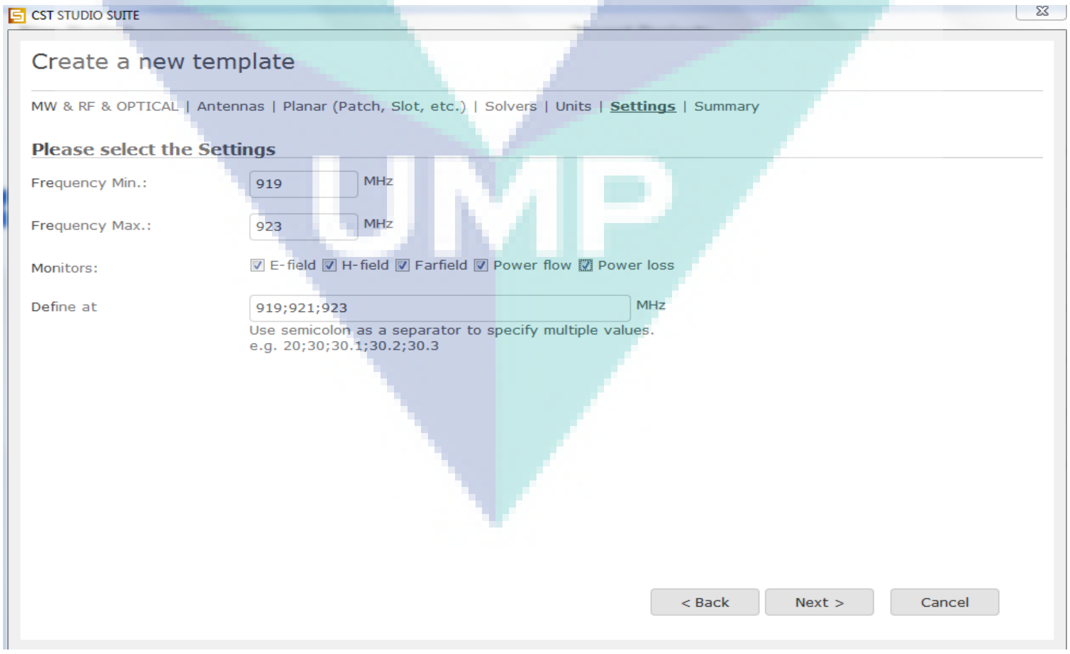


Figure 3.10 Selecting Frequency, Field to Monitor and Define at

STEP 7: Click Finish

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

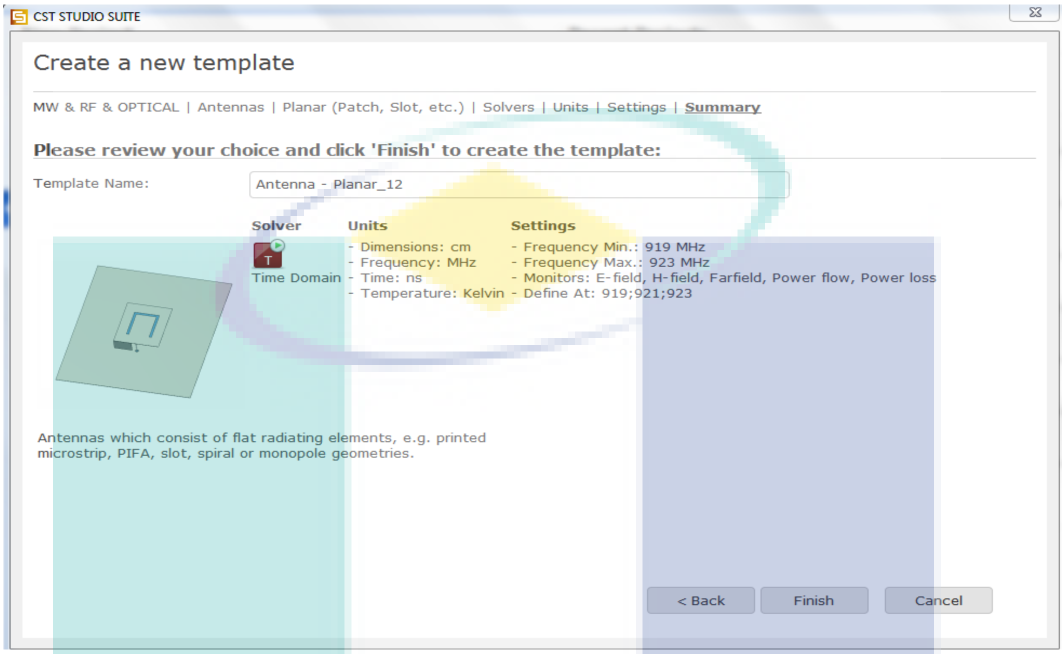


Figure 3.11 Creating the Project Template

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

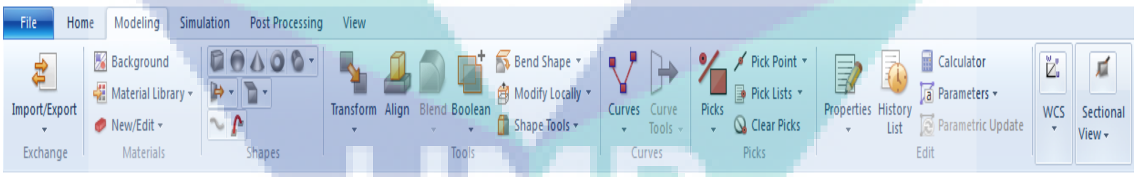


Figure 3.12 CST Toolbar to Start Designing Microstrip Antenna

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

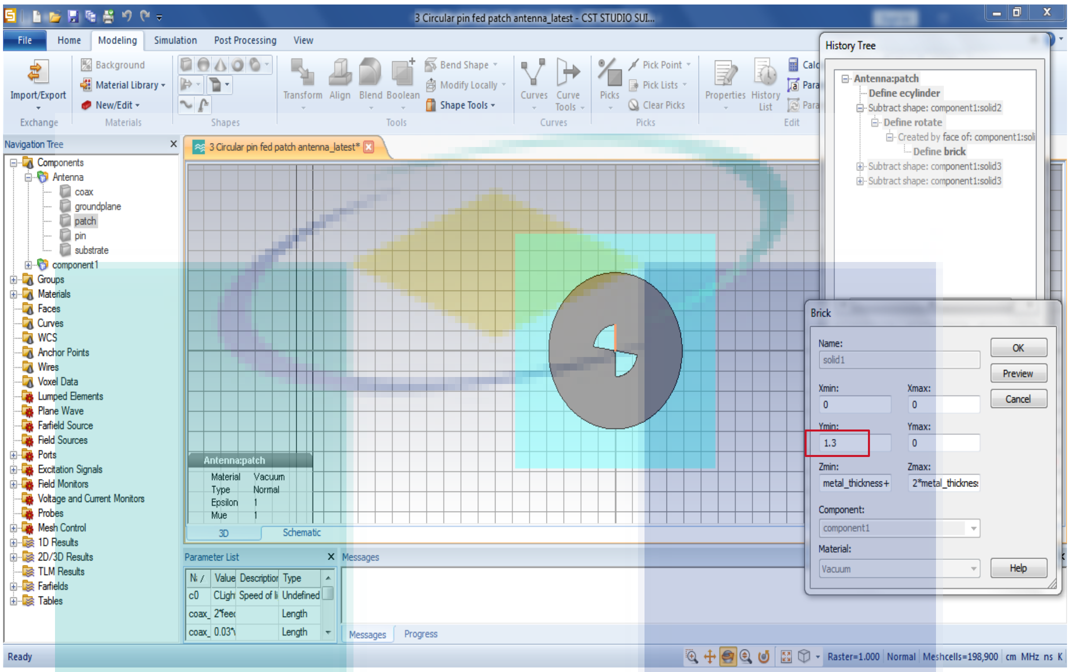


Figure 3.13 Create the Radius of Angle Slot

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

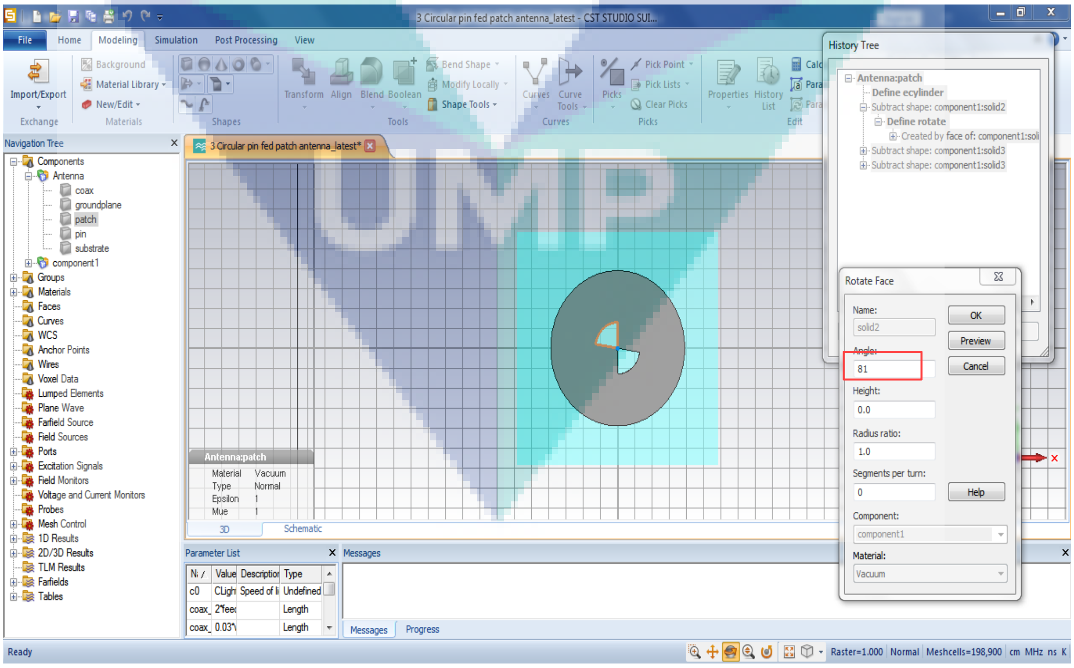


Figure 3.14 Create Angle of Slot

STEP 11: Click Component at navigation tree > Select Antenna > Right click at groundplane > Click Change material > Select PEC > Click Ok.

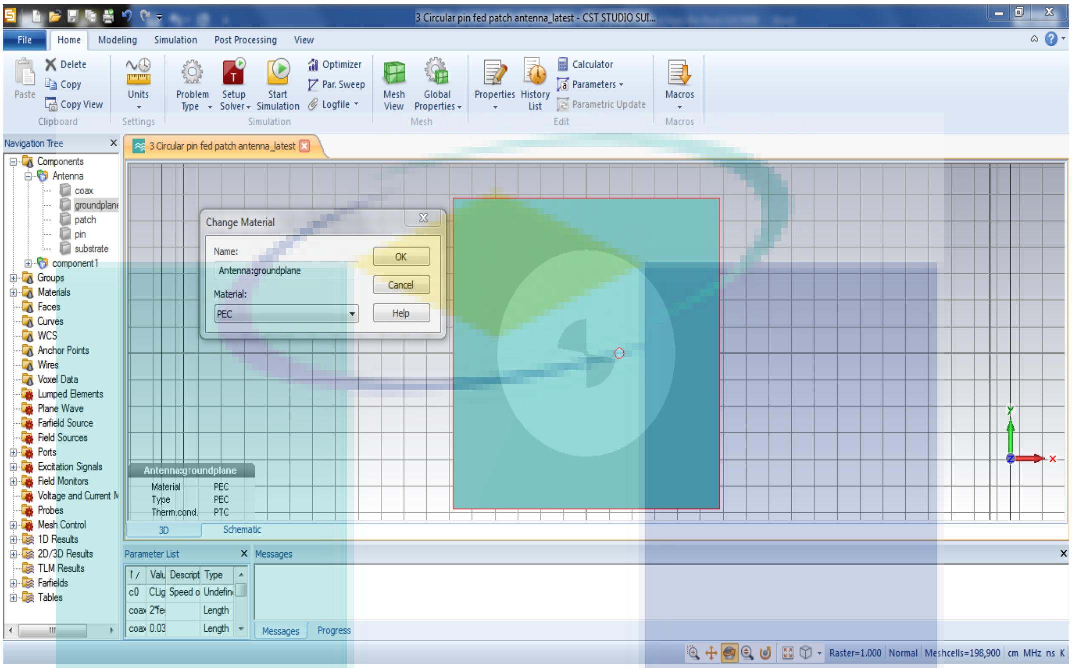


Figure 3.15 Selecting the Material

STEP 12: Select Pick > Pick the first point > Pick the second point

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

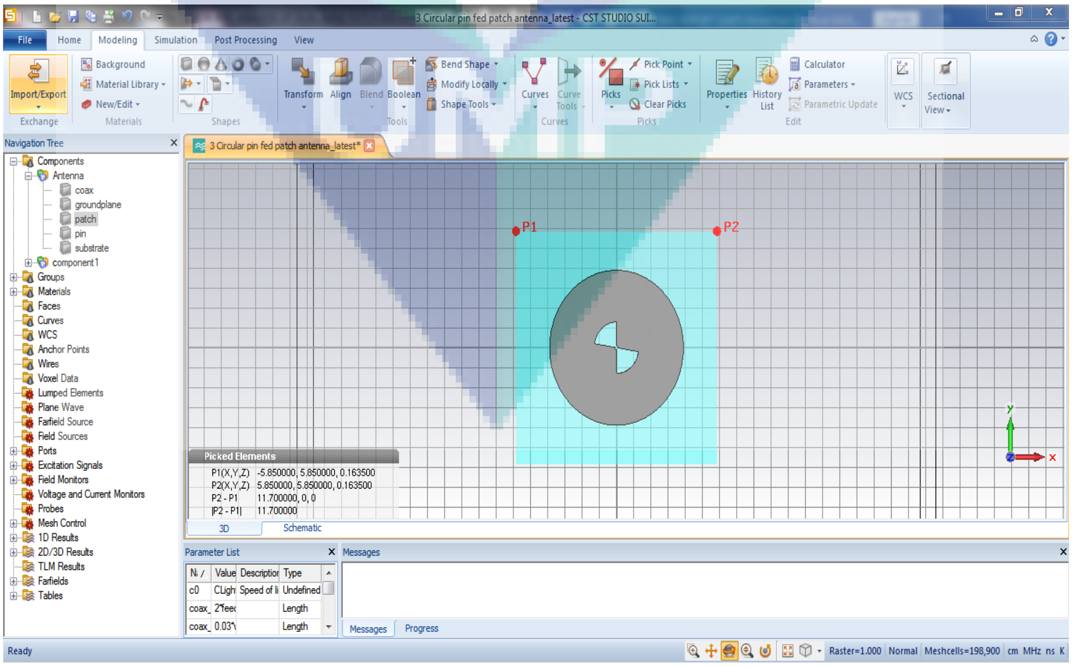


Figure 3.16 Determine the Dimension of The Antenna

3.5 Fabrication Process

3.5.1 Brush Cleaning Machine 305 mm Model RBM300

The brush cleaning machine as shown in figure 3.17 is suitable for small industries and laboratories used. The main purposed of this machine is to cleaning PCB board and other metal surface to ensure the surface of the material free from dust and dirt before start another process. This machine also able to eliminated oxide layer on the PCB board. Other than that, this machine is operated automatically by conveyor. The conveyor speed has been set on 0.2 m/min and the PCB board need to be placed on the conveyor to start the cleaning process and wait until the cleaning process 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 has been used to dry the PCB board after cleaning process. This unit chassis made from high quality material of stainless steel and has special features to remove and eliminate water from PCB board after cleaning process to avoid any problem during fabrication process. This machine can withstand the maximum panel width of 610 mm (24 inches) and 6 mm of thickness. The PCB board need to place on the conveyor to start the drying process and repeat the same process until the PCB board dry perfectly.

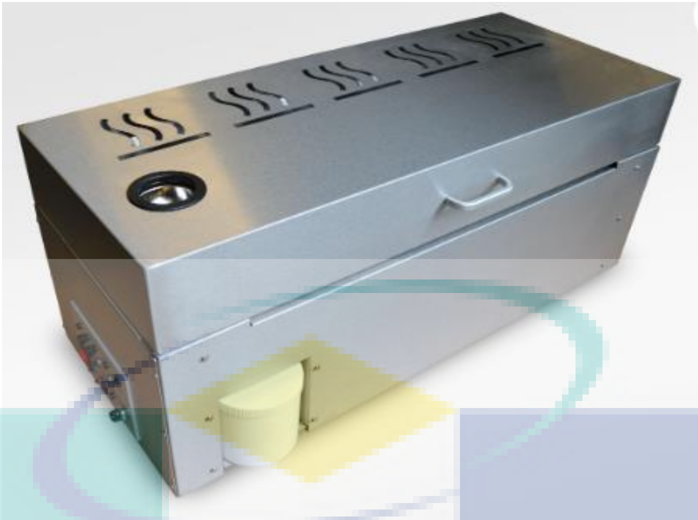


Figure 3.18 PCB Board Panel Dryer Machine

3.5.3 Dry Film Photoresist Sheet Laminator

The dry film photoresist sheet laminator as shown in figure 3.19 is suitable for small laboratories used. This units provide a small control panel for user to set up the suitable temperature and roller speed to applying dry film on the PCB board. The selection of temperature and roller speed is important in lamination process to sidestep the dry film from burned. After lamination process, make sure the dry film and PCB board stick together without any bubble to avoid any problem during etching process.

Figure 3.19 Dry Film Photoresist Sheet Laminator

3.5.4 UV Double Sided Exposure Units with Vacuum

The figure 3.20 shows the UV double sided exposure units that suitable for double sided PCB panel. This units also provided a small control panel and digital display for user to set up the process time. For this process, the UV exposure units has been set at 30 seconds to transfer the antenna layout on PCB film to the PCB board by using UV beam. In additions, this process needs to be done in dark room to avoid the dry film from damage before etching process.

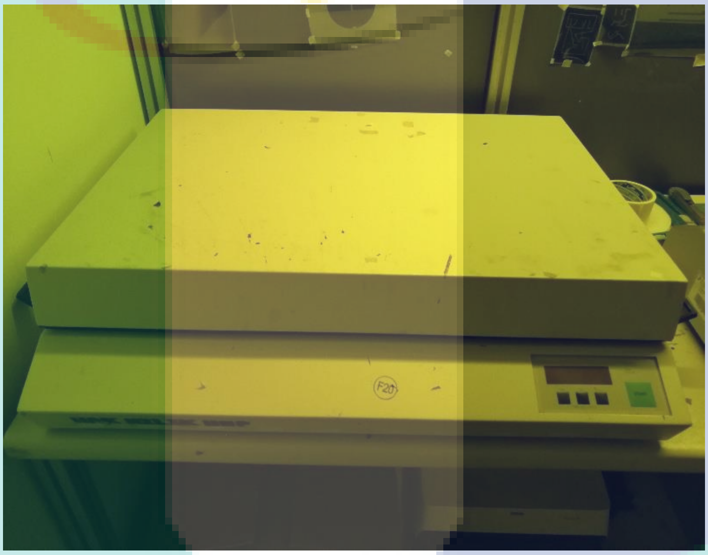


Figure 3.20 UV Double Sided Exposure Units with Vacuum

3.5.5 Rota Spray Developer Machine

The Rota spray developer machine as shown in figure 3.21 has been used in developer process. The developer process needs to be executed to remove unwanted dry film that covered the etching area on the PCB board. Safety precaution is importance before and after execute this process to avoid any accident happen by using the hand glove and face mask during handling 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

The acid remover machine also known as etching machine as shown in figure 3.22 has been used for etching process to removed unwanted copper on the PCB board that not covered by dry film to forming the angular slot. This machine contained acid that can removed the copper layer on the PCB board easily. Safety precaution need to be followed by wearing the personal protective equipment (PPE) such as hand glove and face mask to reduce any accident during the 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 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.

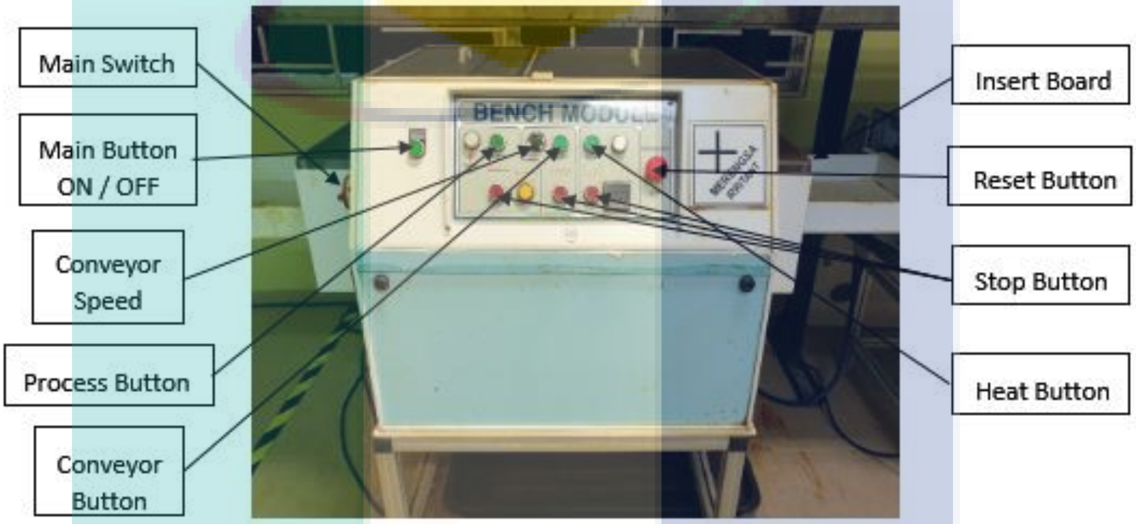


Figure 3.22 Acid Remover Machine

3.6 Antenna Testing

3.6.1 The Vector Network Analyzer

After done fabrication process, the network analyser as shown in figure 3.23 will be used to test the performance of microstrip patch antenna. if the expected results unable to achieved, the microstrip patch antenna need to be redesigned using CST Microwave Studio 2014. This phase is very importance to identify potential contradictions between simulated structure, the fabrication errors, and the effect of lead that used to connect the PCB layer with feed joint. Then, the antenna needs to be redesigned again until all requirement for the desired antenna are met.

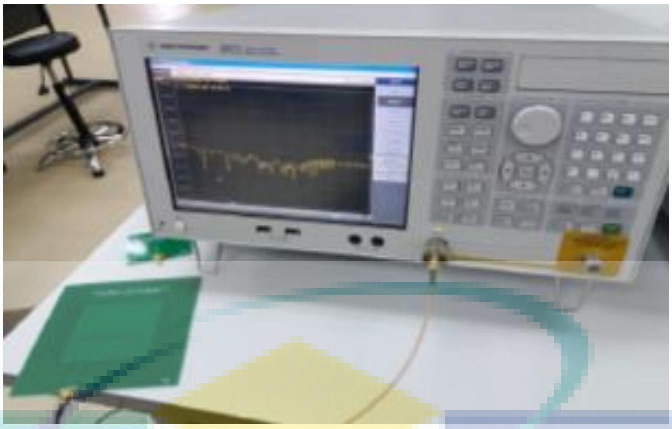


Figure 3.23 Microstrip Patch Antenna Tested Using Network Analyzer

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 passive tag in varies length. Then, this test needs to be executed to identify the maximum recognition length between antenna reader and the RFID tags. RFID tags. The antenna reader and passive RFID tag was place at the same height as shown in figure 3.24 and the maximum recognition length will be tested and recorded. Then, repeat the same procedure until all scope design were recorded for different RFID tags.

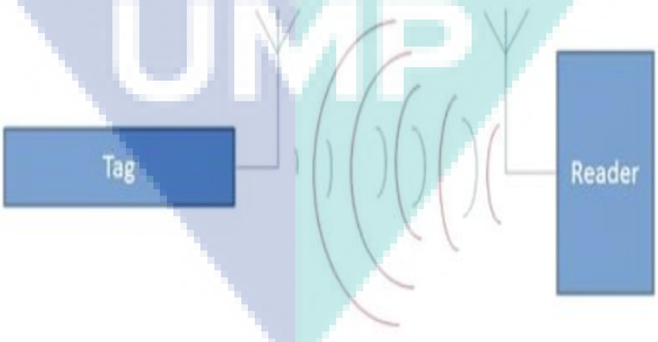


Figure 3.24 The Antenna and Tag at the Same Position

The figure 3.25 shown the antenna reader that we used to executed the antenna testing and its ideal for ultra-high frequency (UHF) coordinate. The RFID reader is instrument used to track RFID tag data through radio wave form. The RFID system is more advanced compared to barcode scanner system. The RFID tag does not require any viewable pathway to the reader and no need specific part to be detected. The tag must be inside the radio wave range in order to be detected.

Figure 3.25 RFID Reader

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

Table 3.2 Reader Specification

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

The antenna angle detection test needs to be executed to investigate the antenna performance when the position of tag is changes in various angle. In this test, the angles to be tested are 30°, 60° 90°, 120° and 150° with the tag being placed on the field. In this investigation, we used five tags that showing the longest distance in length detection test we've ever done. The figure 3.26 describe how the antenna angle test is executed.

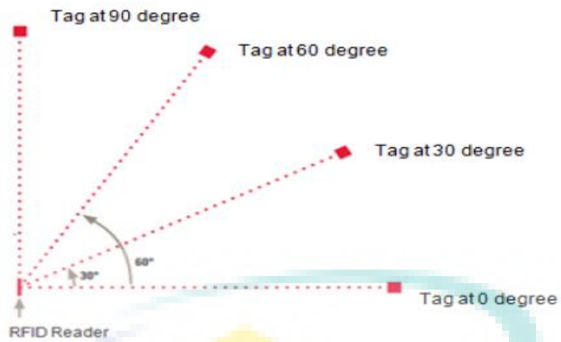


Figure 3.26 The Position of Antenna and Tag

CHAPTER 4

MICROSTRIP PATCH ANTENNA WITH ANGULAR SLOT FOR UHF RFID READER

4.1 Introduction

The main purpose of this chapter is to determine the proposed antenna design in term of antenna performance in order by comparing with simulation result and measured result of losses and s-parameter (S11). The fabrication antenna will be test to analysis the performance whether it meet the propose operating frequency which is 921 MHz and the s-parameter (S11) below than -10dB same as simulation result. This chapter also shows the simulation result of VSWR and gain of propose antenna. The simulation result of VSWR must below than 2 to make sure the antenna can operate. The gain is very importance to the microstrip patch antenna in term of detection range. It also plays a big role in the parametric study to find out the antenna performance in different antenna parameter. The performance of prototype antenna in term near field tag detection range in several distance and angle of the RFID tags. The overall result is extremely valuable to identify the best position of antenna to optimize the detection range and execution. The design of patch antenna discussed the development and analysis of the antenna reader work carried out on the basic circular patch antenna to produce linear polarization antenna.

4.2 The Geometry of Purpose Angular Slot Antenna

The figure 4.1 and figure 4.2 present the geometry of the angular slot antenna. The angular 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 4.1 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 2014 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.

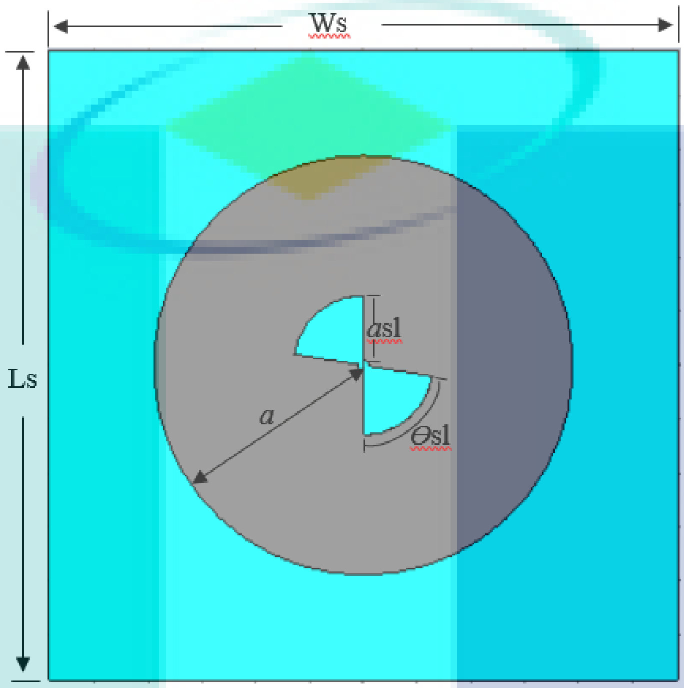


Figure 4.1 Front View of Antenna

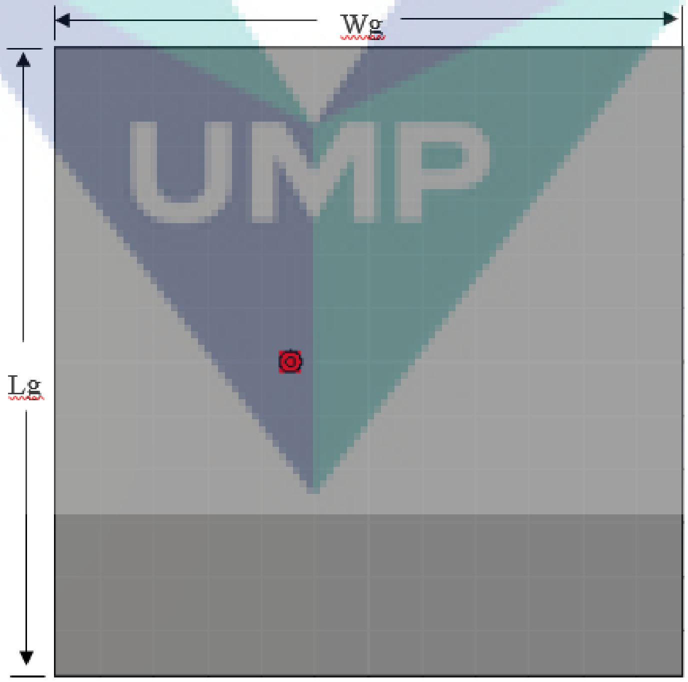


Figure 4.2 Back View of Antenna

Parameter	Symbol	Segment	Dimension
Patch	*a*	Radius	39 mm
Substrate	Ws	Width	117 mm
	Ls	Length	117 mm
	h	Thickness	1.6 mm
Ground	Wg	Width	117 mm
	Lg	Length	117 mm
Slot	*a*sl	Radius	13 mm
	*Ө*sl	Angle	81°

Table 4.1 Specification of Antenna Design

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 be cannot 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 -22.52 dB.

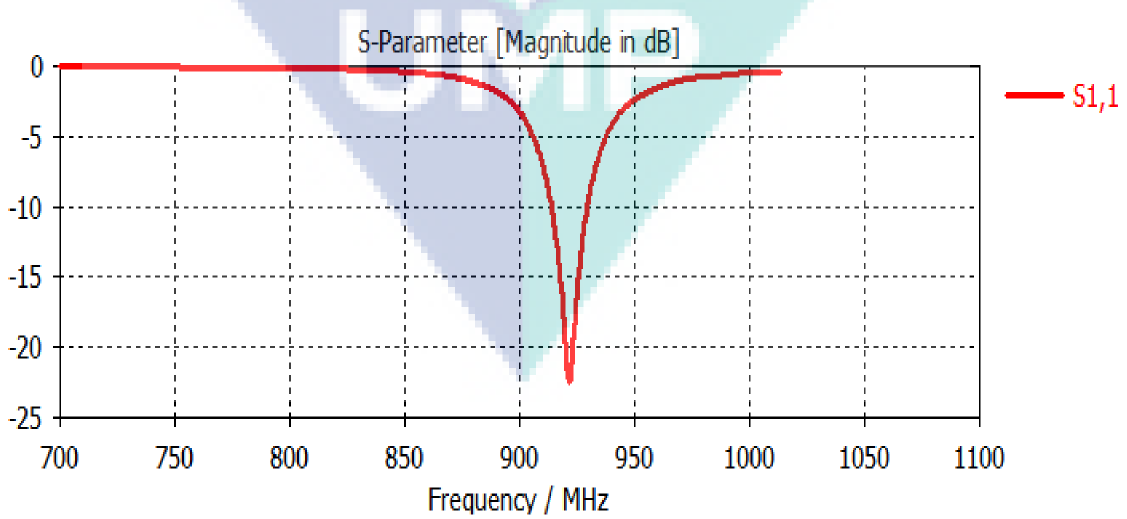


Figure 4.3 Simulation Result of Return Loss (S11)

4.3.2 Simulation Result of Voltage Standing Wave Ratio (VSWR)

The voltage standing wave ratio also known as VSWR is indicated the mismatch amount between feed 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 4.4 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.

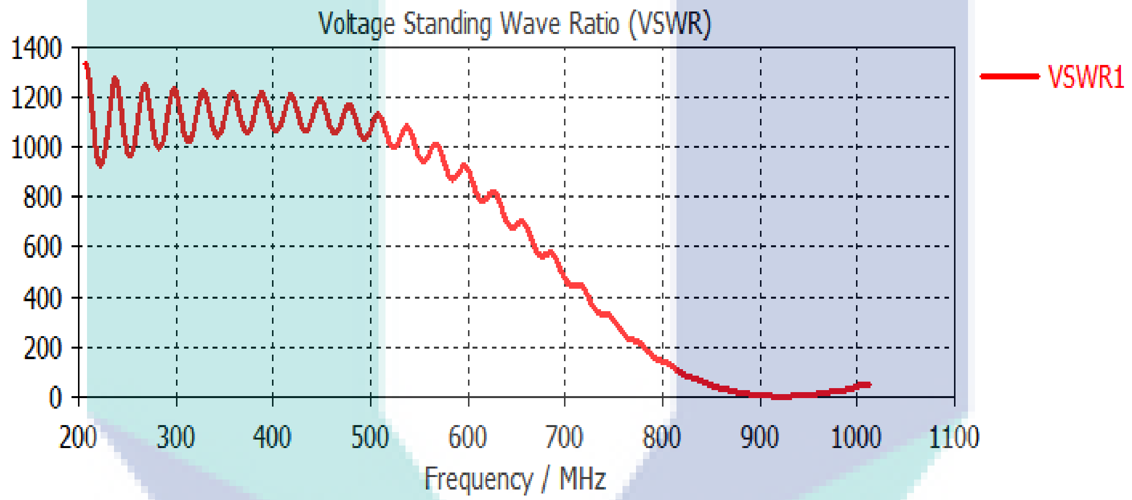


Figure 4.4 Simulation Result of VSWR

4.3.3 Simulation Result of Radiation Pattern

The radiation pattern simulation result can determine the information about radiated energy. Generally, radiation pattern results of antenna in 360 degree 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 5.81 dB 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.

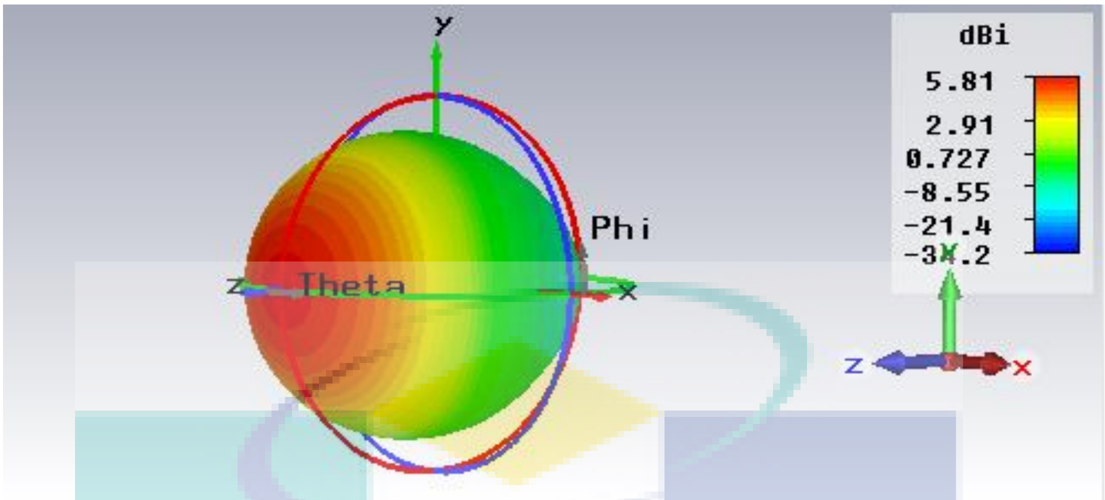


Figure 4.5 Simulation Result of Radiation Pattern

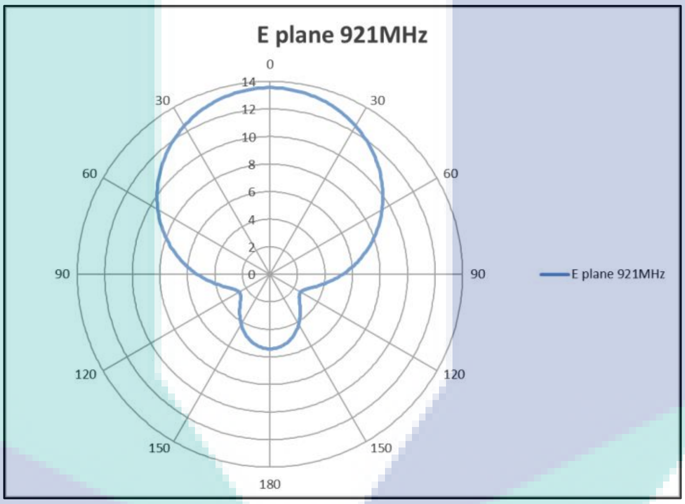


Figure 4.6 E-Plane

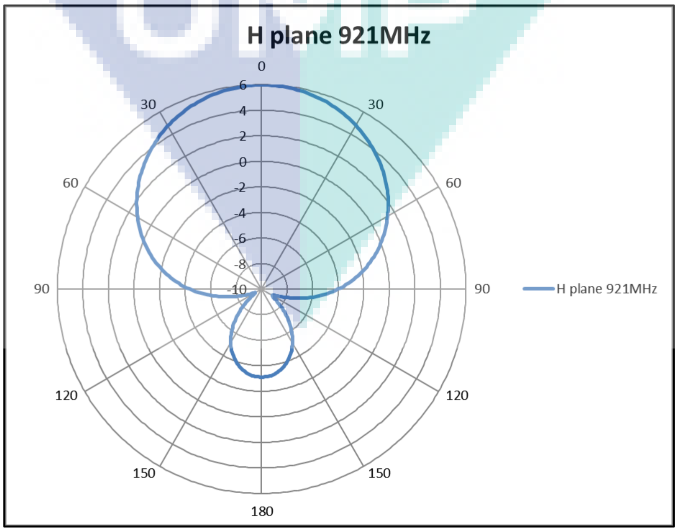


Figure 4.7 H-Plane

4.3.4 Simulation Result of Gain

This simulation result is also important for describing the performance of antenna whether it's working or vice versa. From the figure 4.8, 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.

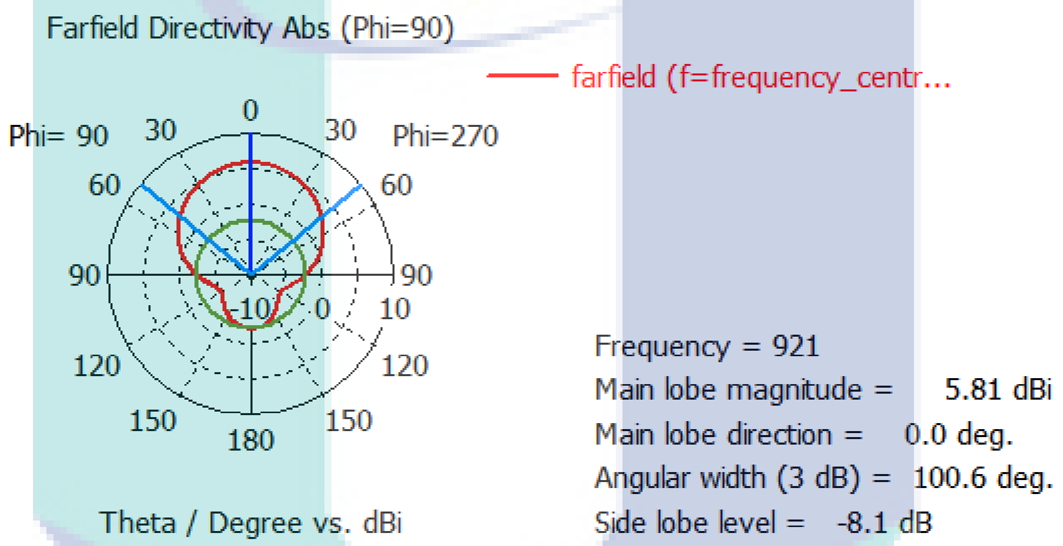


Figure 4.8 Simulation Result of Gain

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

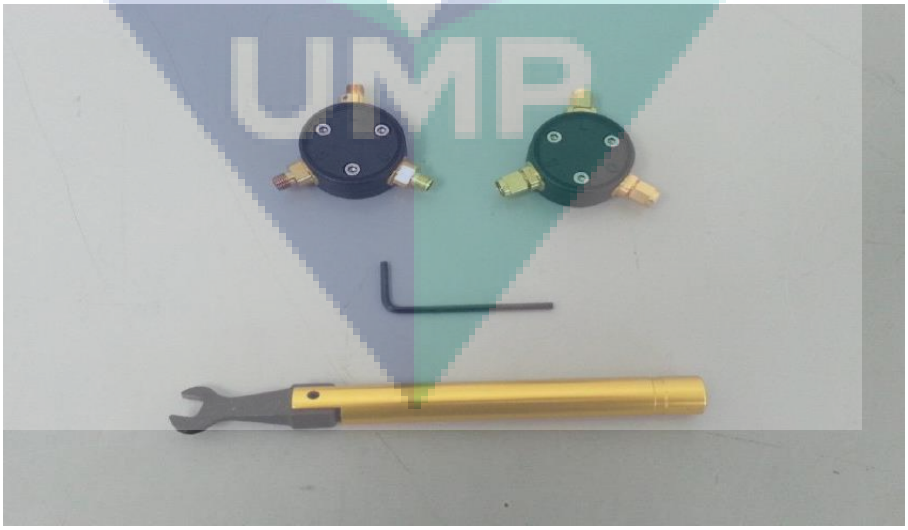


Figure 4.10 Calibration tool

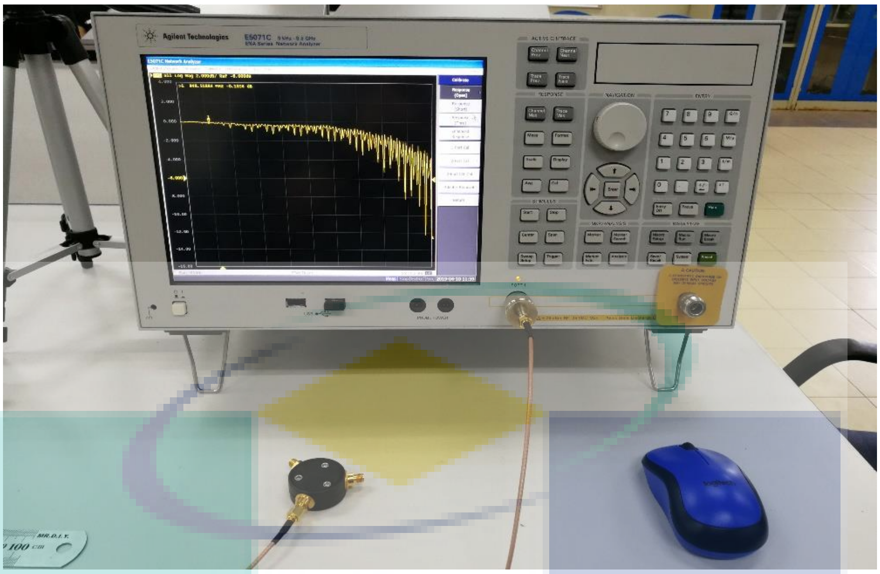


Figure 4.11Vector Network Analyzer Calibration Process

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 -28.92 dB compared to simulation antenna result which is -22.52 dB respectively at resonant frequency of 921 MHz.

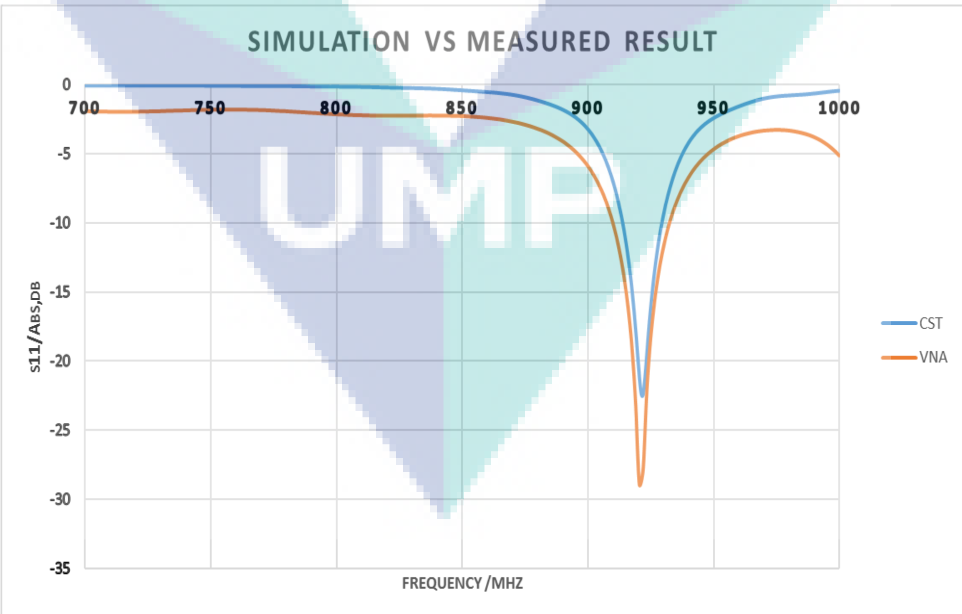


Figure 4.12 Comparison Result Between Simulation and Actual Antenna

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-814, AD-824, AD-815, AD-805, AD-223, AD-828 and AD-833 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 4.20 shows the correct configuration to execute this examination.

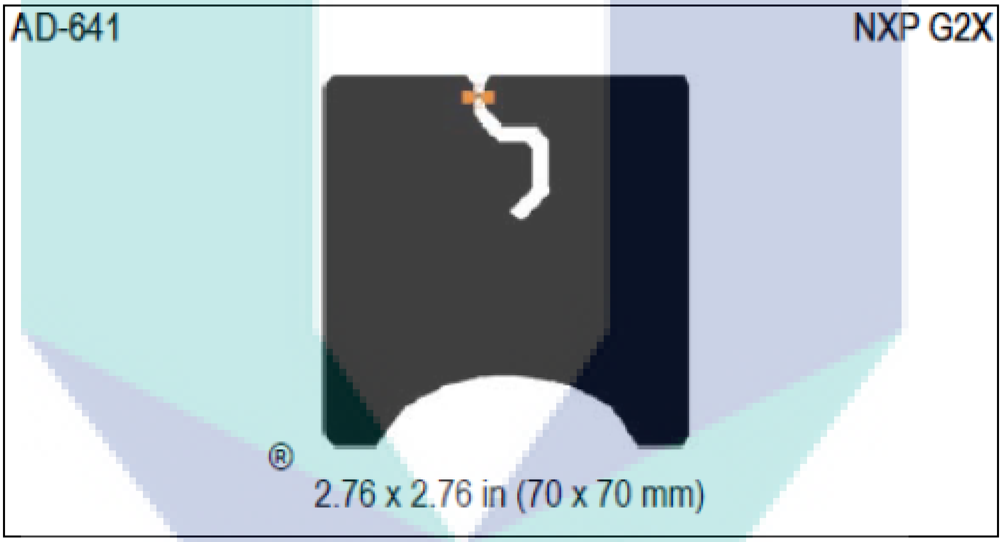


Figure 4.13 AD-641 UHF RFID Tag

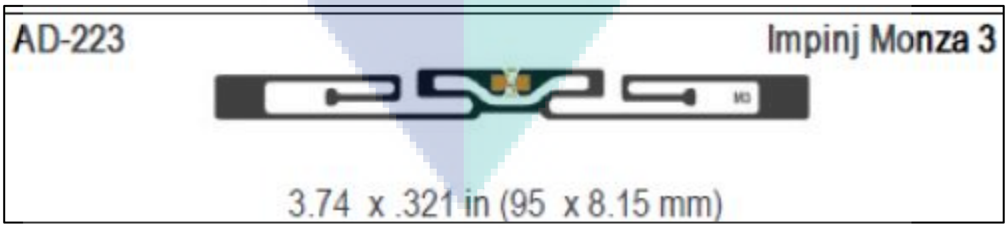


Figure 4.14 AD-223 UHF RFID Tag

Figure 4.15 AD-814 UHF RFID Tag

Figure 4.16 AD-815 UHF RFID Tag

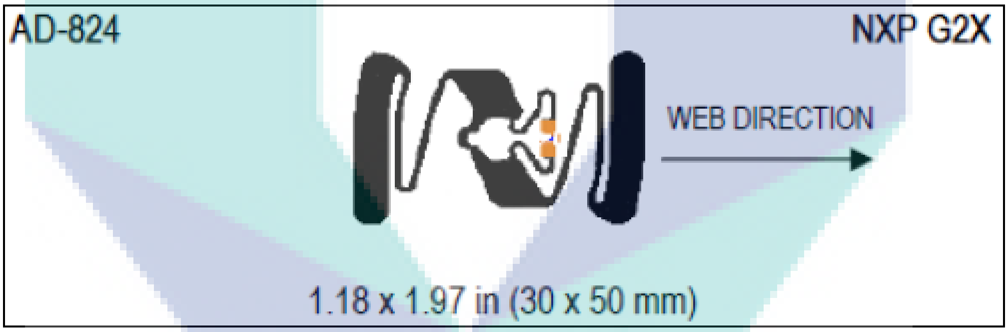


Figure 4.17 AD-824 UHF RFID Tag

Figure 4.18 AD-828 UHF RFID Tag

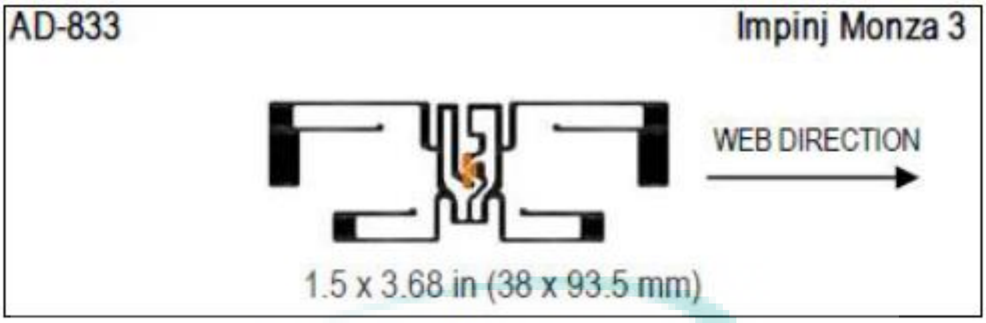


Figure 4.19 AD-833 UHF RFID Tag

Figure 4.21 shows the result for all eight different tags after execute this examination. Due to the largest size of 38 mm x 93.5 mm, AD-833 produces longest length of detection compared to other tags, and AD-805 produces shortest length of detection due to its size of 16 mm x 16 mm. The AD-833 tag recorded 109 cm of length detection area followed by AD- 828 with 67 cm and AD-223 with 47 cm of length detection area. Then, AD- 641 and AD-824 recorded same length detection area which is 45 cm respectively. Lastly, AD-805 tag produces the shortest length detection area with 8.7 cm followed by AD-815 with 20 cm and AD-814 with 26.5 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 4.20 Length Detection Performance Test Configuration

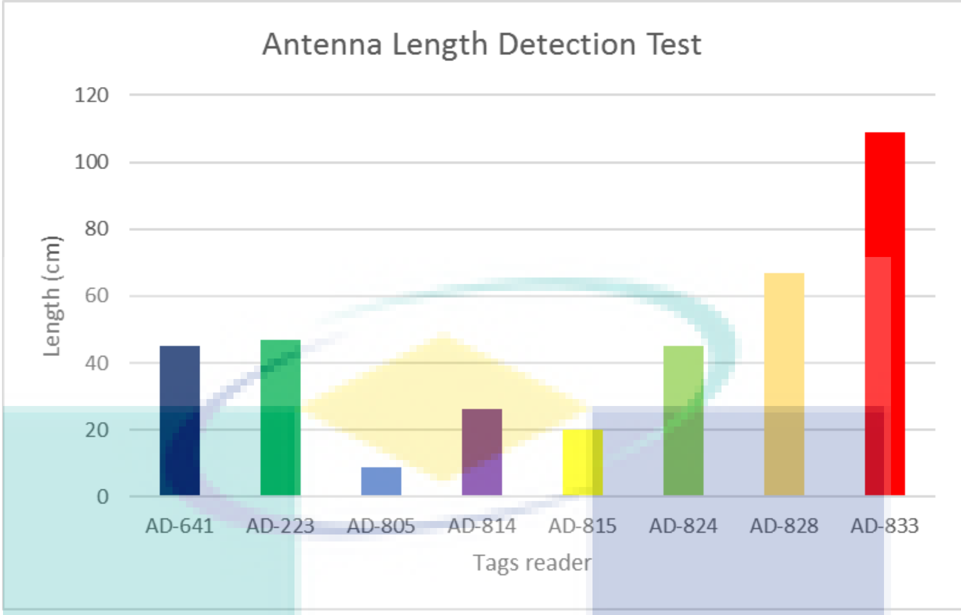


Figure 4.21 Result of Antenna Length Detection Test

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. This examination also studies the effective angle of antenna to capturing data from tags. The figure 4.22 shows the correct configuration to execute this examination. Then, five angles have been picked to executed this examination which is 30°, 45°, 60°, 75° and 90°. This examination also used tags that produces longest length detection area, then the AD-833 has been selected.

Figure 4.22 Angle Detection Performance Test Configuration

Figure 4.23 shows the result after this examination finished. At 30 angles shown the antenna can captured the data from the tag with 77.1 cm 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 78.7 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 78.7 cm to 82.2 cm to antenna 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 116.5 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.

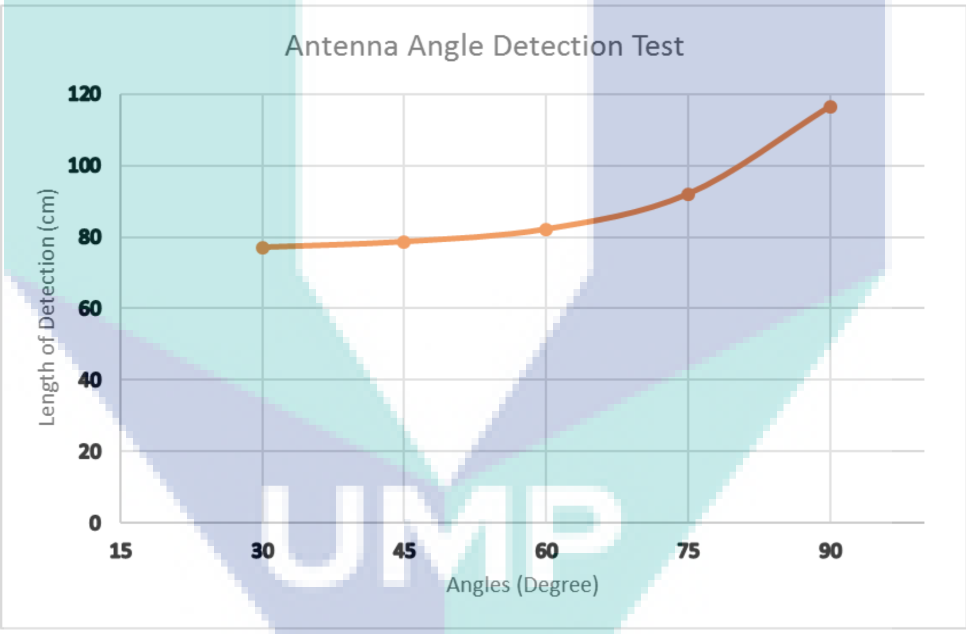


Figure 4.23 Result of Antenna Angle Detection Test

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 patch diameter, upper and lower slot angle, upper and lower slot radius, 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 2014 software. The structure of antenna parameter that will study on this subchapter as shown in figure 4.24.

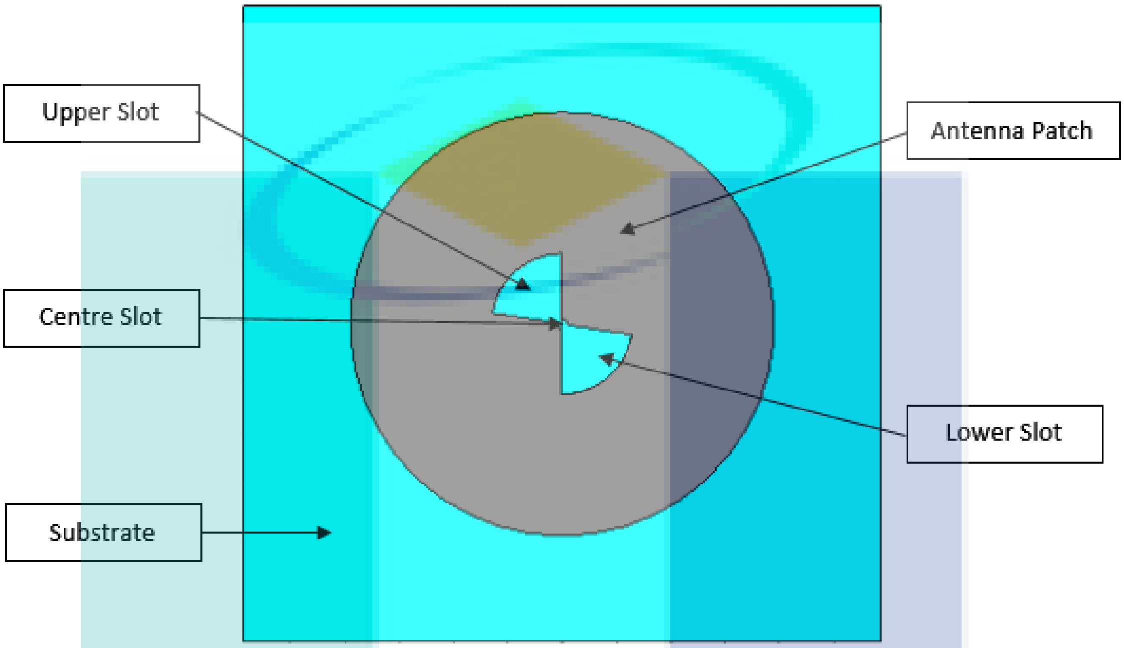


Figure 4.24 Antenna Parameter

4.5.1 Diameter of Patch

This examination was executed to determine the effect of antenna performance due to changing of patch diameter. 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 4.25 shows the effect on the proposed microstrip patch antenna due to diameter patch changes. By decreasing the diameter of patch to 7.7 cm, the resonant frequency rises up from 921 MHz to 934 MHz and the value of return loss also improved from -22.52 dB to -20.69 dB respectively. Then, by increasing the diameter of patch to 7.9 cm, the resonant frequency drops off from 921 MHz to 912 MHz but improved the return loss value from -22.52 dB to -23.53 dB. This examination also decreasing and increasing the patch diameter by 7.6 cm and 8.0 cm and the result is shows by green (7.6 cm) and purple (8.0 cm) line. The conclusion can be made is, if the diameter of the patch antenna increases, the value of frequency will be decreasing and the value of S11 will be improved.

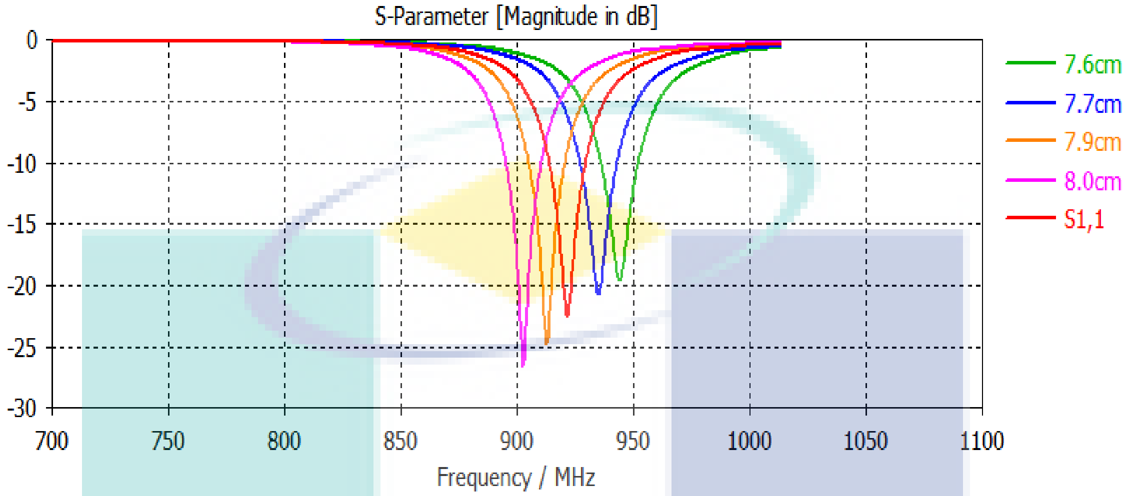


Figure 4.25 Return Loss and Resonant Frequency Effect Due to Changes of the Diameter of Antenna

4.5.2 Radius of Upper and Lower Slot

Figure 4.26 shows the effect of antenna performance due to changing of upper and lower slot radius. In this examination, all parameter such as diameter of patch, thickness of substrate, and radius of centre slot are fixed. Originally, radius of upper and lower slot is 1.3 cm and the result of the return loss and working frequency shows at figure below is red line (S1,1). By decreasing the radius upper and lower slot to 1.2 cm, the resonant frequency increase from 921 MHz to 937 MHz and the return loss (S11) value also improved from -22 dB to -27 dB. Then, by increasing to 1.4 cm the radius of upper and lower slot, the resonant frequency drop off from 921 MHz to 905 MHz. It also increasing the value of return loss (S11) from -22 dB to -19 dB. This examination also decreasing and increasing the radius of upper and lower by 1.1 cm and 1.5 cm and the result is shows by green (1.1 cm) and purple (1.5 cm) line. In a nutshell, the antenna can produced high working frequency and improved their return loss (S11) by decreasing the radius of upper and lower slot.

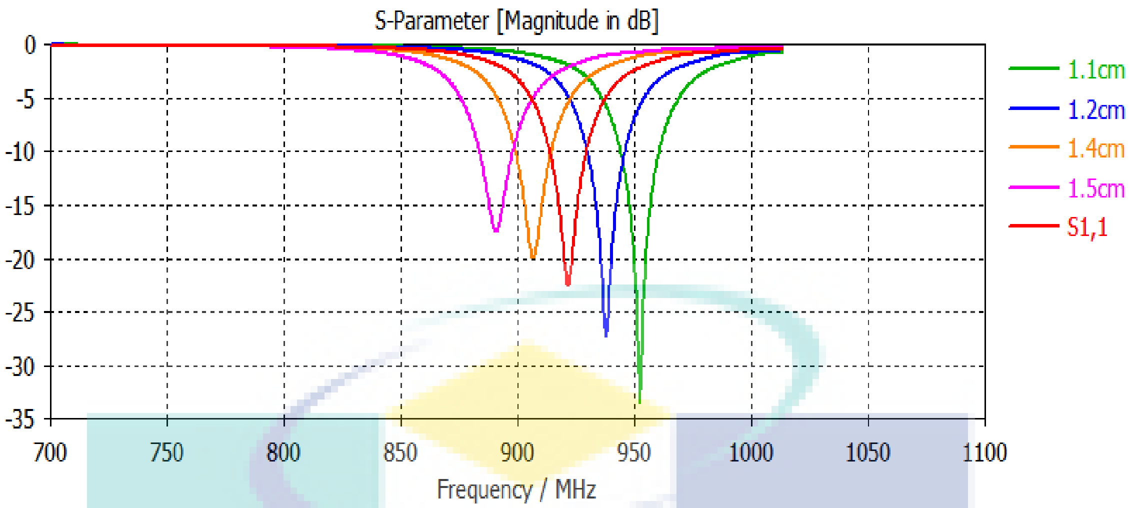


Figure 4.26 Return Loss and Resonant Frequency Effect Due to Changes of Upper and Lower Radius.

4.5.3 Angle of Upper and Lower Slot

Figure 4.27 illustrate the effect of antenna performance due to changing of angle (ϴ) od upper and lower 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 radius of upper and lower slot is fixed. the original angle before modification is 81° and the simulation result shows at figure below that represent in red line (S1,1). By decreasing the angle to 76°, the resonant frequency drops off from 921 MHz to 919.35 MHz and the return loss (S11) also changes from -22.52 dB to -21.88 dB. Then, by increasing the angle to 86°, the resonant frequency rises up from 921 MHz to 922 MHz. It also improved the value of return loss (S11) from -22.52 dB to -23.69 dB. This examination also increasing and decreasing the angle of slot by 91° and 71° and the result represent in purple line (91_degree) and green line (71_degree). The conclusion can be made after this examination is by increasing the angle of the slot can produced high resonant frequency and improved the antenna performance to other application that need high resonant frequency and good return loss (S11).

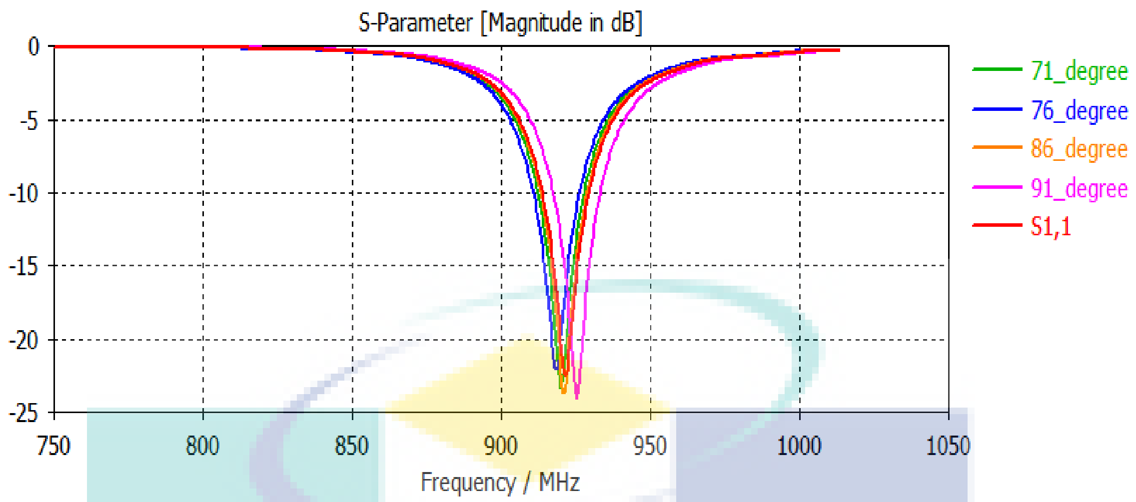


Figure 4.27 Return Loss and Resonant Frequency Effect Due to Changes of Upper and Lower Slot Angle

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, angle 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 4.28 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 894.84 MHz of working frequency and -6.82 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 0.8 mm, the working frequency is rises up from 894.84 MHz to 908.21 MHz and it also improved the value of return loss from -6.83 to -14.95 dB. Lastly, the working frequency increasing from 908.21 MHz to 920.89 MHz when 0.8 mm of substrate thickness was applied. It also improved the return loss from -14.95 dB to -23.45 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.

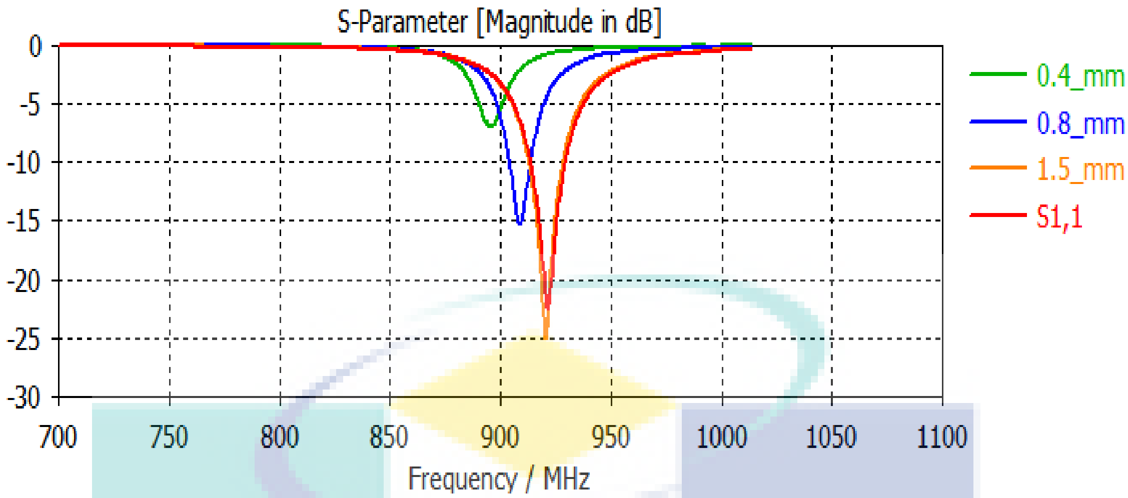


Figure 4.28 Return Loss and Resonant Frequency Effect Due to Changes of Substrate Thickness

4.6 Comparison Angular Slot Circular Patch Antenna between Circular Patch Antenna

This comparison has been done to study the impact of angular slot against circular patch antenna in term of antenna performance. The circular patch antenna as shown in figure 4.29 has been set to operate at the same working frequency of 921 MHz and used the same material as angular slot circular patch antenna. It also used 4.7 of substrate permittivity ($\mathcal{E}r$). The dimension of circular patch antenna is 13.0 cm x 13.0 cm x 0.16 mm, while 11.7 cm x 11.7 cm x 0.16 cm of angular slot circular patch antenna. The CST MWS 2014 has been used in this comparison test to generated the simulation result for these two types of antenna.

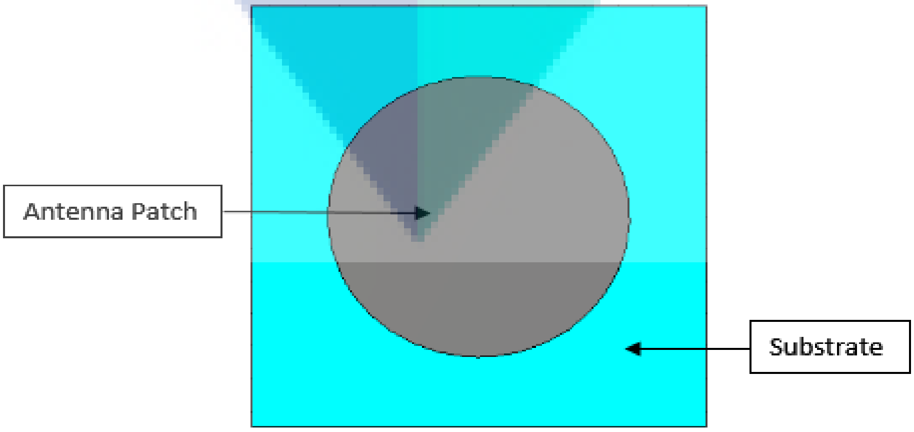


Figure 4.29 Circular Patch Antenna

The comparison results between angular slot circular patch antenna and circular patch antenna as shown in figure 4.30. By referring from the result, the angular slot patch antenna produces a good value of return loss (S11) which is -22.52 dB at 921 MHz of working frequency compared to the return loss that produces by circular patch antenna which is -11.11 dB. By using the CST MWS 2014, 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, angular slot gave high impact to return loss (S11). Other than that, the size of circular patch antenna will be decreased by applying angular slot on it and produces a good return loss (S11) at 921 MHz.

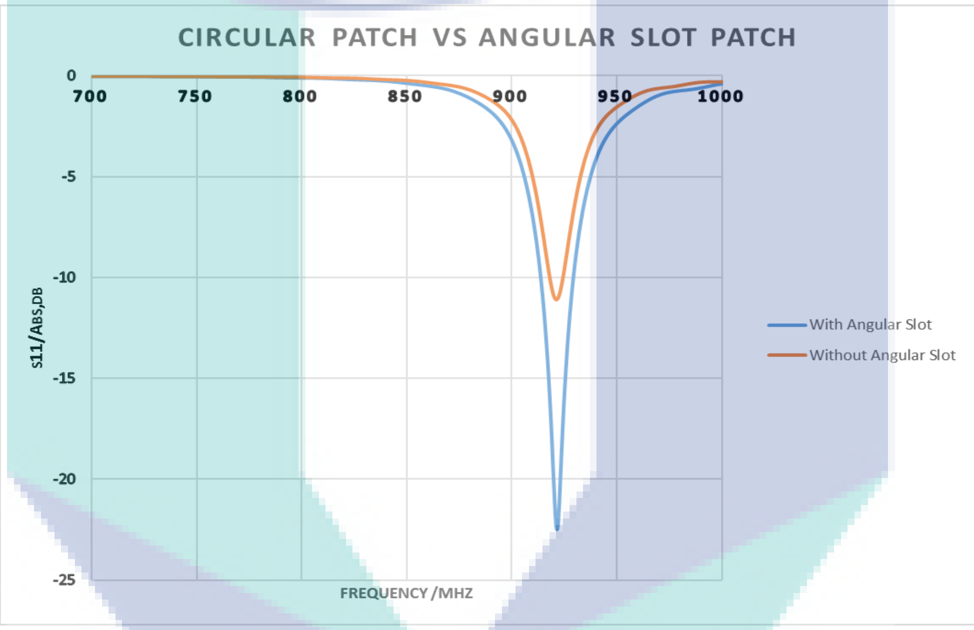


Figure 4.30 Comparison Result between Circular Patch Antenna and Angular Slot Patch Antenna

CHAPTER 5

CIRCULAR SHAPED PATHC ANTENNA WITH RECTANGULAR SLOT

5.1 Introduction

This chapter discusses the proposed antenna performance in terms of simulation and measured result of return loss and frequency assignment. The performance of the fabricated antenna has been tested whether it meets the desired frequency of 921 MHz and return loss which must (S11) below -10 dB. This chapter also displays the simulated VSWR and the gain of the proposed antenna. The VWSR is tested to ensure that it has a good level of efficiency of the antenna design. For gain consideration, it is important factor to reflect the process antenna readability performance. Furthermore, it also covers the parametric study of the antenna by changing the certain parameter of the antenna in term of width, length, substrate permittivity and diameter of antenna in order to see the variation performance in return loss S11. The fabricated antenna also be a tested of its performance capabilities on the range detection by changing the distance between of RFID reader and tags. The general results are very valuable for real RFID set up in assigned environment to distinguish the best position of the correction antenna to improve the size of detection, separation and implementation.

5.2 Final Design of UHF RFID Microstrip Patch Antenna

5.2.1 Simulated and Measured Return Losses

After completion fabrication process, patch antenna will be tested using the Network Analyzer available in the Communication Lab. During this phase, an attempt is made to identify the possible difference between the fabrication and measured antenna return loss (S11). The image below of the microstrip patch antenna is created as shown in Figure 5.1 respectively.

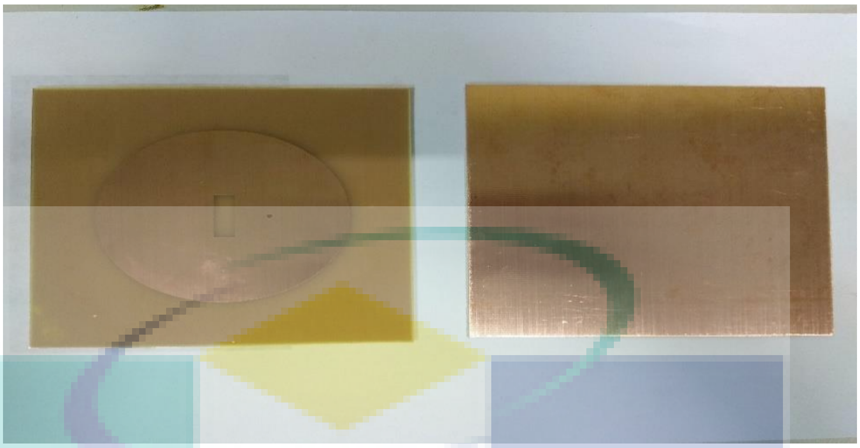


Figure 5.1 Fabricated Microstrip Patch Antenna

Using Agilent Analyzer E5071C ENA (9 kHz -8.5 GHz), the return losses and antenna frequency range are measured. Figure 5.2 below shows the result between measured and simulation return losses. From the result, it shows that the antenna working well in 921 MHz. The result for the bandwidth had shown and improvement form 1.62% in simulation to 3.58% for measured value. The increasing size of the bandwidth will also improve the performance of data storage in RFID reader. Based on the measured value, more tag id can be stored during tagging process.

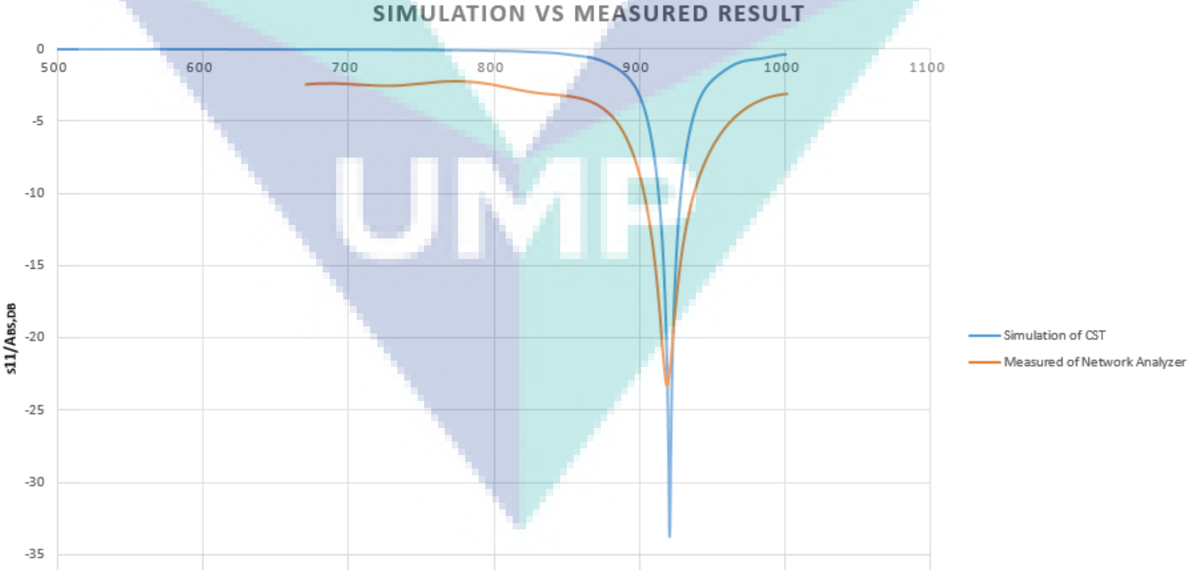


Figure 5.2 Measured and Simulated Return Loss

5.2.2 Simulated Radiation Pattern

Radiation pattern of the antenna give the explanation of information to us how much energy can radiated to it. Figure 5.3 below shows the 3-D radiation diagram of the correction antenna with a gain of 5.97 dB at 921 MHz. The simulated radiation pattern is plotted in E-plane and H-plane as shown in Fig. 5.4 and Figure 5.5 respectively. The desired polarization pattern is obtained at levels E and H. E-Plane is where the correction antenna radiates its vertical polarization energy. However, for H-Plane, the antennas send energy in the horizontal polarization. In this project, it was observed that the radiation pattern of the antenna was practically identical in both plane and the patch antenna covered a wide range of tag detection. The positive value of gain as in figure 5.3 shows that this antenna is working well to operate because the normal gain is around 2 dBi.

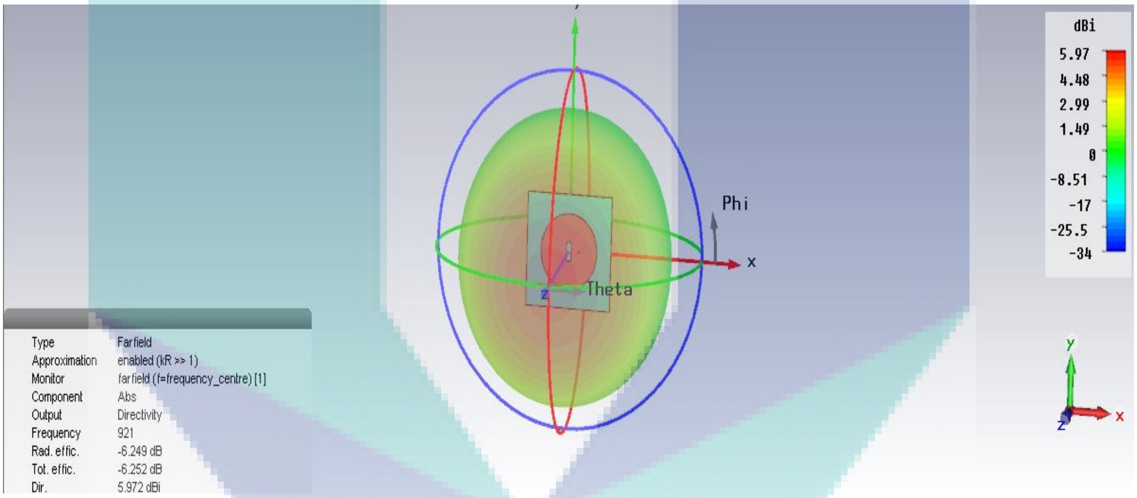


Figure 5.3 Simulated Patch Antenna Radiation Pattern

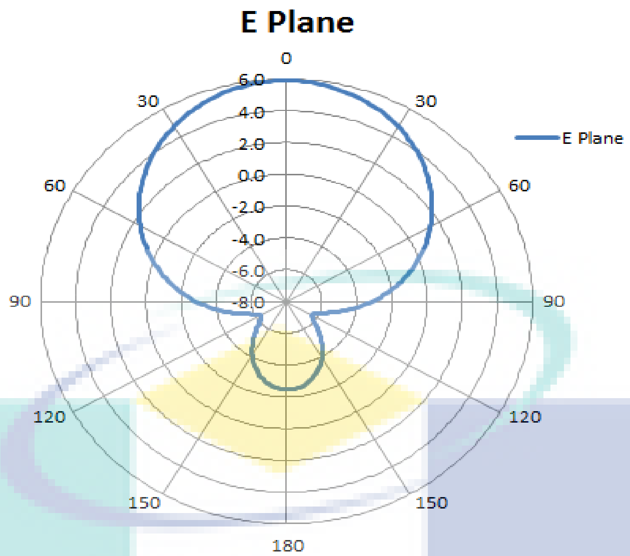


Figure 5.4 E-Plane Radiation Pattern

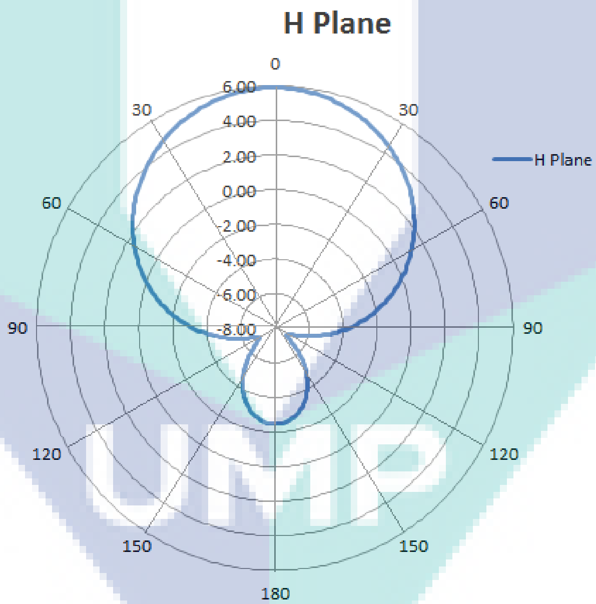


Figure 5.5 H-Plane Radiation Pattern

5.2.3 Simulated VSWR

The Voltage Standing Wave Ratio (VSWR) is one of the element to find good efficiency of the antenna design. The Voltage Standing Wave Ratio known as VSWR mean that the relationship between transmissions line with patch of antenna. It shows the different of amount indication between an antenna and the feed line connecting to it. Furthermore, VSWR always be used as an indicator of power reflected from the antenna. To achieve the perfect value of the VSWR, it should less than 2.

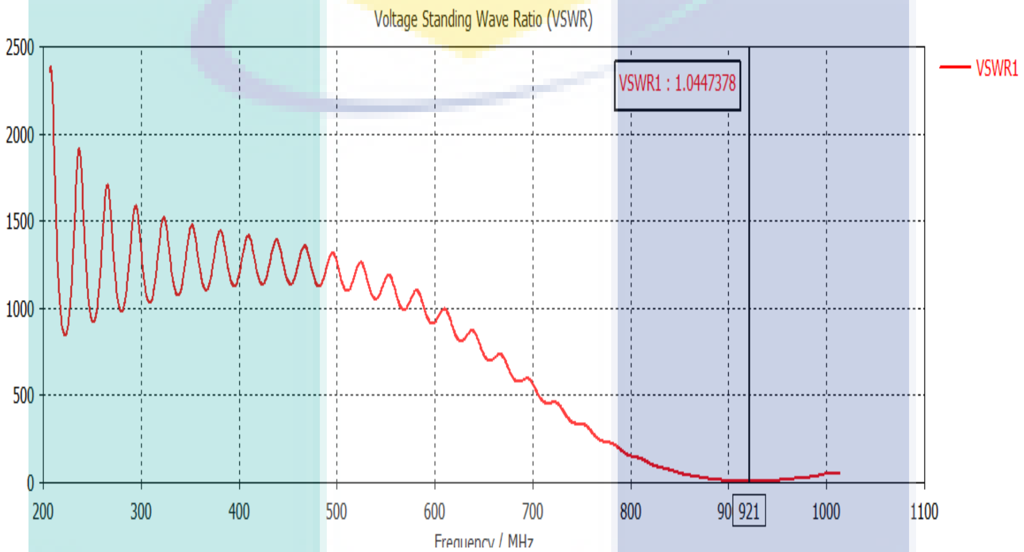


Figure 5.6 VSWR of the antenna is 1.044

5.2.4 Simulated Gain

Another measure of value to describe the implementation of a microstrip patch antenna is the gain parameter. Indeed, antenna gain is determined strongly with directivity, which yields standard productivity for the performance of the correction antenna as well. It looks like a combination of the antenna efficiency and directivity.The lobe in Fig. 5.7 shows the range of antenna reading that is linear polarization. It covers all the linear around the antenna located in the front and back of the antenna at the every angle. This is also called the radiation scheme of the precise correction antenna that contains a multi-level radiation (E-plane and H-plane). The ordinary simulated gain of the receiving wire in Fig. 5.7 demonstrates that the gain with the main lobe is 5.97 dB for the polarization of the designed antenna. It shows that the antenna has a higher gain for better antenna performance.

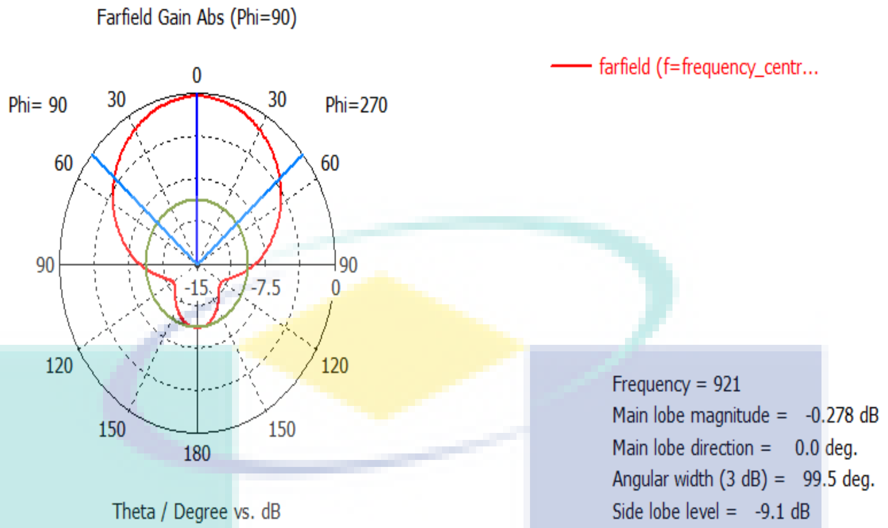


Figure 5.7 Polar Plot Graph for Gain

5.3 Parametric Study

In this subtopic, parametric study of the exact patch was carried out to detect the effect of changes in the geometry parameters of the correction antenna on antenna performance. This study was conducted using CST Microwave Studio Suite. Parameters under review include the length and width of the patch antenna, diameter patch antenna, the substrate dimension used in the antenna for the project (εr). Figure 5.8 below shows part of the microstrip patch antenna, which includes the antenna correction slot, the patch and the substrate. This study will also explain the effect of changing some geometric parameters of the antenna, whether there is a change in frequency of resonance or return loss antenna.

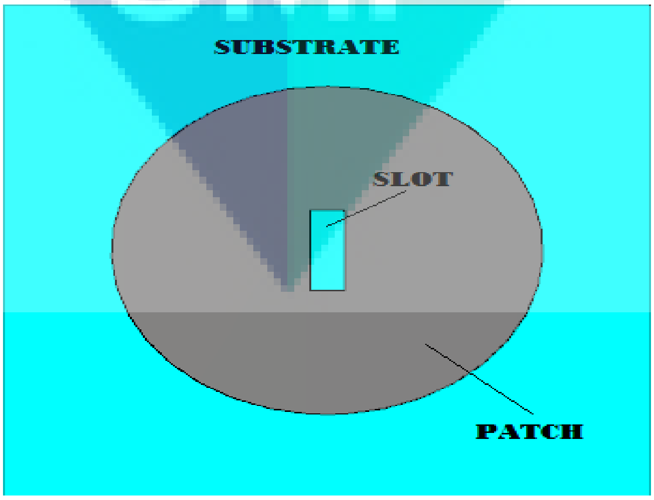


Figure 5.8 Antenna Design

5.3.1 Asymmetric Slot Width

Figure 5.9 show the effect of changing the slot width of the patch antenna. Originally, the width of the slot antenna is 0.65 cm and the result of the return is show at figure above which is red line (S1,1) is equal to -33.2 dB. In this research, the slot width of the patch antenna is reduce by 1 mm become 0.45cm and 0.55cm and increase by 1 mm become 0.75cm and 0.85cm. The simulation result was change when the slot width of the patch antenna is changed. The result was changed included the value of return loss and resonant frequency are different. The resonant frequency also changes due to the changes of the slot width of patch antenna.

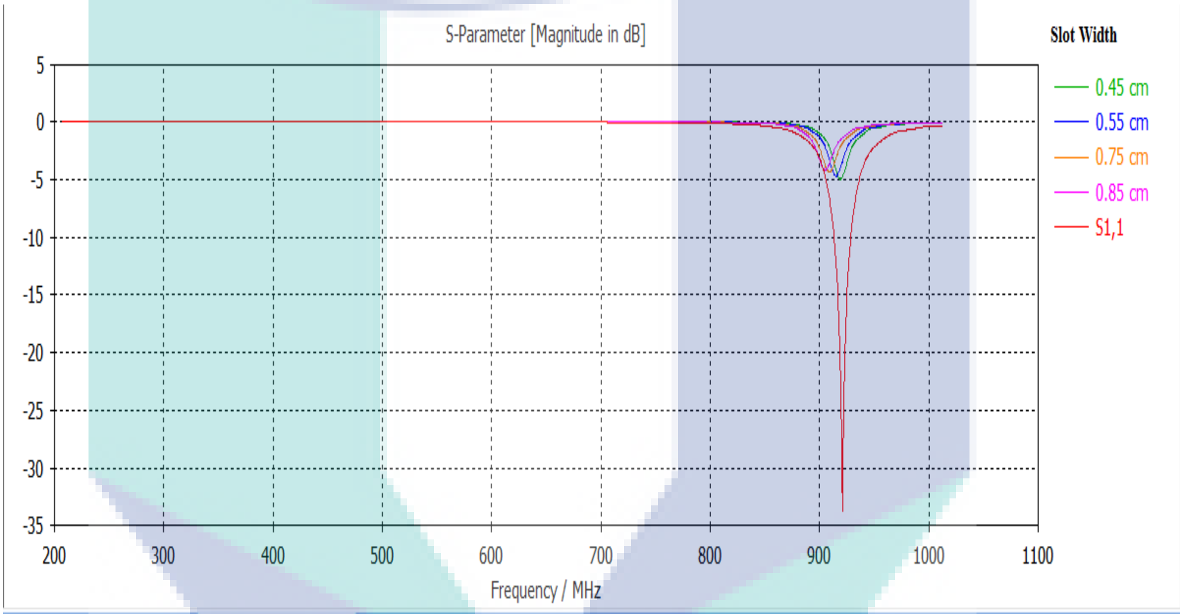


Figure 5.9 Effect in Variation of Antenna Slot Width to the Resonant Frequency and Return Losses

5.3.2 Asymmetric Slot Length

Figure 5.10 show the effect of changing the slot length of the patch antenna. In this study other parameter such as width of slot, length of slot, diameter of patch and thickness of the substrate are fixed. Originally, the length of the slot antenna is 2 cm and the result of the return is show at figure above which is red line (S1,1) is equal to -33.2 dB. In this research, the length of the slot antenna is reduce by 1 mm become 1.8 cm and 1.9 cm and increase by 1 mm become 2.1 cm and 2.2 cm. The simulation result was change when the length of the slot patch antenna is changed. The result was changed included the value of return loss and resonant frequency are different.

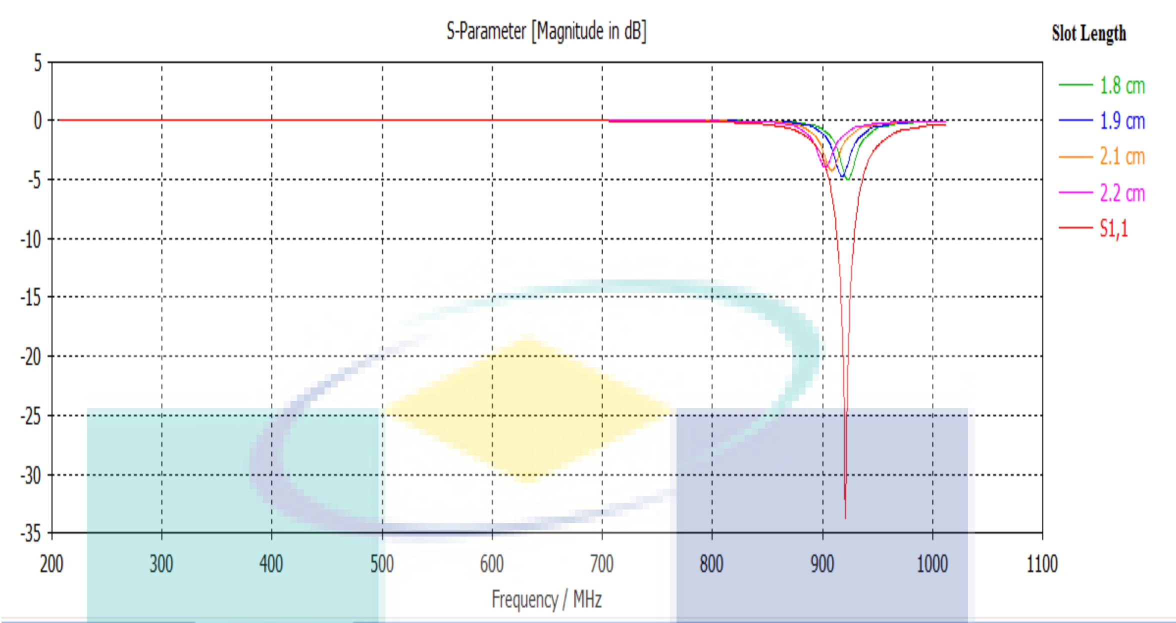


Figure 5.10 Effect In Variation of Antenna Slot Length to the Resonant Frequency and Return Losses.

5.3.3 Substrate Permittivity

In the design of the antenna, it is important to obtain a good material from the substrate that is your constant electrostatic insulation (εr) and antenna thickness (H) for better performance. The physical substrate will affect the coupling; along these lines will change the resonance frequency of the antenna. It aimed to examine the effect of substrate on microstrip patch performance of the antenna. In this review, four substrates are common, to be specified in FR4 (r = 4.7, tan = = 0.019), RO4003 (r = 3.38, tan = = 0.0027), RO3010 (r = 10.2, tan = = 0.0023) and RT5880 εr = 2.2, tan = = 0.0009), with similar thickness (h), from 0.16 cm used. The measurement of the other antenna is similar to the correction as specified. It has been found that when the patch antenna is adjusted on different substrates, the resonance frequency and yield losses (S11) are changed in addition as shown in Figure 5.11. Note that with increased substrate tolerance, the resonance frequency of the antennas becomes less frequent, but for unknown reasons, some substrates have different readings. For example, RO3010 (with εr = 10.2) additionally contributes at a lower frequency. To conclude that the substrate with higher dielectric permitting leads to a lower frequency of the antenna.

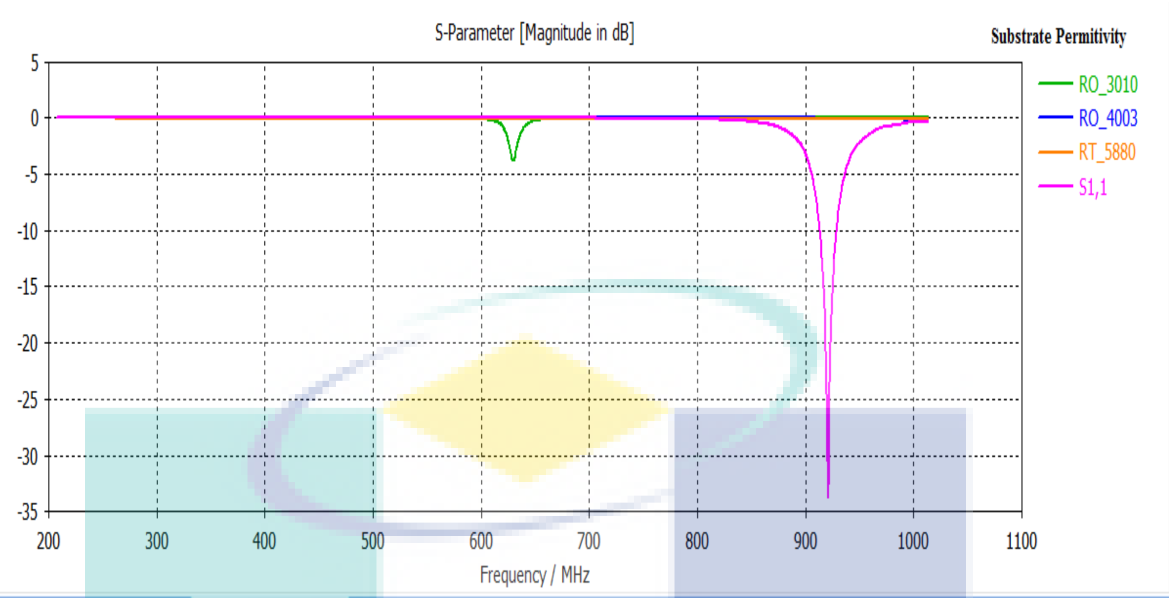


Figure 5.11 Effect in Variation of Substrate Permittivity to the Resonant Frequency and Return Losses

5.3.4 Diameter of Patch

This examination was led to decide the impact of antenna diameter on antenna performance. By maintaining the antenna thickness of 0.16 cm and the antenna length and width at 2 cm and 0.65 cm are in contrast to observe the effect of the modified patch diameter on antenna frequency and return losses. Figure 5.12 illustrates the effect of diameter variation on the proposed microstrip patch antenna. By increasing the antenna diameter, the S11 value will improve but the resonance frequency will be reduced. The antenna diameter corrects at 8.2 cm at 921 MHz and -33.2 dB for S11 reading. As the diameter decreased to 8.1 cm, the antenna frequency shifted to 926 MHz but different in the S11 reading, which improved to -49.6 dB, respectively. It can be concluded that by increasing the diameter of the antenna, the buzz frequency will decrease and produce a good S11 value.

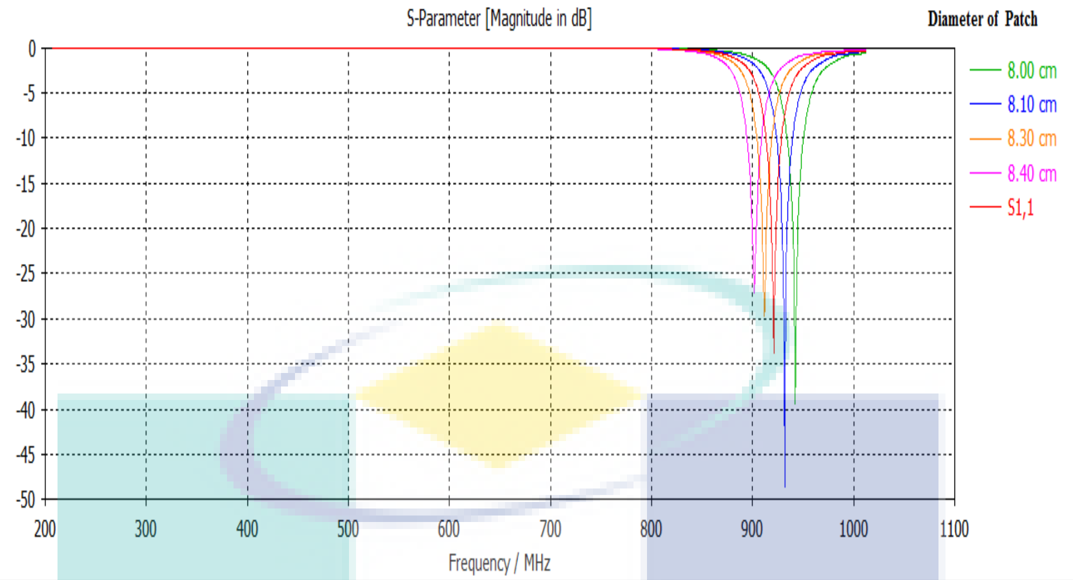


Figure 5.12 Effect in Diameter of Patch Antenna to the Resonant Frequency and Return Losses

5.4 Antenna Testing

In this subtopic, the microstrip patch antenna will be tested to detect the antenna performance in the field of return loss, resonance frequency, antenna reading range, and maximum detection angles. Conduct investigations into the comparison of antenna and measured antenna loss, study the length of the detector distance and study the effect of angles of patch antennas on the maximum detection length.

5.4.1 Antenna Testing with Network Analyzer

After completion of the fabrication process, the patch antenna will be tested using the Network Analyzer as shown in Figure 5.13. Using Net Agilent's E5071C Aga business analyzer series (9 kHz -8.5 GHz) in the communications lab ICOE UMP, return loss and frequency range are often measured. This network analyzer can be used to test the patch, because it can be covered from 9 kHz to a frequency of 8.5 GHz and an antenna frequency (921 MHz) in range. To complete the antenna testing process, the measurement and simulation are compared. There are slight differences between the improved and measured return loss of the antenna due to the fabricate of the hand on the substrate and the antenna segment, which means that the antenna measurement is not accurately coordinated between theory and manufacturing. Low quality FR4 substrate addition will affect the antenna performance. During this phase, attempts are made to identify imaginable helmets between the simulated and measured structure, for fabrication errors, the effect of the paste used to bind the PCB or current layers to the outside of the feed.

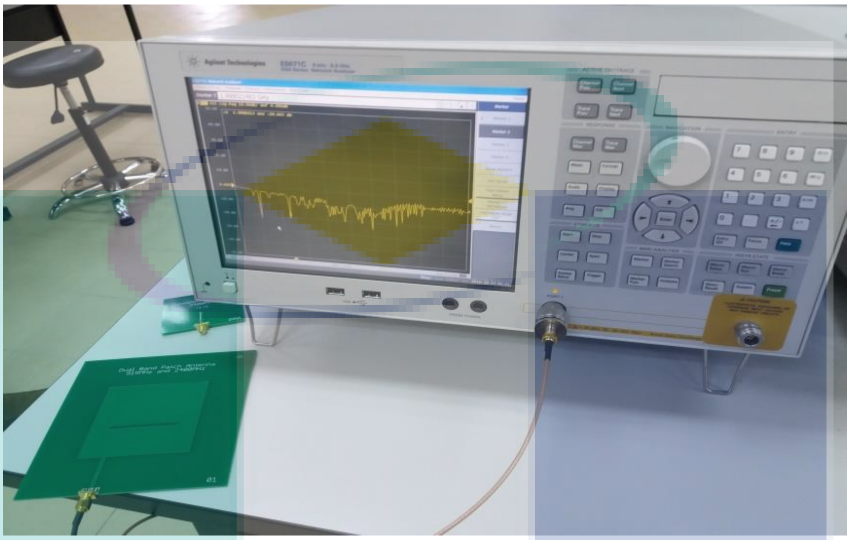


Figure 5.13 Antenna Testing with Network Analyzer

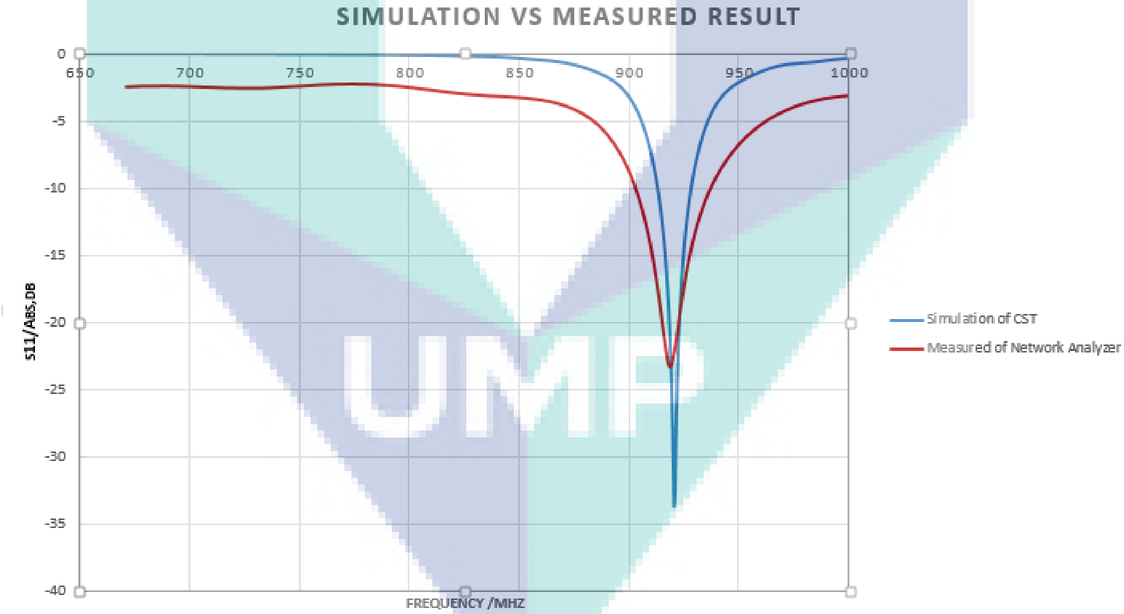


Figure 5.14 Comparison Between Measured and Simulated Return Losses

5.4.2 Field Test of Length Detection Performance for Different Tags Type.

There were many types of RFID cards that were accessible in the industry. Each tag has different properties in terms of the length of identification of marks and the coverage and size of identity. Test the implementation of tags with eight types of RFID tag with special labels AD-641, AD-814, AD-824, AD-815, AD-805, AD-833, AD-828 and AD-223 as shown in Chapter 4. Under the RFID, the tags can be determined by antenna via radio frequency. Figure 5.15 shows the setting of the correction antenna to detect the markings. Figure 5.16 shows the result of the maximum detection length of a tag with a different type of markup. The length of the definition was compared to eight tag RFID Tag. The maximum detection distance of the AD-833 was the most impressive compared to the other marks due to the largest size of 38 mm x 93.5 mm, the lowest length to detect the maximum degree goes to the AD-805 with the smallest size 16 mm × 16 mm followed by AD-815 AD-814 tag. The maximum detection limit is the most detected of the extreme signs that the antenna recorded successfully before losing the signal. The AD-833 had the highest detection level at 104 cm followed by AD-823, AD-223, AD-641, AD-824, AD-814, AD-815 and AD-805, respectively. The AD-805 marker recorded the shortest detector length limit which is only 4.5 cm. Different types of labels have created different lengths to distinguish in light of the fact of the impact, size, shape and design of the antenna.

Figure 5.15 Antenna Setup for Tags Detection Length

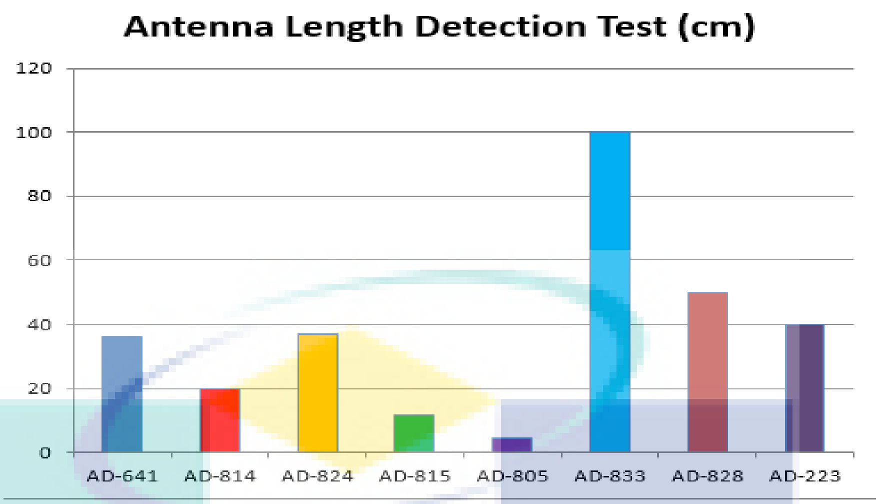


Figure 5.16 Effect of Different RFID Tags Type to the Maximum Detection Length

5.4.3 Field Test of Angle Detection

Achieve the angles of correction antennas that are intended to justify whether there are changes in the maximum detection length when antenna angles change. In this review, five corners of the patch antennas were selected, to be defined as 30, 45, 60, 75, 90 and 90 respectively with a tag in the field. Only one tag is used and fixed in this experiment, AD-833. The maximum detection length in each corner is as shown in Figure 5.18. Also show the antenna setting in Figure 5.17 below. For the antenna angle at 30 °, the maximum detection distance is 70 cm. The two angular angles change to ^{0}45 and produce a detection length greater than the angle of the antenna 30 ^{0} with 71.5 cm. At the antenna angle increase point at 60 ° C and 75 °, the maximum length of detection is increased in addition to 73 cm and 85 cm, respectively. After changing the angle to 90 degrees, the maximum detection length increases to 103 cm. As a conclusion, when the antenna angle increases the patch, it increases, and increases the maximum distance detector also. This is because different antenna angles transmit different radio wave patterns and the mark cannot be well recognized.

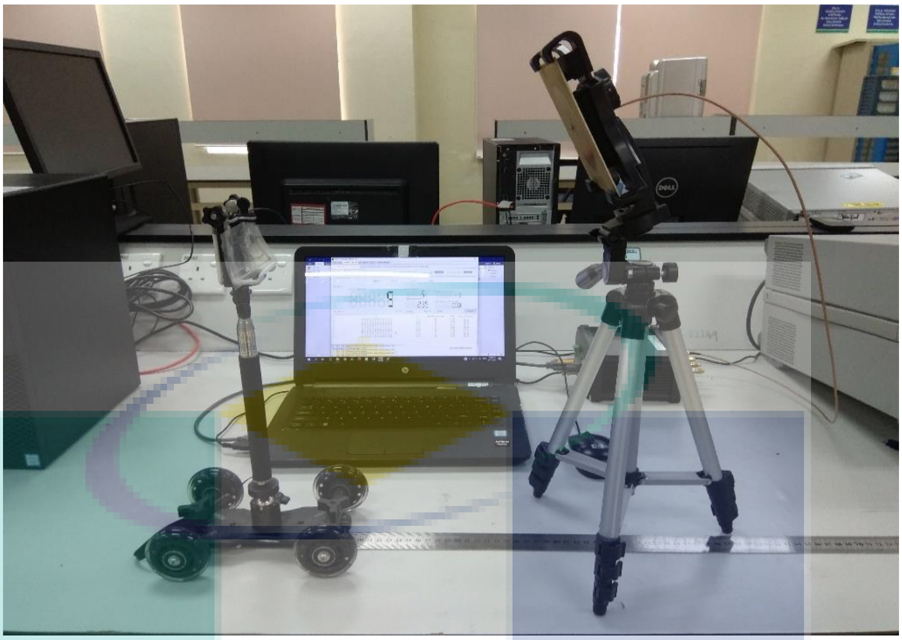


Figure 5.17 Antenna Setup for Effect of Antenna Angles

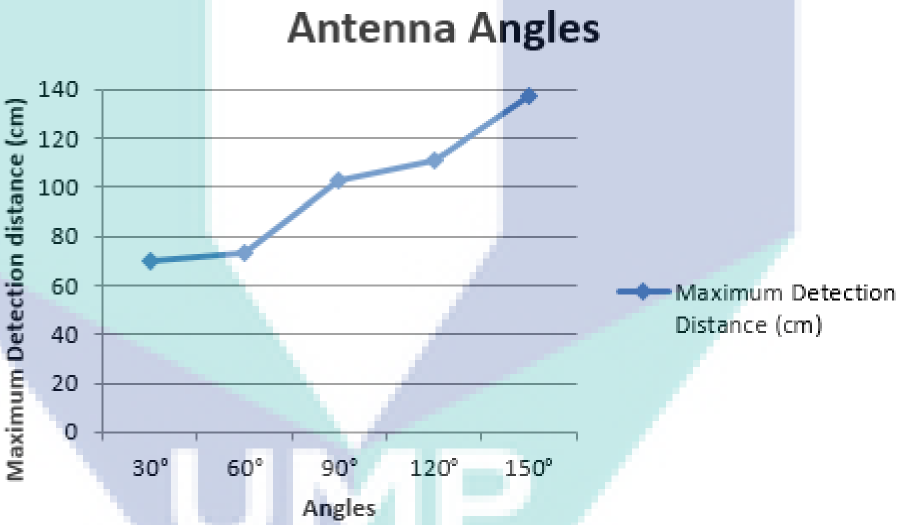


Figure 5.18 Effect of Antenna Angles to The Maximum Detection Length

5.5 Comparison of circular patch antenna with I-slot circular patch

Figure 5.19 show the original circular patch antenna without I-slot. Based on the simulation result using CST Software 2014, circular shaped microstrip antenna has been operated at the same frequency which is 921 MHz. This antenna has been proposed with size 120mm x 120mm x 1.6mm. The result for simulated return loss at frequency 921 MHz are -11.2 dB which is less than -10 dB. Figure 5.20 show the comparison of return loss (S11) the circular patch without I-slot and without I-slot.

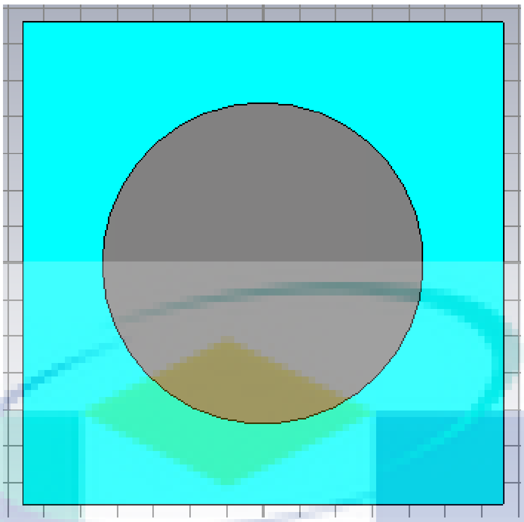


Figure 5.19 Circular Patch Antenna without I Slot

On the other hand, the I-slot circular patch microstrip antenna also has been pre-sented for RFID applications which is will operate at frequency 921 MHz. This antenna has been tested with size 122 cm x 122mm x 1.6mm. This antenna have the same permittivity is using FR4 substrate with permittivity 4.7. It also measure different parameters by using CST software simulation such as return loss, Voltage Standing Wave Ratio (VSWR), directivity and gain. The result for simulated return loss at frequency 921 MHz are -33.2 dB which is higher than circular patch without I-slot. The maximum return loss for antenna to operate is -10 dB. Without I-slot, the value of return loss will be low and cause gain value will also be low.

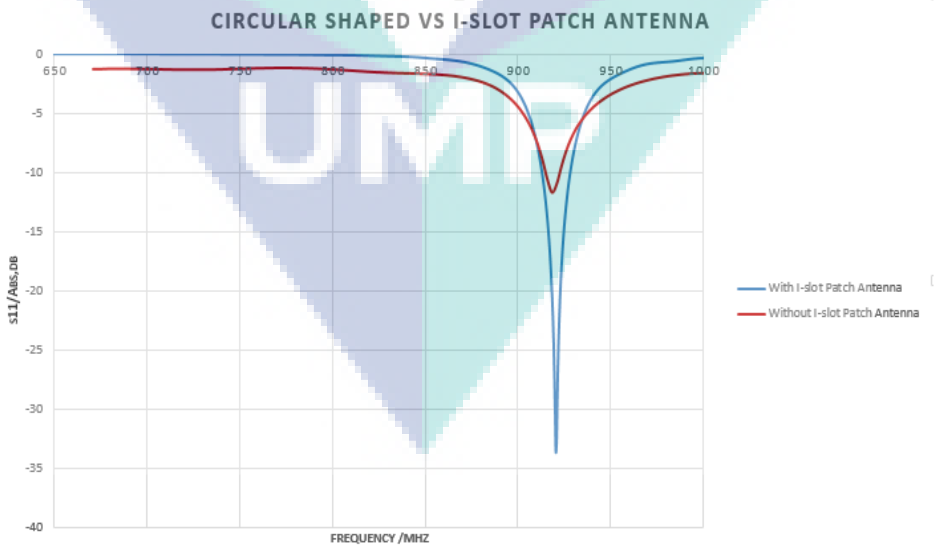


Figure 5.20 Circular Patch Antenna versus I-slot circular patch antenna

CHAPTER 6

MICROSTRIP PATCH ANTENNA WITH T SLOT

6.1 Introduction

This chapter will discuss about the performance of proposed antenna in term of comparing the simulation and measured result of return losses and frequency. The performance of the fabricated antenna will be test whether it meets the desired frequency which is 921 MHz and the return losses (S11) below than -10 dB. This chapter also presents the simulated VSWR and gain of the proposed antenna. The VWSR also be tested to make sure that it have a good level of match between the transmission line and the patch antenna. For the gain, it is important to for the patch antenna performance in term of the antenna read range. It also covers the parametric study of the microstrip patch antenna to find out the effect of changes in the antenna parameter to the antenna performance.The antenna prototype also will be test of their performance on the near field tag detection range by changing the RFID tags distance and angle. The general outcome are very valuable in other to distinguish the best patch antenna position to optimize the detection size, separation and execution.

The first antenna design discussed the development and analyses work done on the antenna reader antenna work carried out on the basic circular patch antenna with notches to achieved circular polarized antenna that have been discussed in Chapter 2. A circular polarized wave radiated energy in both horizontal and vertical planes and all planes in between.

6.2 Final Design of UHF RFID Microstrip Patch Antenna

6.2.1 Simulated and Measured Return Losses

After finishing the fabrication process, the patch antenna will be testing using Network Analyzer that are available in the Communication Lab. During this stage it is attempted to recognize conceivable contrasts between the simulated and measured of fabricated antenna return loss (S11). The picture below of the created microstrip patch antenna as appeared in Figure 6.1 respectively.

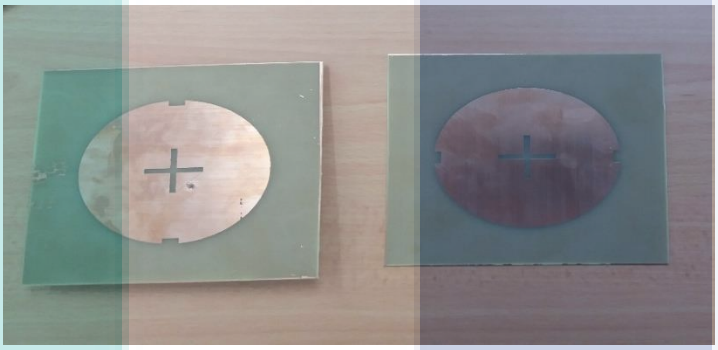


Figure 6.1 Fabricated Microstrip Patch Antenna

Utilizing the Agilent E5071C ENA Series Network Analyzer (9kHz-8.5GHz), the return losses and antenna frequency range is measured. Figure 6.2 underneath displays the measured and simulation return losses. Contrasted with the simulation, great agreement is accomplished. Be that as it may, there are slight differences between the simulated and measured return losses of the created antenna due to the hand fabrication on the substrate and patch of antenna which implies the measurement of antenna are not precisely coordinated between the theory and fabrication.Using low quality of FR4 substrate additionally will influence the antenna performance.

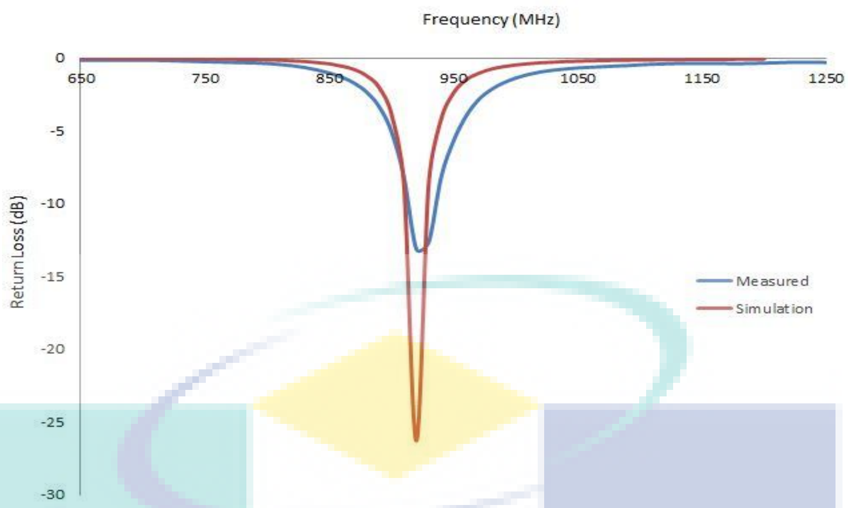


Figure 6.2 Measured and Simulated Return Losses

6.2.2 Simulated Radiation Pattern

Radiation pattern is characterized as the power transmitted or got by an antenna in a component of the angular position and spiral separation from the antenna. In Figure 6.3 below demonstrates the 3D radiation pattern for the patch antenna with 5.98 dB gain at 921 MHz. The simulated radiation pattern in E-Plane and H-planes are plotted as appeared in Figure 6.4 and Figure 6.5 respectively. The desired circular polarization pattern are acquired in the E and H planes. E-Plane is where the patch antenna radiates its energy in vertical polarization, yet for H-Plane the antennae transmits the energy in horizontal polarization. In this project, it is observed that the pattern of antenna radiation are practically symmetrical in both planes and this patch antenna likewise cover extensive variety of tag detection. Likewise, the front-to-back proportion of the antenna is better which is 5.8 dB at the working frequencies. That why, a circular polarization microstrip patch antenna with great performance has been intended for the worldwide UHF RFID reader.

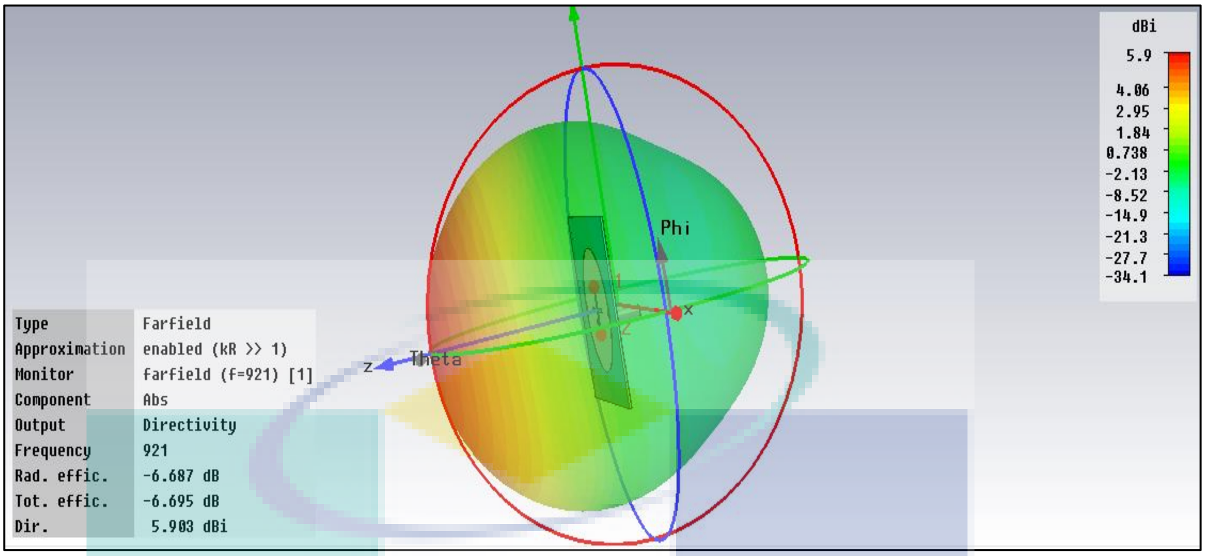


Figure 6.3 Simulated Patch Antenna Radiation Pattern

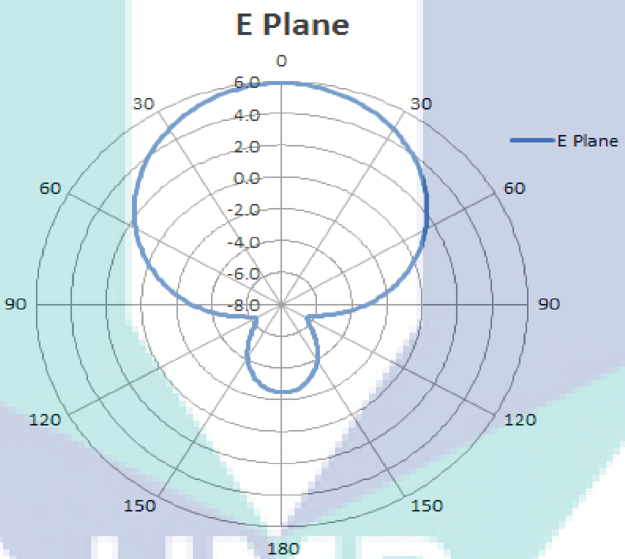


Figure 6.4 E-Plane Radiation Pattern

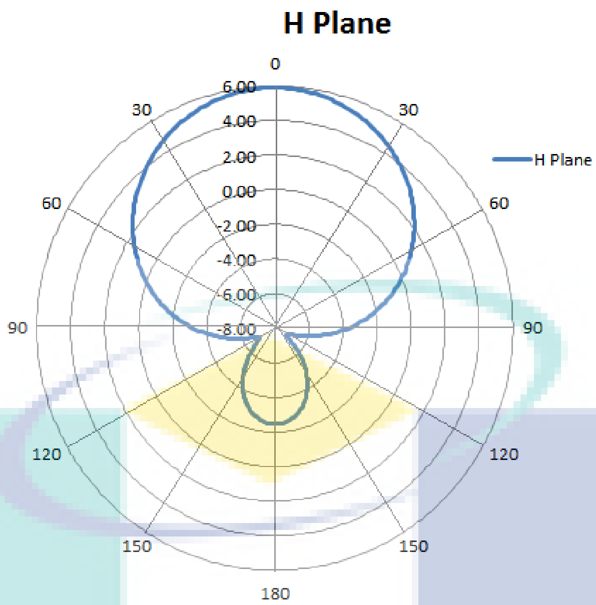


Figure 6.5 H-Plane Radiation Pattern

6.2.3 Simulated VSWR

The VSWR communicates the level of match between the transmission line and the patch antenna. At the point when the VSWR is 1 to 1 (1:1) the match is immaculate and all the vitality is exchanged to the antenna before being transmitted. By definition VSWR can never be under 1. For this project, VSWR that is most appropriate for microstrip patch antenna which is 1.09:1. Figure 6.6 demonstrate that VSWR for the antenna is 1.09 dB. In the result, for the frequency at 900Mhz and 921Mhz shows that the value of VSWR is 4.58 and 2.22 respectively. This value are not suitable for the good antenna performance because it has higher value of VSWR which above 2. At the frequency of 921Mhz, the result shows that the value of VSWR IS 1.0901005. This considers a good result due to the level of mismatched is not high. High VSWR implies that the port is not legitimately coordinated.

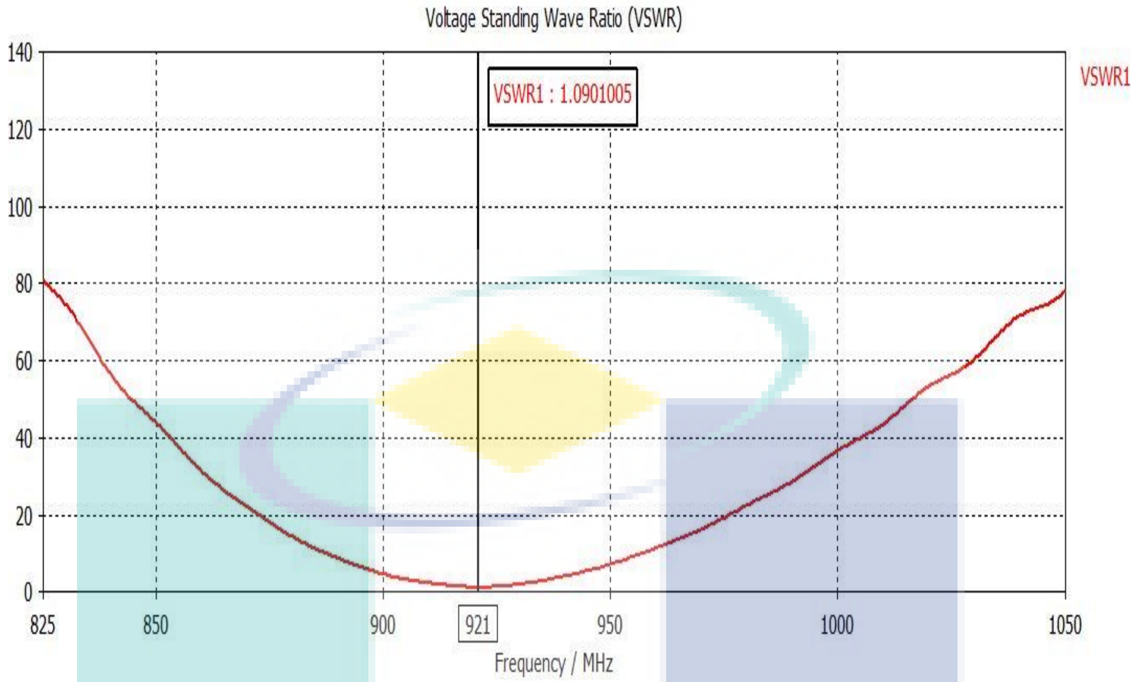


Figure 6.6 Simulated VSWR

6.2.4 Simulated Gain

Another valuable measures for describing the execution of microstrip patch antenna is the gain parameter. Indeed, the gain of the antenna is firmly identified with the directivity, it is measures that into record productivity of the patch antenna performance as well. The lobe in the Figure 6.7 shows the antenna read range which is circular polarization. It cover all the area around the antenna which is in front and the back of antenna at avery angle. This also called radiation pattern of microstrip patch antenna which is contain of multiple radiation plane (E-plane and H-plane). The normal simulated gain of patch antenna in Figure 6.7 demonstrates the gain with main lobe is 5.8 dB for polar plot of the designed patch antenna. It shows the antenna have higher gain for better antenna performance.

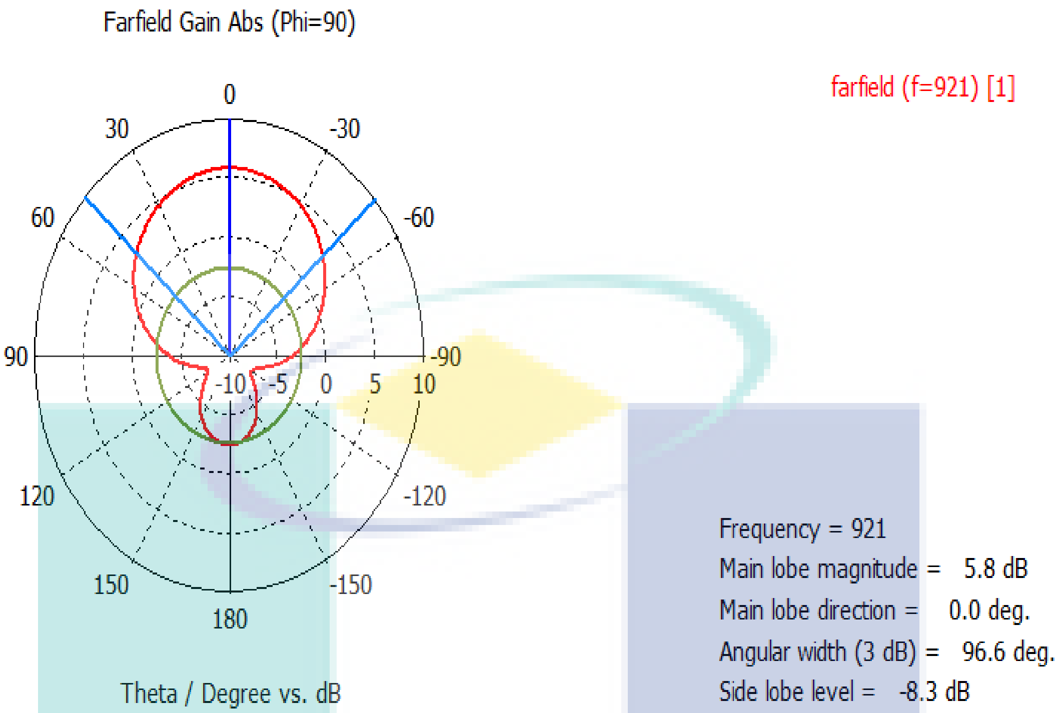


Figure 6.7 Polar Plot Graph for Gain

6.2.5 Parametric Study

In this chapter, a parametric study of the microstrip patch antenna is conducted to discover the impact of changes in the patch antenna geometric parameters on the antenna performance. This studies was conducted utilizing the CST Microwave Studio Suite software. The parameters under review include the length and width of the patch antenna, the diameter of patch antenna, the type substrate permittivity used on antenna for this project (εr), the antenna thickness (H) and changes of patch antenna notch. For better understanding the impact of parameters on the patch antenna execution, just a single parameter is shifted at once, while the others are keep up unless indicated. Figure 6.8 below shows a part of microstrip patch antenna which is include the antenna patch slot, notch and substrate. This study also will show the effect of changing some antenna geometric parameter, whether there are changing of resonant frequency or the antenna return losses.

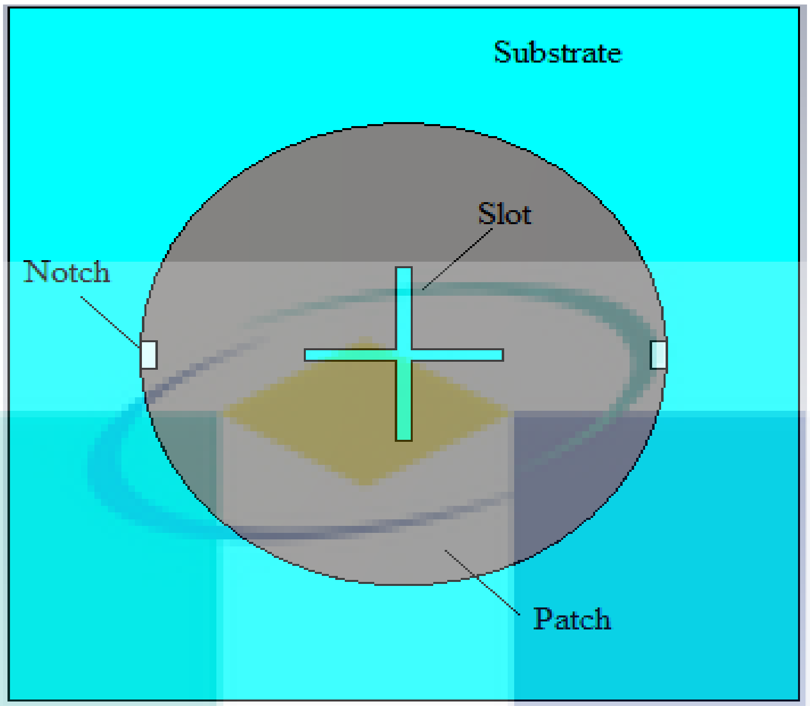


Figure 6.8 Antenna Parameter

6.2.5.1 Asymmitric Slot Width

This study is done to decide the impact of the variety in width of antenna slot,on the performance of the patch antenna. By keeping the general length and width of the patch antenna at 11.87 cm,antenna thickness of 0.16 cm, antenna diameter at 7.915 cm correspondingly to observe the impact of variety width on the antenna frequency. Figure 6.9 demonstrates the impact of the variety in the antenna slot width on the proposed microstrip patch antenna. By expanding the width of the antenna slot, the resonant frequency shifts toward a lower frequency. The patch antenna slot with the width of 0.0275 cm meets the frquency of 948 MHz. As the width of the antenna slot is being expanded to 0.11 cm and 0.22 cm, the antenna frequency shifted down to 934 MHz and 921 MHz.

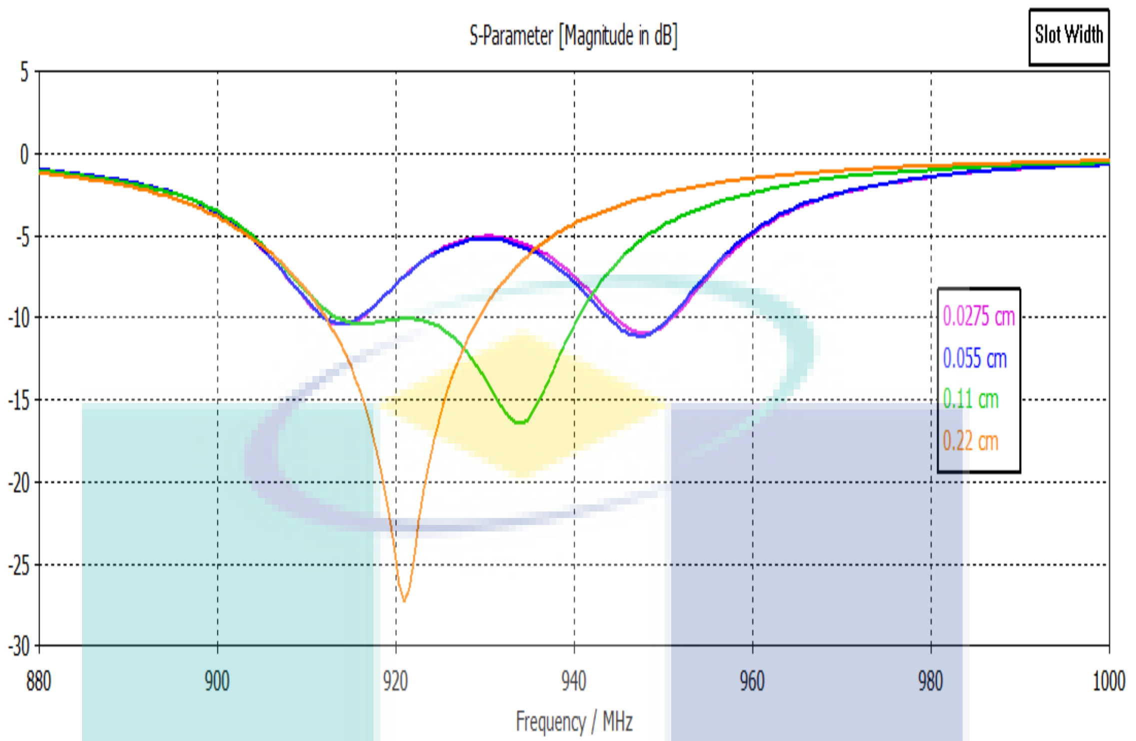


Figure 6.9 Effect in Variation of Antenna Slot Width to the Resonant Frequency and Return Losses

6.2.5.2 Asymmetric Slot Length

This study is done to decide the impact of the variety in length of antenna slot,on the performance of the patch antenna. By keeping the general length and width of the patch antenna at 11.87 cm,antenna thickness of 0.16 cm, antenna diameter at 7.915 cm correspondingly to observe the impact of variety length on the antenna frequency. Figure 6.10 demonstrates the impact of the variety in the antenna slot width on the proposed microstrip patch antenna. By expanding the length of the antenna slot, the resonant frequency shifts toward a higher frequency. The patch antenna slot with the length of 0.7475 cm meets the frequency of 913 MHz. As the length of the antenna slot is being expanded to 1.495 cm and 2.99 cm, the antenna frequency shifted up to 913.5 MHz and 921 MHz.

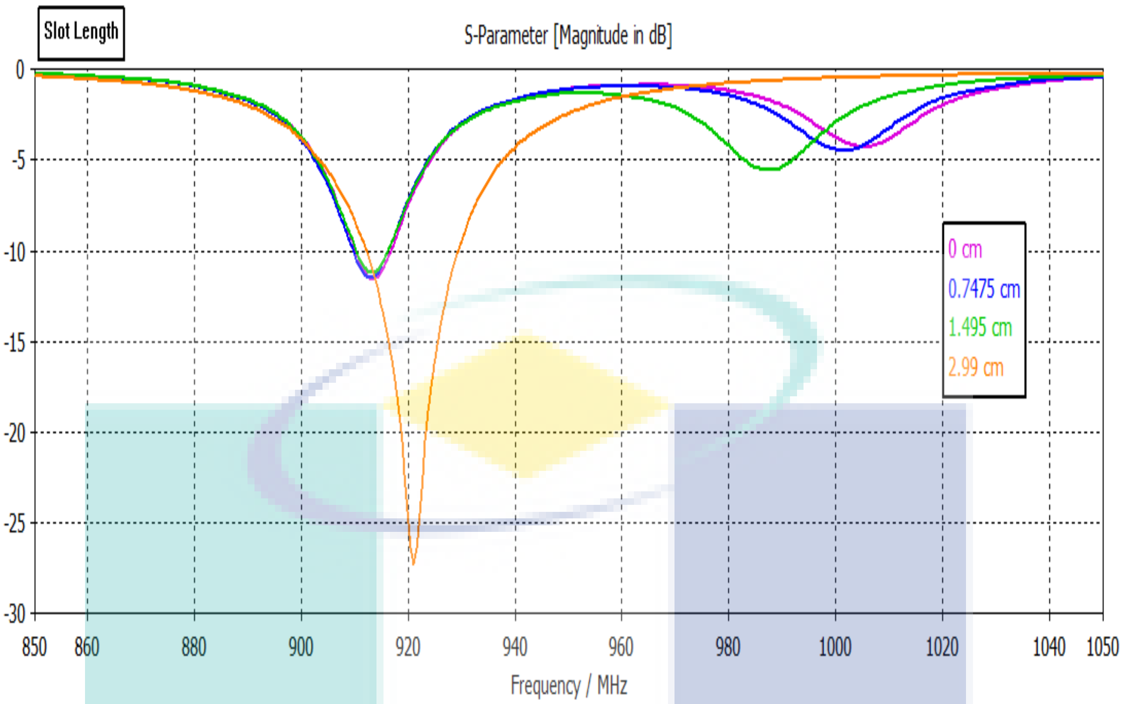


Figure 6.10 Effect in Variation of Antenna Slot Length to the Resonant Frequency and Return Losses

6.2.5.3 Substrate Permittivity

In antenna design, it is important to have a good material of substrate which is particular dielectric constant (εr) and antenna thickness (H) for better performance. The material substrate will influence the coupling between the transmission line areas and the patch of antenna, along these lines will change the resonant frequency of the antenna. This study aims to inspect the impact of substrate on the performances of microstrip patch of antenna. In this review, four common substrates, to be specific the FR4 (εr = 4.7, tanδ =0.0199), the RO4003 (εr = 3.38, tanδ = 0.0027), the RO3010 (εr = 10.2, tanδ = 0.0023), and the RT5880 (εr =2.2, tanδ = 0.0009), with a similar thickness (h), of 0.16 cm are utilized. The other patch antenna measurement are like those specified in Section 6.2.5.1. It is found that, when the patch antenna is set on various substrate, the resonant frequency and its return losses (S11) additionally changes as appeared in the Figure 6.11. It is watched that as the permittivity of the substrate increase, the resonant frequency of patch antenna shifts to a lower frequency, however for reasons unknown, there are some substrate have diverse readings. For example, RO3010 (with εr = 10.2) additionally contribute higher frequency.The related resonant frequency remain even for various substrates are 1139 MHz (with εr =2.2), 1075 MHz (with εr = 3.38) and 921MHz (with εr = 4.7) respectively. To conclude that the substrate with higher dielectric permittivity brings down the resonant frequency of antenna.

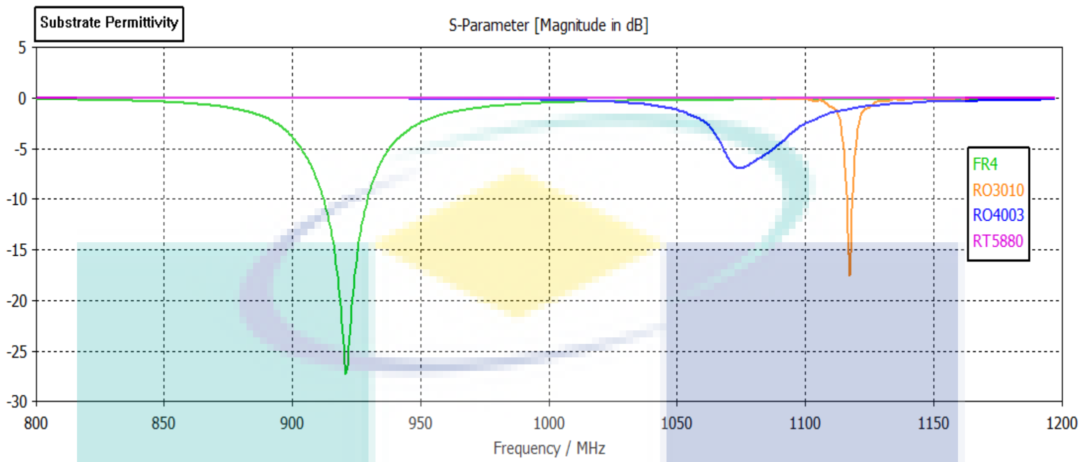


Figure 6.11 Effect in Variation of Substrate Permittivity to the Resonant Frequency and Return Losses

6.2.5.4 Asymmitric Notch

This study is done to decide the impact of the various length and width of antenna notch on the performance of the patch antenna. By keeping the general length and width of the patch antenna at 11.87 cm,antenna thickness of 0.16 cm, antenna diameter at 7.915 cm correspondingly to observe the impact of variety length on the antenna frequency and the return losses. Figure 6.12 demonstrates the impact of the variety in the antenna notch width and length on the proposed microstrip patch antenna. By expanding the length and width of the antenna notch, the resonant frequency does not affected but will shifts toward a lower return losses,the lower S11 the better antenna performances. The patch antenna notch with the length and width of 0.2011 cm and 0.4422 cm meets the frequency of 921MHz and -26.49 dB for S11 reading. As the length and width of the antenna notch is being expanded to 0.2611 cm and 0.5022 cm, the antenna frequency maintained at 921 MHz but different in S11 reading which is shifted down to -27.31 dB respectively. It can be conclude that by increasing the notch length and width, the resonant frequency thus not be affected but will improve the return losses.

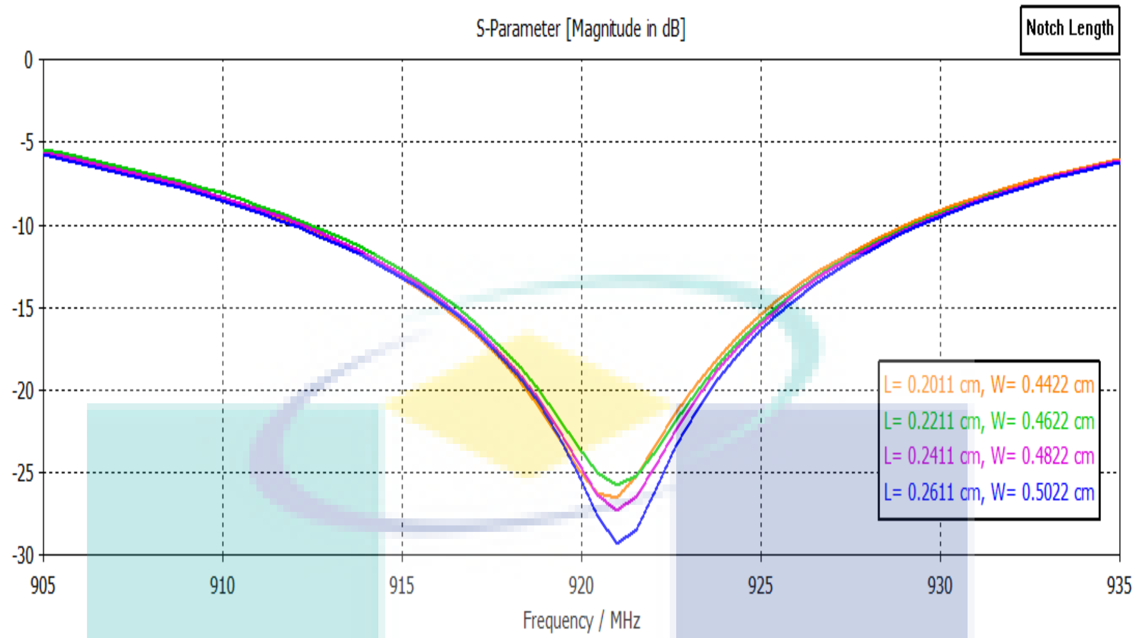


Figure 6.12 Effect in Variation of Substrate Permittivity to the Resonant Frequency and Return Losses

6.2.5.5 Diameter of Patch

This study is done to decide the impact of the various patch antenna diameter on the performance of the patch antenna. By keeping the general length and width of the patch antenna at 11.87 cm, antenna thickness of 0.16 cm and antenna notch length and width at 0.2411 cm and 0.4822 cm correspondingly to observe the impact of variety patch diameter on the antenna frequency and the return losses. Figure 6.13 demonstrates the impact of the variety of diameter to the proposed microstrip patch antenna. By increasing the patch antenna diameter, the value of S11 will improve but the resonant frequency will be decrease. The patch antenna diameter at 7.905 cm meets the frequency of 922 MHz and -26.95 dB for S11 reading. As the diameter increase to the 7.920 cm, the antenna frequency shifted down to 920.47MHz but different in S11 reading which is improved to -27.45 dB respectively. It can be conclude that by increasing the antenna diameter, the resonant frequency will be decrease and resulting the good S11 value.

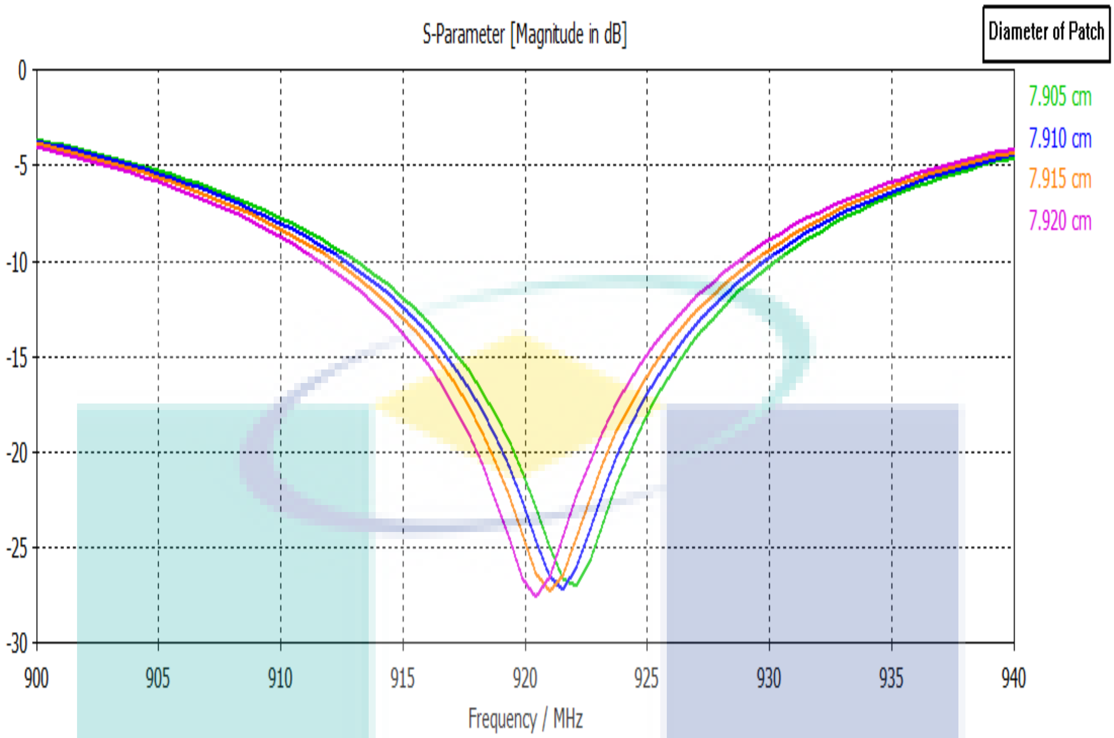


Figure 6.13 Effect in Diameter of Patch Antenna to the Resonant Frequency and Return Losses

6.2.5.6 Substrate Thickness (h)

This study is done to decide the impact of the substrate thickness (h), on the patch antenna frequency and return losses, S11. By keeping all the antenna dimension as mention above, the antenna thickness will be varied from 0.12 cm, 0.16 cm, 0.2 cm to 0.24 cm correspondingly to observe the impact of variety substrate thickness on the antenna frequency and the return losses. Figure 6.14 demonstrates the impact of the variety of substrate thickness to the proposed microstrip patch antenna. By changing the antenna thickness, the value of resonant frequency and S11 also changes. The patch antenna thickness at 0.12 cm meets the frequency of 898.5 MHz and -10.34 dB for S11 reading . As the thickness increase to the 0.16 cm , the antenna frequency shifted up to 921MHz but different in S11 reading which is improved to -27.65 dB respectively. It can be conclude that by increasing the antenna thickness,it also will change the resonant frequency and S11 reading.

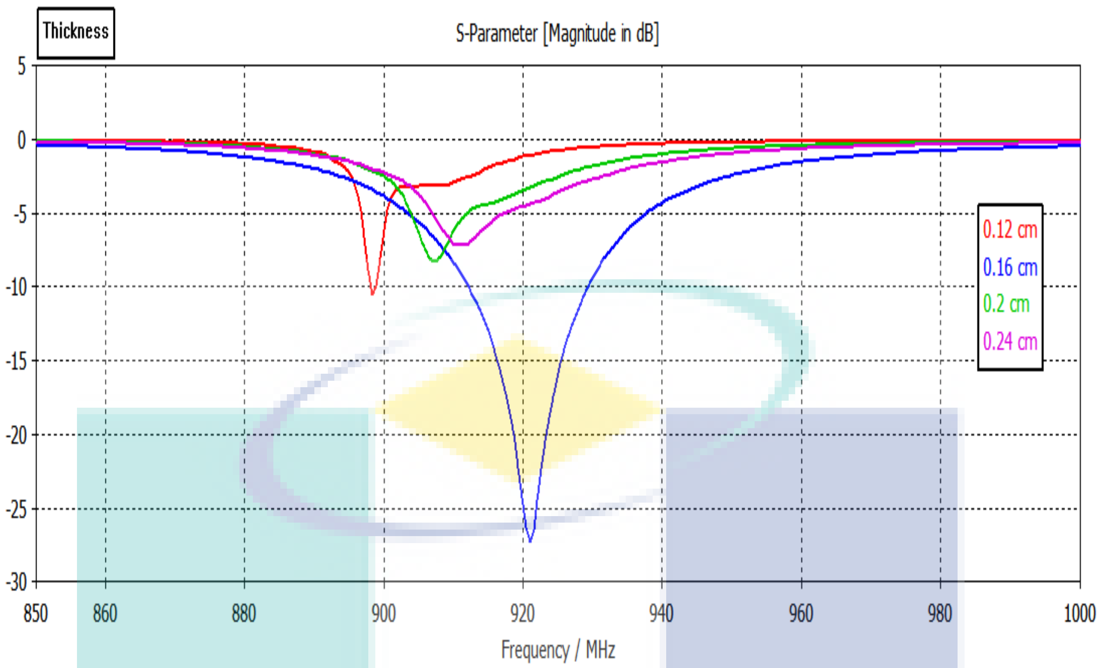


Figure 6.14 Effect of Substrate Thickness to the Resonant Frequency and Return Losses

6.2.6 Antenna Testing

In this subtopic, the fabricated microstrip patch antenna will be test to discover the antenna performance in term of return losses, resonant frequency, antenna read range and maximum detection angles. This investigations were classified into three to be specific; investigations of the comparison between measured and simulated antenna return losses, study the most extreme detection length and studies the impact of patch antenna angles to the maximum detection length.

6.2.6.1 Antenna Testing with Network Analyzer

After finishing the fabrication process, the patch antenna will be testing using Network Analyzer as shown in the Figure 6.15. Utilizing the Agilent E5071C ENA Series Network Analyzer (9kHz-8.5GHz) at the Communication Lab, the return losses and antenna frequency range is measured. This Network Analyzer can be used for the patch antenna testing because it can cover 9kHz to 8.5GHz frequency and the antenna frequency (921Mhz) are in the range. For completing antenna testing process, the measured and simulated are compared. Figure 6.16 demonstrates the estimation of return loss of the fabricated patch antenna which is –13 dB at 921MHz resonant frequency, contrasted with the simulation -27.31 dB at 921MHz , great agreement is accomplished. Be that as it may, there are slight differences between the simulated and measured return losses of the created antenna due to the hand fabrication on the substrate and patch of antenna which implies the measurement of antenna are not precisely coordinated between the theory and fabrication.Using low quality of FR4 substrate additionally will influence the antenna performance. During this stage it is attempted to recognize conceivable contrasts between the simulated and measured structure, for case fabricating errors, effect of paste used to tie the PCB layers or current on the outside of the feed.

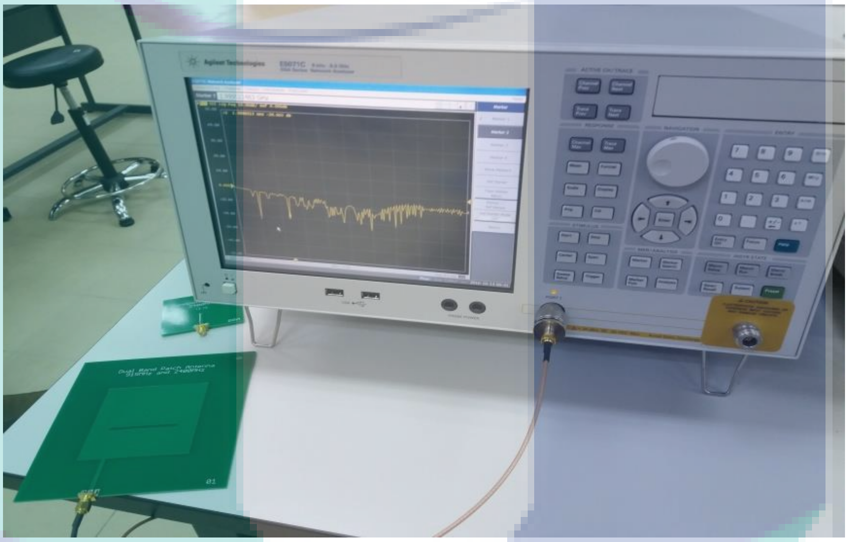


Figure 6.15 Antenna Testing with Network Analyzer

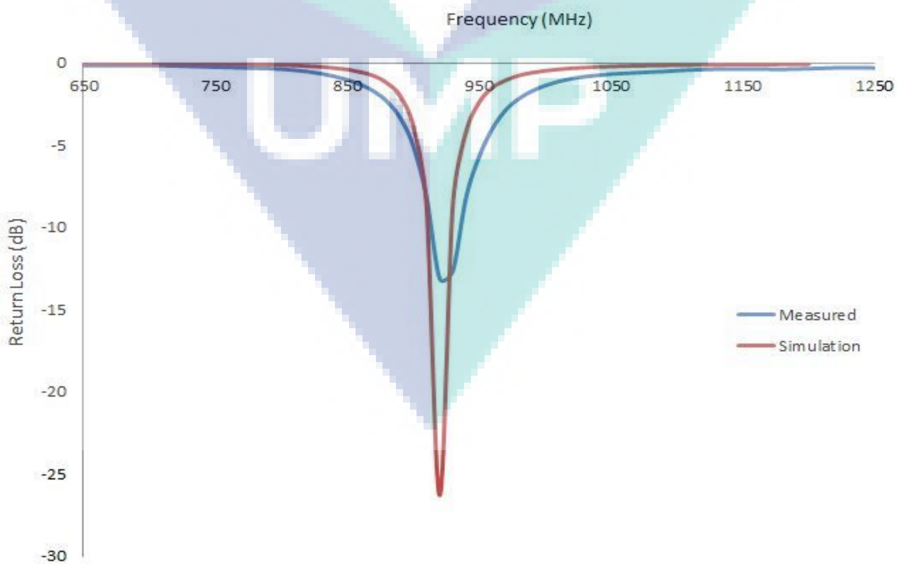


Figure 6.16 Comparison between Measured and Simulated Return Losses

6.2.6.2 Field Test of Length Detection Performance for Different Tags Type.

There were numerous RFID tags type accessible in the industry. Each tags has a different characteristic in term of tags detection length, identification coverage region and size. Test for tags execution considered eight distinctive kind of tags in particular AD-641, AD-814, AD-824, AD-815, AD-805, AD-833, AD-828 and AD-223 as shown in Chapter 4. In RFID framework, the tags can be identified by the antenna trough the radio frequency. Figure 6.17 demonstrates the patch antenna setup for tags detection and for Figure 6.18 demonstrates the result of maximum tags detection length with different type of tags. The identification length for eight distinct tags were compared. The maximum detection distance of AD-833 tag was the most astounding compared with other tags because of the greatest size which is 38 mm x 93.5 mm, the least most extreme detection length goes to AD-805 with the smallest size 16 mm x 16 mm followed by AD-815 tag then AD-814 tag. The maximum detection length represent the most extreme tag detection that successfully recorded by the patch antenna before it loss the signal. AD-833 tag had the highest detection length at 104 cm followed by AD-823, AD-223, AD-641, AD-824, AD-814, AD-815 and AD-805 respectively. The AD-815 tag recorded the shortest maximum detection length which is only 3.8 cm. Various tags types created the different recognition length in light of the fact that the impact from tag antenna material, size, shape and design outline.

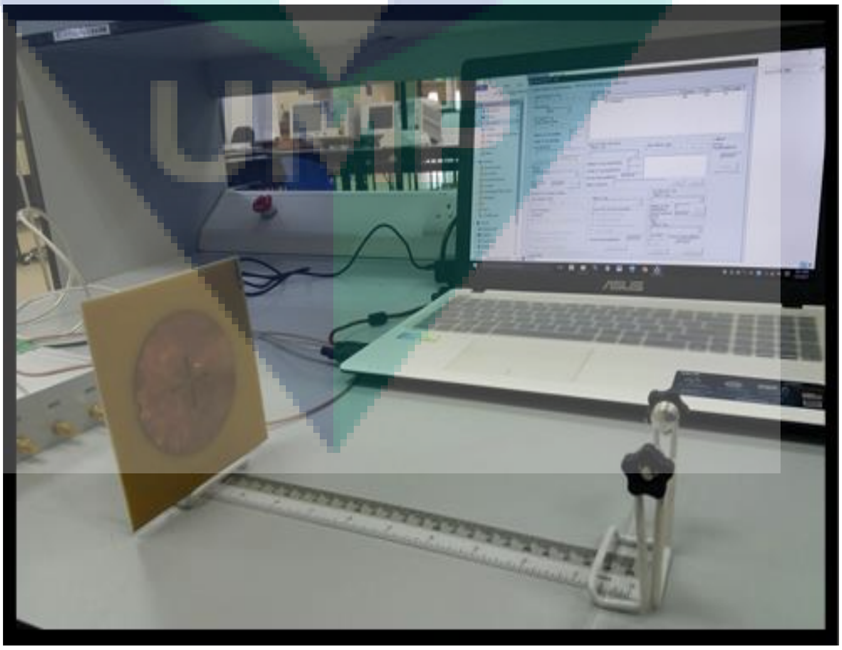


Figure 6.17 Antenna Setup for Tags Detection Length

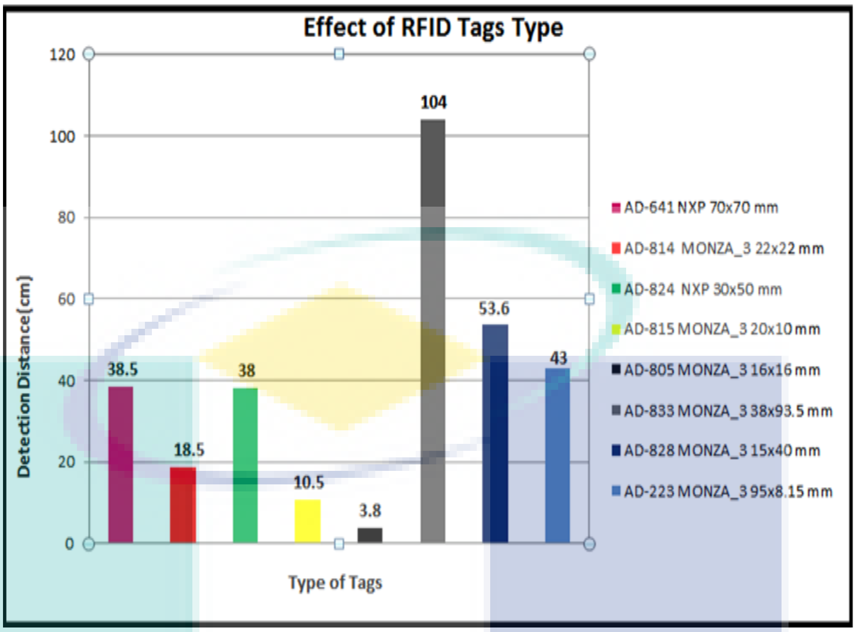


Figure 6.18 Effect of Different RFID Tags Type to The Maximum Detection Length

6.2.6.3 Field Test of Angle Detection

The investigation of patch antenna angles intended to justify whether there are changes of maximum tag detection length when the antenna angles changes.In this review, five patch antenna angles were picked, to be specific 30^o, 45^o, 60^o, 75^o and 90^o with the tag put on the field. Only one tag is used and fixed in this experiment which is AD-833 .The maximum tag detection length result at each angles as shown in the Figure 6.20. The antenna setup also shown in the Figure 6.19 below. For antenna angle at 30^o, the maximum detection distance is 81 cm. The antenna angles changes to 45^o and created the greater detection length than antenna angle 30^o result with 85 cm. At the point when increment the antenna angle at 60^o and 75^o, the maximum detection length additionally increase with 112 cm and 123.5 cm respectively. After the angle changed to 90^o, the maximum detection length increase to 159 cm. As conclusion, when the patch antenna angle increase, the maximum detection distance also increase. This is because that the diverse antenna angles transmit different radio wave pattern and the tag can't be recognized well.

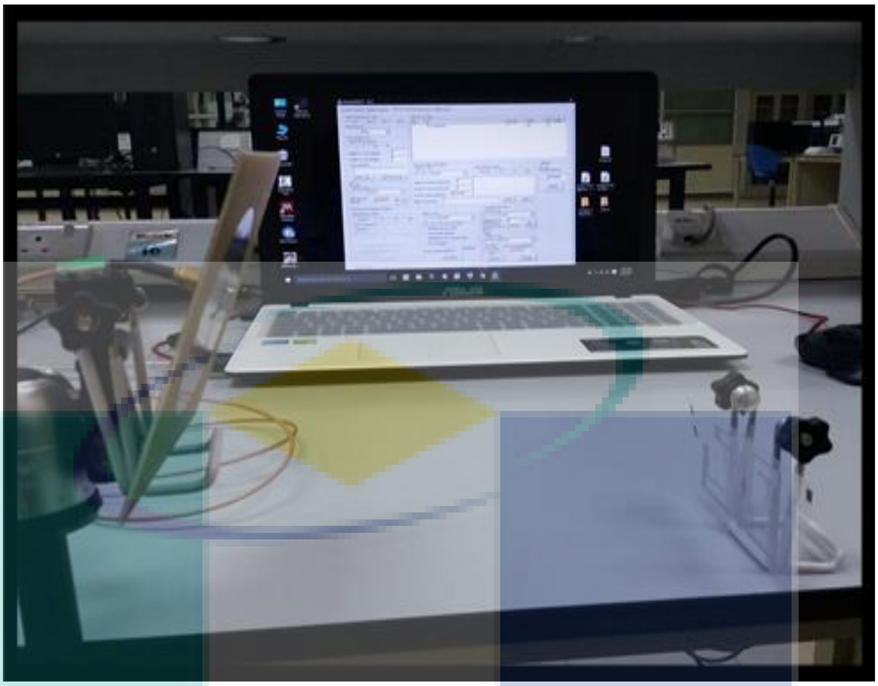


Figure 6.19 Antenna Setup for Effect of Antenna Angles

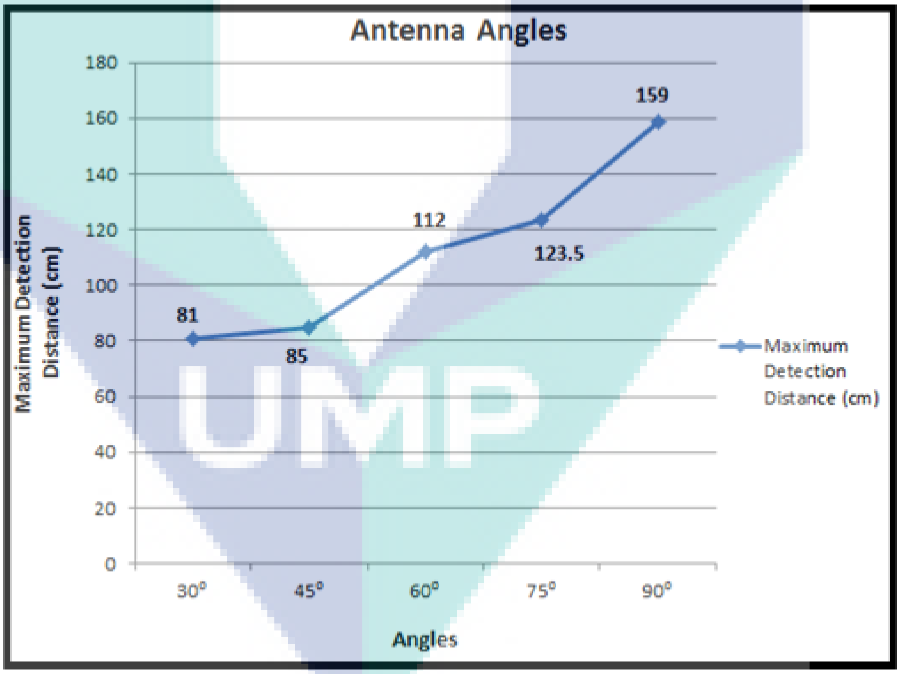


Figure 6.20 Effect of Antenna Angles to the Maximum Detection Length

CHAPTER 7

CONCLUSION

7.1 Introduction

Nowadays, there are a lot of research being done to develop the microstrip antenna. The popularity in commercial RFID applications is the main reason why these applications become expensive and exclusive. Tagging people, animal and object with its passive transponder (tag) and low power consumption in wireless sensor network are all the main function of this antenna systems. However, the two types of microstrip patch antenna can energize either in linear or circular polarization.

Microstrip patch antenna with angular and rectangular slot which are in linear polarization are designed to concentrate RF energy in a narrow plane. Linear polarization occurs when electromagnetic waves broadcast on a single plane (either vertical or horizontal). Linear polarized antennas must have a known RFID tag orientation and the RFID tag must be fixed upon the same plane as the antenna in order to get a consistent read. Due to the concentrated emission, linear polarized antennas typically have greater read range than circular polarized antenna which shown in T slot antenna.

A circular-polarized antenna, on the other hand, is designed to emit energy in a conical pattern. The advantage of using the circular polarization is not required special degree of tag orientation.

CST Studio Suite 2014 was utilized to develop the antenna design. During the project, all the positive and negative factors of the microstrip patch antenna had been discussed in detail. The objectives to design such a small size of antenna that will be used in RFID application had been achieved. The same achievement also proved in reducing the budget of the antenna design by using FR-4 substrate.

All the designed patch antenna resonates at 921 MHz. The good results had been achieved as the simulation showed all antennas below -10 dB of the return loss. 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. Copper layer with 0.035 mm of thickness is used at the ground plane and patch. The VSWR is also a common parameter used to characterize the matching property of a transmitting antenna. The good VSWR result of the microstrip patch antenna should be below than 2 and all the antenna design achieved value of VSWR below than 2. The microstrip patch antennas can be a great achievement and attributes for future life, based from the outcome of the result. It can be applied as antenna reader along the UHF RFID framework.

7.2 Future work

This microstrip patch antenna with angular slot need more attention as there are many more important things need to be studied 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, linear polarization can be suggested. Different kind of energize either circular or linear polarization can be found in the antenna. The circular patch can be changed for single feed square polarization in the form of square patch. There are many types of techniques 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.

7.3 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 replace the conventional antenna for many other applications in this world. Some upgraded application antenna give 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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RFID reader," *IEEE Microw. Wirel. Components Lett.*, vol. 20, no. 2, pp. 106–108, 2010.

APPENDIX A – LIST OF PUBLICATION

Journal

1) M.H. Ariff, M.Y. Hisyam, M.Z. Ibrahim, S. Khatun , I. Ismarani ,‘ Circular Microstrip Patch Antenna for UHF RFID Reader', Journal of Telecommunication, Electronic and Computer Engineering (JTEC), January 2018, pp. 61-65.

2) Circular Microstrip Patch Antenna with angular slot for UHF RFID reader, this paper will be presented 7th ICAST 2020 - Malacca, Malaysia, All accepted papers will be published in Scopus Journal* or other indexed journals.

Proceedings

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Circular Microstrip Patch Antenna for UHF RFID Reader

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Abstract—This paper presents an analysis of Circular shape patch antenna for Ultra High-Frequency Identification (UHF) Radio Frequency Identification (RFID) Reader Applications. The fabricated antenna has lightweight, simple structure, low profile and easy for fabrication due to the used of FR-4 materials with loss tangent 0.019, the dielectric constant of 4.7 and thickness of 1.6 mm. It can be operated for UHF RFID system in Malaysia with the frequency assigned from 919 MHz to 923 MHz. The antenna simulation was analysed by using CST Studio Suite 2016. From the results, the antenna has the reflection coefficient (S_{11}) less than -10dB together with the bandwidth of 90 MHz. Other results of antenna parameter such as voltage standing wave ratio (VSWR), circular polarized radiation pattern, return loss and gain were also discussed. The complete size of the proposed antenna is 120 mm x 120 mm x 1.6 mm. Thus, it is suitable for RFID portable reader applications.

***Index Terms*—Microstrip Antenna; Radio Frequency Identification; Ultra High Frequency; Return Loss.**

I. INTRODUCTION

In recent years, radio frequency identification technology (RFID) has moved from unpopular technology into mainstream applications such as in agriculture product, electronics equipment, manufacturing products that produced in large quantity in order to track the location, delivery record and facilitate location [1].

RFID utilizes an electromagnetic field to electronically track and identify tags enclosed to objects and these tags contain electronically stored information [2]. RFID has many advantages over barcodes, for instance, in the operation of barcode reading, the scanner must be placed directly in front of each label and both need to be oriented to a very specific position to function properly [3-4]. On the other hand, RFID tags do not need strictly oriented to RFID readers right away because RFID uses radio waves to communicate and the RFID tag only needs to be in the reader reading range, which will vary depending on the types of handheld RFID reader used in the application [5]. With an improvement of the anti-collision element in RFID technology, readers can read multi-tag and identify multiple objects at the same time [6]. This will ensure the safeness and security of the object and also reduce the need for the time taken and manual personnel to identify the objects.

The RFID reader antenna designed in the (UHF) ultra-high frequency, (300MHz-3GHz) frequency band has been extensively used to detect objects rather than other frequency such as (LF), low frequency (30-300 kHz) and HF, high frequency (3 MHz-300 MHz) because it has advantages in term of better read range and can read many tags per second [7].

Nowadays, there are many categories of the designed antenna built for RFID readers such as monopole antenna [8], PIFA antenna [9], loop antenna [10], helical [11] and three elements printed Yagi antenna [12]. By implementing the same printed antenna approaches as mentioned above, this aimed antenna design takes benefits of the FR-4 substrate material.

Microstrip patch antennas (MPA) comprises of grounded patch and substrate of metallization. These are lightweight, low profile and most suitable for mobile applications and electronic integrated applications. Furthermore, microstrip patch antenna is usually designed at UHF and microwave frequencies because the dimension of the antenna is right away tied to the wavelength at the resonant frequency. There is a unique property for the microstrip patch antenna which is the capability to have a variant of polarization.

Circularly polarized (CP) antenna is a type of antenna with circular polarization. CP antenna is far better than linear polarization antenna since it is very effective in reducing fading or multipath interference [13]. Many designs have been built by the researchers to find this horizontal, vertical, right-hand circular polarization (RHCP) or left-hand circular polarization (LHCP) using a single feed point arrangement[14]. These advantages allow patch antennas to be adopted in different types of frequency bands that may have varied specifications.

The main disadvantages of microstrip patch antennas are narrow bandwidth, lesser gain and poor efficiency, which disturbed the efficiency of this antenna. Various researchers currently studied different shapes of antenna design for RFID readers by applying a varied approach of patch and ground geometry such as E shaped patch [15], U shaped patch [16], C shaped patch [17], L shaped patch [18]. Other modes to decrease these deficiencies are including the make use of notches [19], cutting various slots [20], antenna array [21], material thickness [22] and different substrate material [23] in the patch geometry.

This work discovers the potentiality of advancing the UHF RFID performance to any UHF reader module by focusing on increasing the read range and antenna gain in comparison with the state of the art. The aim of this study is to design a low profile circular patch antenna for an ultra-high frequency RFID based on Malaysia Frequency Allocation (921 MHz-923MHz). The communication between the fabricated antennas, RFID module and computers can enhance the potential of this study.

II. Antenna Geometry and Design

The antenna consists of a modified circular patch shaped microstrip element printed into the FR-4 substrate with a dielectric constant (ε_r) of 4.7, loss tangent of 0.019 and thickness of 1.6 mm. The patch and ground were used PEC material with the thickness of 0.0035 mm. Figure 1 shows the dimension and geometry of the antenna.

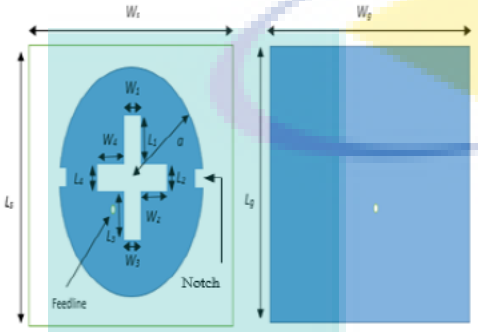

Figure 1: The geometry design of the proposed antenna.

The complying mathematical model has been analysed in designing the Circular Patched Microstrip antenna [24].

The relationship between the radius of circular patch radius (a), resonant frequency (f_r), dielectric constant (ε_r) and thickness of the substrate (h);

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad (1)$$

where;

$$F = \frac{8.791\times10^{9}}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

The condition above does not take into consideration over the fringing impact. Since fringing makes the patch electrically bigger, the effective radius (a_e) of the patch is utilized and can be defined as:

$$a_e = a\left\{1+\frac{2h}{\pi a\varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{1/2} \quad (3)$$

The relationship between the resonant frequency (f_r) and velocity of light (v_o) is given as;

$$(f_r)_{110} = \frac{1.8412 v_0}{2\pi a_e\sqrt{\varepsilon_r}} \quad (4)$$

The circular shaped microstrip antenna consists of four arms etched onto the metallised dielectric substrate. The ground plane covers one section of the dielectric, which does not fall directly beneath the monopoles. The antenna is probe fed via microstrip ground connected to the base circular patch. The default value of this antenna design is shown in Table 1.

Table 1
Dimension of the Antenna

Parameter	Symbol	Segment	Dimension (mm)
Patch	a	Radius	40
Notch	W_n	Width	3
	L_n	Length	7
Arm 1	W_1	Width	3
	L_1	Length	11
Arm 2	W_2	Width	11
	L_2	Length	3
Arm 3	W_3	Width	3
	L_3	Length	11
Arm 4	W_4	Width	11
	L_4	Length	3
Ground	W_g	Width	120
	L_g	Length	120
Substrate	W_s	Width	120
	L_s	Length	120
	h	Thickness	1.6
	ε_r	Dielectric Constant	4.7
SMA	Ω	Impedance	50

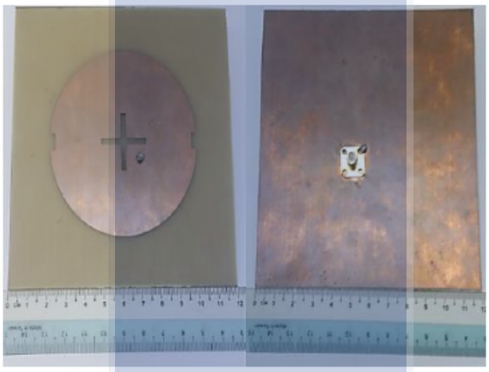

Figure 2: Fabricated Microstrip Antenna

III. Result and Discussion

A. Result of simulation of the proposed antenna

The simulation of important parameters prototype of the proposed antenna is done by using CST Microwave Design Studio 2016 software. It is worth mentioning that the used time domain simulation is useful to study the field propagation along the traces of FR4 such as reflection coefficient S_{11}, Voltage Standing Wave Ratio (VSWR) and directivity.

The comparison of simulated and measured S- Parameter is shown in Figure 3. The measured bandwidth and simulation bandwidth of this antenna is 90 MHz (915 MHz – 1005 MHz) and 30 MHz (908 MHz – 938 MHz) respectively.

Moreover, the desired of operating frequencies slightly change from 921 MHz (simulation) to 925 MHz (measured) and $|S_{11}|$ values shifted from -27.43 dB (simulation) to -13.78 dB (measured).

The Voltage Standing Wave ratio is important in order to find the good efficiency of the antenna design. In addition, VSWR always be used as an indicator of power reflected from the antenna. For practical application, the value of VSWR should be a real and positive number with values less than 2. Thus, in Figure 4, the VSWR is equal to 1.09 and this value satisfies the practical antenna design.

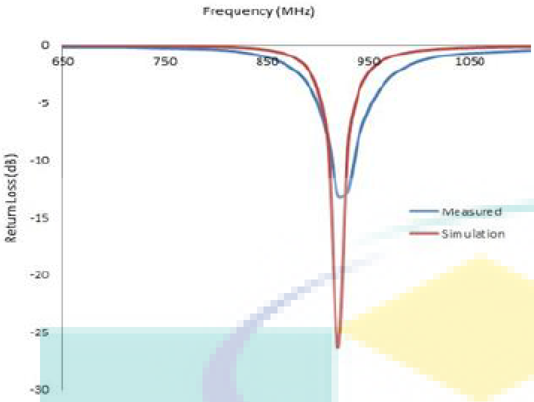

Figure 3: Simulated and measured of Return Loss S_{11}

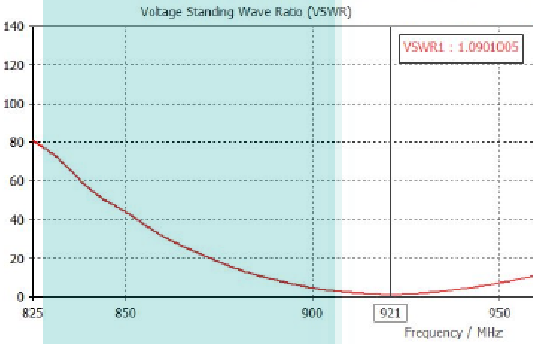

Figure 4: Simulated Voltage Standing Wave Ratio

Figure 5 shows the simulated radiation pattern in the 3D plot. The standard majority radiation is focused in one direction and can be achieved throughout the operating frequency of the antenna. The value of directivity for the antenna is at 5.970 dBi for 921 MHz.

Figure 6 shows the beamwidth was at 95.4 degrees when the main direction at 0 degree. Beamwidth is important to be considered because it shows the measurement of the area over which the antenna receives signal.

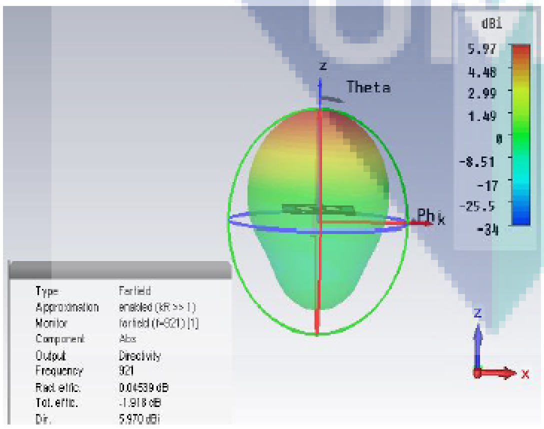

Figure 5: Simulated radiation pattern in the 3D plot for the proposed antenna.

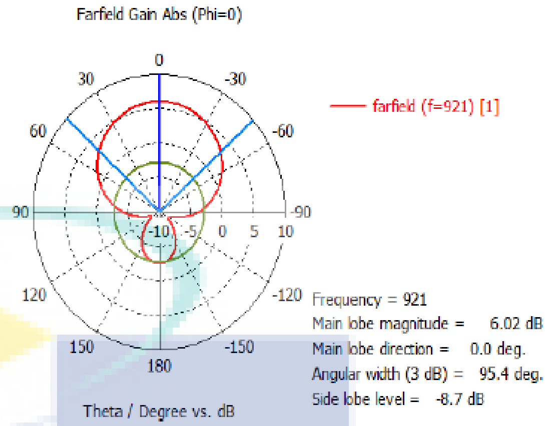

Figure 6: Simulated radiation patterns in polar plot for proposed antenna with Phi=0^0

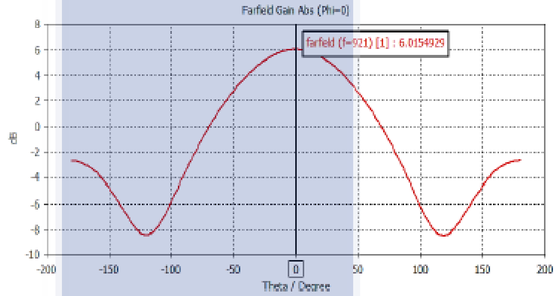

Figure 7: Simulated Gain in Cartesian Plot

It is also noticed that the simulated Gain in the Cartesian plot as in Figure 7 is also important to measure efficiency and directional capabilities of an antenna. The simulation gain value of this antenna is 6.015 dB for 921 MHz.

B. Parametric Studies of the Effect on Return Loss S_{11}

In order to view the effect of the return loss, characteristic value of the bandwidth and movement of the resonant frequency, a parametric study has been used by changing the dimension variation of the antenna.

There are three factors to be analyzed which are the change in diameter of patch, width and length of Arm 1 and Arm 3. Only one parameter is permitted to be changed at a time whereas other values are fixed. All of the dimension variation in the mentioned simulated graph are in millimeters (mm).

C. Diameter of Patch Effect

The diameter of the patch was simulated in four dimensions which are 80 mm (purple), 80.5 mm (orange), 81 mm (blue) and 81.5 mm (green). From Figure 8 (a), it has been found that by increasing the value of *a*, the resonance frequency of designed antenna slightly increased from 920 MHz to 923 MHz. Furthermore, the diameter of a patch with the value of 80 mm give higher return loss of -27.48 dB. Likewise in Figure 8 (b), it is observed from the axial plot that the minimum AR (axial ratio) point shift corresponding to the patch diameter. From figure 8 (b), the axial ratio is 2.87 dB at 921 MHz operating frequency. An antenna can be claimed as a circular polarized antenna when the axial ratio is less than 3 dB.

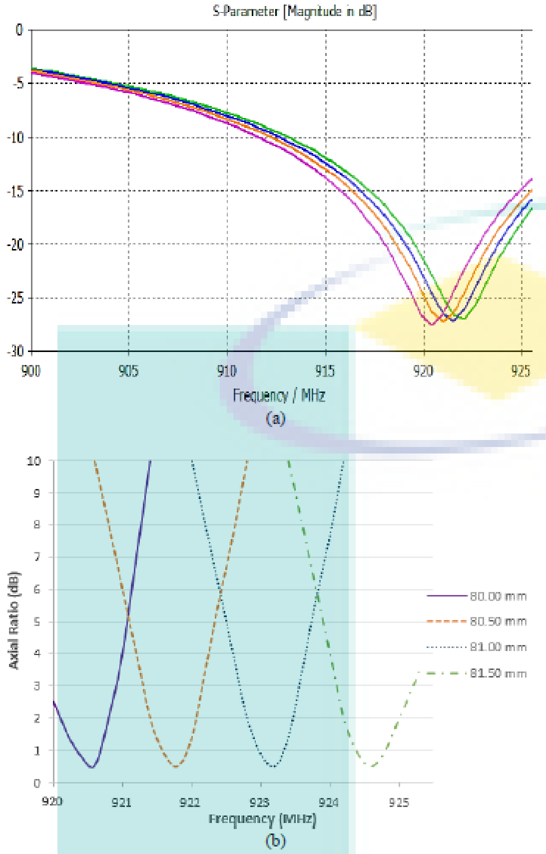

Figure 8: The effect of varying patch diameter (a) reflection coefficient (b) axial ratio.

D. *Arm 1 and Arm 3 Slot Width Effect*

The slot width of the arm 1 and arm 3 were simulated in four widths which are 0.5 mm (purple), 1 mm (blue), 2 mm (green) and 3 mm (orange) as in Figure 9. By using a value of 3 mm, an increment of the bandwidth is shown at 17 MHz (911 MHz - 928 MHz) compared to 0.5 mm that showing bandwidth at 7 MHz (910 MHz – 917 MHz). This bandwidth enhancement is probably because of the two possible paths of length L_2 and L_4, which contribute to the excitation of the two resonances at much closed frequencies and perform wide operating bandwidth.

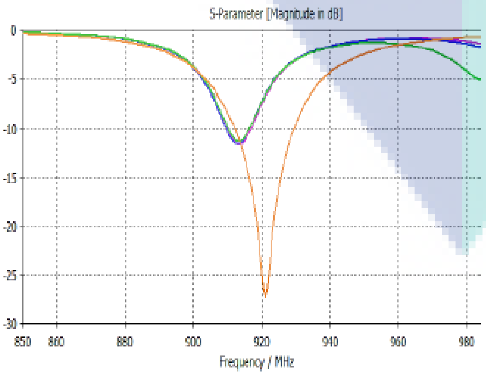

Figure 9: Arm 1 and arm 3 width effect vs Return Loss S_{11}

E. *Arm 1 and Arm 3 slot length effect*

Figure 10 shows the result of the variation in return loss with the respect to the Arm 1 and Arm 3 length size. Four lengths are simulated which are 11 mm (orange), 12 mm (green), 13 mm (blue) and 14 mm (purple).

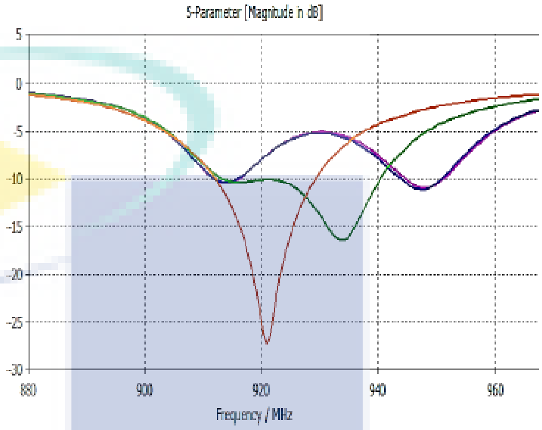

Figure 10: Arm 1 and arm 3 length effect vs Return Loss S_{11}

The arm length design is significantly important in antenna design because the S_{11} is sensitive to this variation effect. Based on the simulation, it shows that best result of S_{11} is at -27.43 dB with 11 mm length.

IV. CONCLUSION

An efficient and lightweight circular shaped antenna with arms has been designed and fabricated on FR4 substrate with a loss tangent of 0.019, the substrate thickness of 1.6 mm and dielectric constant of 4.7. The overall size of the antenna is designed with dimensions of 120 mm x 120 mm x 1.6 mm. This design is pin fed by 50 Ω SMA connector. In order to investigate the antenna reflection coefficient of S_{11}, the different modification of geometric dimensions on the circular patch, arm's length and width of the presented antenna have been studied. After analyzing all the simulations result, we can conclude that the designed antenna structure is in circular polarization and it can work in UHF RFID system in Malaysia which allocated frequency bands from 919 MHz to 923 MHz with return loss below than -10 dB.

ACKNOWLEDGMENT

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Design and Analysis of Circular Shaped Patch Antenna with slot for UHF RFID Reader

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Abstract. This paper presents an analysis of microstrip circular shaped antenna with slot for ultra-high frequency (UHF) portable radio frequency identification (RFID) reader applications. The fabricated antenna is designed to work with UHF RFID system in Malaysia with frequency allocated from 919 MHz to 923 MHz. The antenna design was made with circular patch and rectangular slot that has the dimension of 122 mm x 122 mm. Moreover, the FR-4 material used in this project has thickness of 1.6 mm with dielectric constant of 4.7 and loss tangent of 0.019. Thus, it is easily connected to the portable RFID reader module together with the antenna characteristics of easy fabrication, low profile and simple structure. From the results, the antenna has the reflection coefficient (S_{11}) less than -10 dB along the bandwidth of 3.6% (903 – 936 MHz) for operating frequency at 921 MHz.

Keywords: Microstrip Antenna, Radio Frequency Identification, Ultra High Frequency, Return Loss.

1 Introduction

Radio Frequency Identification (RFID) is a new value tool toward electronic identification and inventory information system. The RFID comprise a reader which can read tag containing the electronic product code (EPC) data that includes the many details on the inventory item. Furthermore, the RFID technology has growing perceptibility in various applications such as animal identification, warehouse, health care industry, transportation and logistics [1-3].

The fundamental of RFID is a mobile technology that uses radio frequency wave to transmit information data for identification purposes. In contrast with the barcode technology, the RFID reader does not require a direct path to read multiple tags simultaneously [4].

The RFID system consists of readers, tags and hosts, which normally have a microchip with a small antenna inserted to it. There are four categories of RFID frequency systems such as 30 to 300 kHz for low frequency (LF), 3 MHz to 300 MHz for high frequency (HF), 300 MHz to 3 GHz for ultra-high frequency (UHF) and 2.4 GHz to 2.48 GHz for super high frequency (SHF) [5-6], but usually readers send electromagnetic waves with a tag signal designed to react. In the passive tag, there has no source of power and appeal power from the field made from the reader and utilize it to channel the microchip circuitry. The chips then modulate the wave that tags transmit back to the reader that transforms the new signal into digital information data. In the active tags, it have their own power source and broadcast their signals to the reader. The host can process the data and then save it to the database for further processing into a specific identification [7].

Over the past years, many researchers were design the antenna that suitable for portable RFID reader such as quadrifilar type antenna [8], helical type antenna [9], loop type antenna [10] and PIFA type antenna [11]. By choosing the similar printed analogy as disclose above, the designed antenna design hold an advantages on FR-4 substrate substance.

The microstrip patch antenna (MPA) consists of emitting patch on upper side and ground on the lower side. The MPA are widely used in electronic wireless communication system because it has advantages such as conformal design, less weight, low profile, low cost, easy to integrate and fabricate. The main demerits of choosing these types of antenna are lower impedance bandwidth, lower gain, poor efficiency due to conductor and dielectric losses that affect the performance of the design antenna. Nowadays, there are many techniques found by the researchers to cater the MPA drawbacks by using different method of patch geometry such as using U shaped patch [12], T shaped patch [13] and C shaped patch [14]. In practical usage, other research approached to scale down these disadvantages involves the use of different thickness [15], use different substrate of dielectric substance [16], antenna array [17], slashing various slots [18] and creating notches [19] in the patch outline for increasing the performance which make this antennas have been widely spotted in wireless implementations such as RFID system, GPS, military track and trace purpose and satellite communication.

This paper is arranged as follows. In section 2 details the antenna design procedures profiles which leads to practical design of circular microstrip antennas together with rectangular slot. The experimental result and discussion of antenna analysis component in this paper with other algorithms are also described in section 3. Finally, our work of this paper is conducted in the last section.

2 Antenna Geometry and Design

The Fig. 1 shows the geometry of the initial proposed modified circular patch antenna with rectangular slot for single band operation. The proposed antenna is designed on FR-4 substrate with dielectric constant (ε_r) of 4.7, loss tangent of 0.019 and the thickness of 1.6 mm. Copper material was used for ground and patch of the designed antenna with the thickness of 0.035 mm.

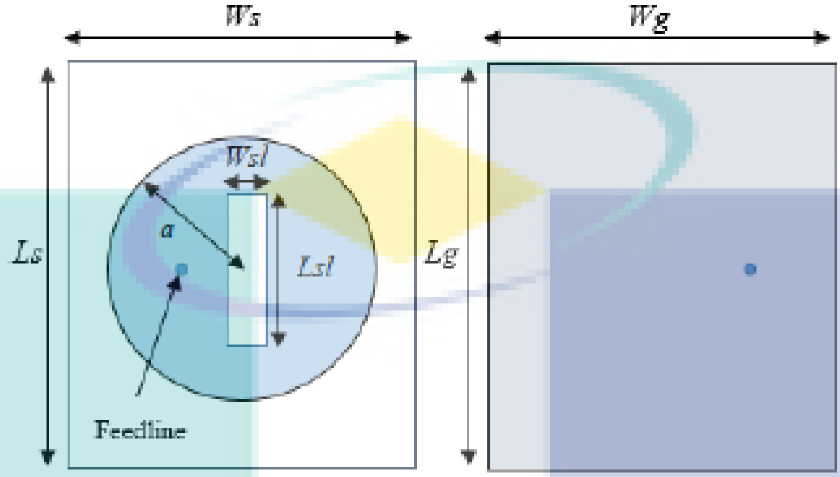

Fig. 1. The geometry of the proposed antenna.

The calculation for patch radius (a), dielectric constant (ε_r), resonant frequency (f_r) and thickness of substrates has been determined using the following equations [20]:

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \tag{1}$$

where;

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \tag{2}$$

The above mode has not been taken into account over the fringing impact. Due to the enlargement of the patch electrically by fringing, hence, the effective radius (a_e) of the patch is implemented and can be formulated as:

$$a_e = a\left\{1+\frac{2h}{\pi a\varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{1/2} \tag{3}$$

The relationship between the velocity of light (v_o) and resonant frequency (f_r) is given as;

$$(f_r)_{110} = \frac{1.8412 v_0}{2\pi a_e\sqrt{\varepsilon_r}} \tag{4}$$

The circular shaped microstrip antenna comprises of slot etched into metallised dielectric substrate. The ground stage controls one area of the dielectric, which does not fall straightly beneath the monopoles. The antenna is probe fed through the microstrip ground engaged with the circular patch. The optimal dimension value of the proposed antenna are listed in Table 1 and Fig. 2 shows the fabricated microstrip antenna.

Table 1. The optimal dimensions of the antenna.

Parameter	Symbol	Segment	Dimension (mm)
Patch	a	Radius	41
Slot Width	Wsl	Width	6
Slot Length	Lsl	Length	20
Substrate	Ws	Width	122
	Ls	Length	122
	h	Thickness	1.6
	ε_r	Dielectric constant	4.7
Ground	Wg	Width	122
	Lg	Length	122

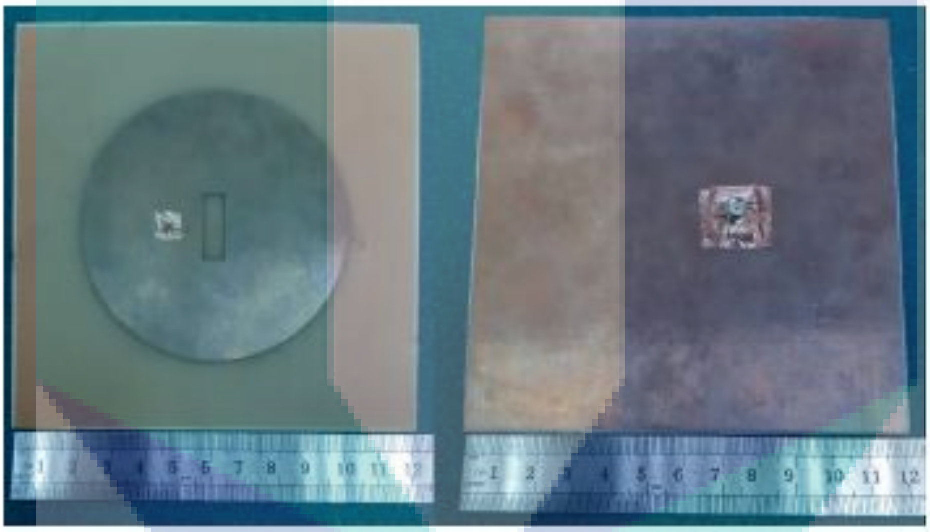

Fig. 2. The fabricated antenna.

3 Results and Discussions

3.1 Result of Simulation of the Proposed Antenna

The better performance of an antenna can be realized when the value of return loss should be less than -10 dB. All the simulation results in this work obtained by using CST Microwave 2014 and Vector Network Analyzer (VNA) is used to measure the return loss for fabricated antenna.

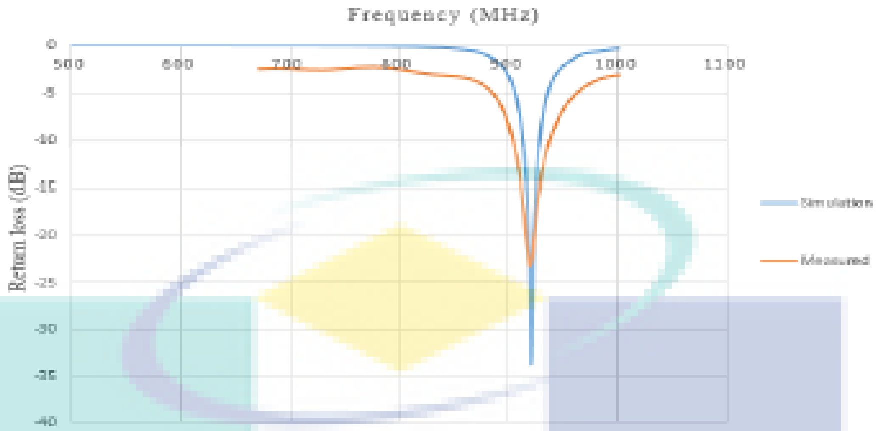

Fig. 3. The simulated and measured S_{11} versus frequency.

The proposed antenna for simulated S_{11} and measured return loss was illustrated in Fig. 3. In this study, the single bands analysis classified into Malaysia RFID frequency bands range from 921 to 923 MHz.

The simulation result for operating frequencies shows in 921 MHz region has pro-duced the bandwidth of 15 MHz (913-928) MHz. Furthermore, for the measured values, the frequency band range from shifted to 903 MHz to 936 MHz with bandwidth of 33 MHz. The difference measured and simulated bandwidth values shows increasing of bandwidth by 18 MHz. The value of S_{11} for simulation and measured are -34 dB and -23 dB, respectively.

The Fig. 4 shows the voltage standing wave ratio (VSWR) of the antenna. The VSWR is an indication of total amount of mismatch between feed line and with an antenna connecting to it. The VSWR value is less than 2 is consider suitable for most RFID antenna applications.

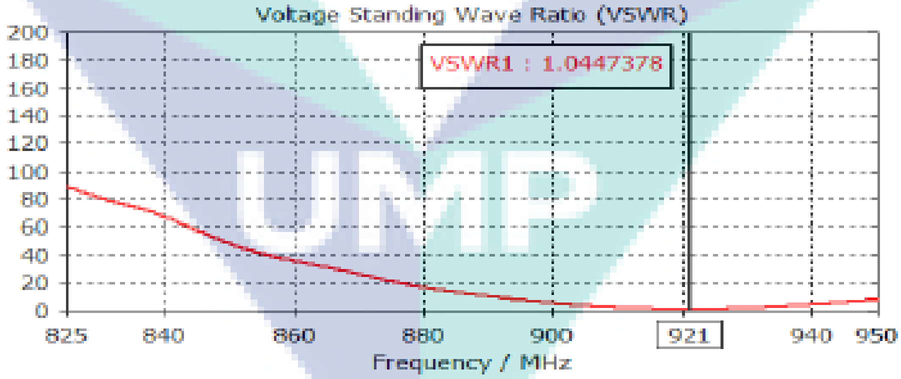

Fig. 4. The voltage standing wave ratio.

The antenna radiation pattern is a graphical image of the radiation plots of the antenna by a sphere and assess the magnetic fields (far field radiation fields) at a length equal to the sphere radius. The value of directivity as in Fig.5 for an antenna is 5.963 dBi and this 3D radiation pattern shows the directional radiation pattern. In RFID, directional radiation tend to produce longer read ranges due to concentration of the beamwidth.

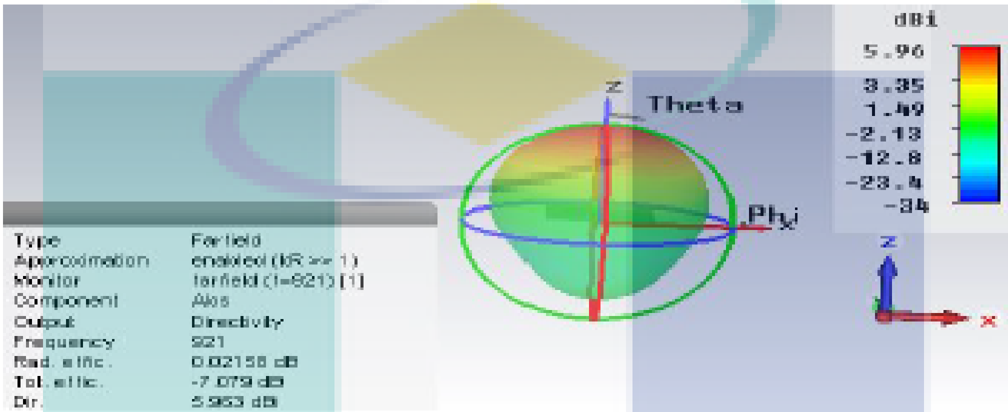

Fig. 5. The simulated Far-Field view 3D radiation pattern for 921 MHz.

Another important impact in the radiation pattern analysis of an antenna also recognized as beamwidth where it shows area receives signal by antenna. The main lobe in the radiation pattern of an antenna is the main beam of the antenna where constant and maximum energy radiated by the antenna outflow. The main lobe magnitude is 5.96 dBi and the beamwidth is 96.3 degree as in Fig. 6. Both if this results shows the antenna has an adequate radiation specification compatible with UHF RFID reader.

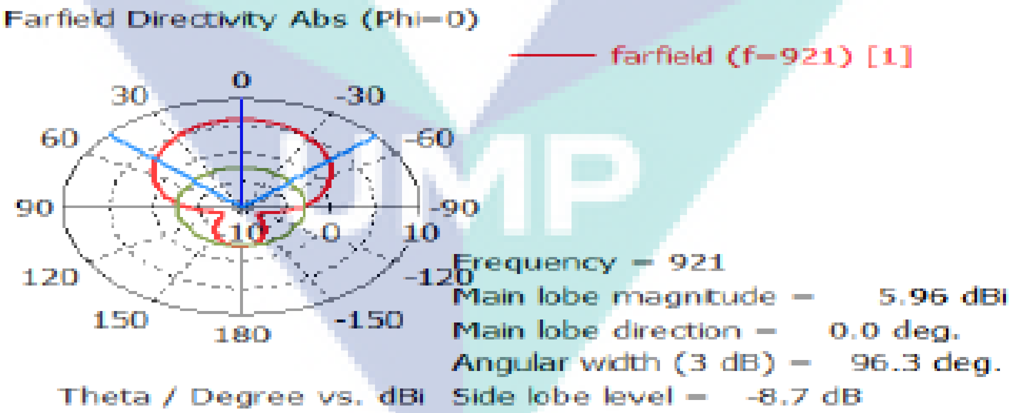

Fig. 6. The simulated radiation pattern view in polar plot.

It is also become aware that simulated gain in Fig. 7 also show antenna power gain is 5.98 dB which combines electrical efficiency and antenna's directivity. In transmitting antenna, the gain acts how good the antenna change input power into radio waves moved in a specified directions.

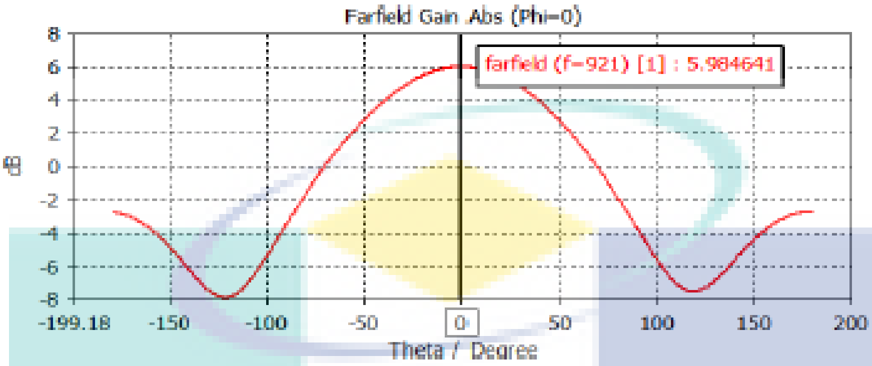

Fig. 7. Simulated gain in Cartesian plot.

3.2 Parametric Studies

The proposed antenna consists of rectangular slot that share the same basic circular patch. In experimental views, the results of return loss, bandwidth and the resonance frequency can be varied by changing the dimensions of the antenna. Three selected parameter has choose such as modification of radius of patch, length and width for slot.

Effects of the Diameter Patch.

The Fig. 8 shows that the result of simulated diameter of patch with values of 80 mm (purple), 81 mm (orange), 82 mm (red), 83 mm (blue) and 84 mm (green). The patch diameter with values 83 mm give a higher return loss of -47dB for 931 MHz operating frequency. Thus, in order to increase the return loss, the best range of patch diameter optimization are from 80 mm to 83 mm.

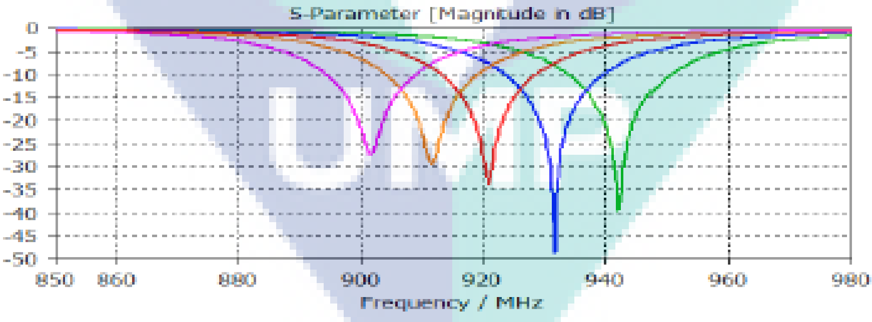

Fig. 8. The effect of varying patch diameter.

Effects of the Rectangular Slot Width.

The Fig. 9 illustrates the result of return loss S_{11} and operating frequency antenna for different values of simulated rectangular slot width. The width has been set as 4 mm (green), 5 mm (blue), 6 mm (red), 7 mm (orange) and 8 mm (purple). Apparently, the most prominent result has been obtained with 6 mm width where the result shows the return loss of -34.2 dB and frequency of 921 MHz. The results of the other width display a similar trend of return loss but with slightly different values of frequencies. The result of return loss and frequency for 7 mm (orange) is nearly overlap with 8mm (purple) width.

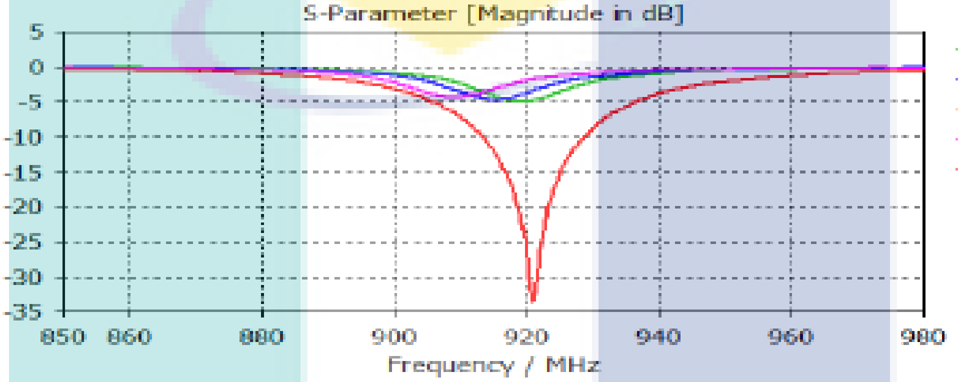

Fig. 9. The effect of varying slot width.

Effects of the Rectangular Slot Length.

The effects of different size of rectangular slot length to the return loss and antenna frequency are shown in Fig. 10. The simulation has been done with slot length of 18 mm (green), 19 mm (blue), 20 mm (red), 21 mm (orange) and 22 mm (purple). Fig. 10 obviously shows that the best result has been generated with 20mm slot length. A good result of return loss should be less than -10dB. However, the other length sizes do not achieved this value.

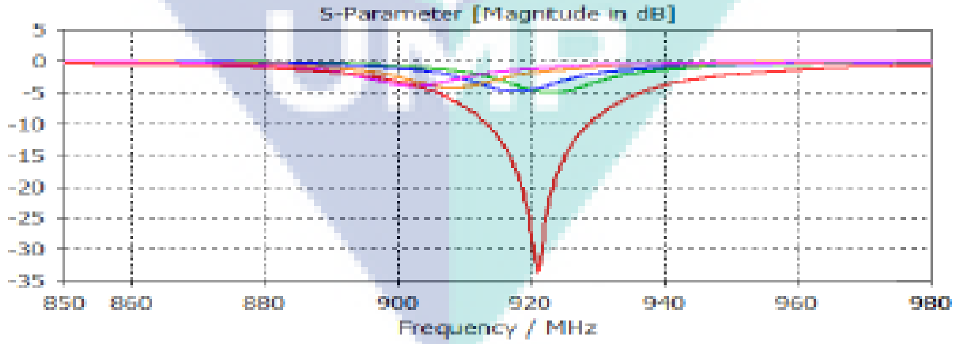

Fig. 10. The effect of varying slot length.

4 Conclusion

A simple microstrip patch with slot derived from an ordinary circular shaped antenna was proposed. The circular patch radiated the single frequencies antenna that working for radio frequency identification reader with the antenna became more compact with the dimensions of only 122 mm x 122 mm x 1.6 mm is the longest wavelength in the operating bandwidth. These acted in two ways: one is the size reduction of the diameter of patch, and the other is a slot used for bandwidth enhancement, as a part of the antenna. This design used a 50 Ω SMA connector with pin fed connected to the feeding point. The antenna was shown to have the impedance bandwidth up to 3.6% for the operating frequency at 921 MHz. On the other hands, with VSWR less than 2 contributes the good efficiencies of the antenna design. For the return loss below than -10 dB for this design shows that the design antenna worked in desired frequency ranging from 919 MHz to 923 MHz which covering the UHF RFID in Malaysia. The presented structure was fabricated, and measured, shown a good compliance with simulated results.

5 Acknowledgement

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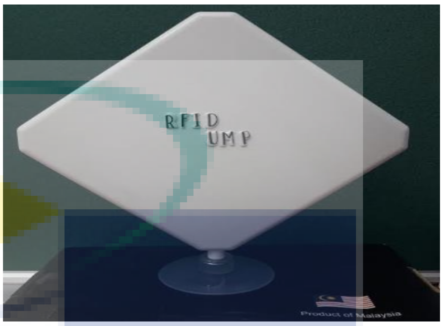
APPENDIX B – PRODUCT SPECIFICATION

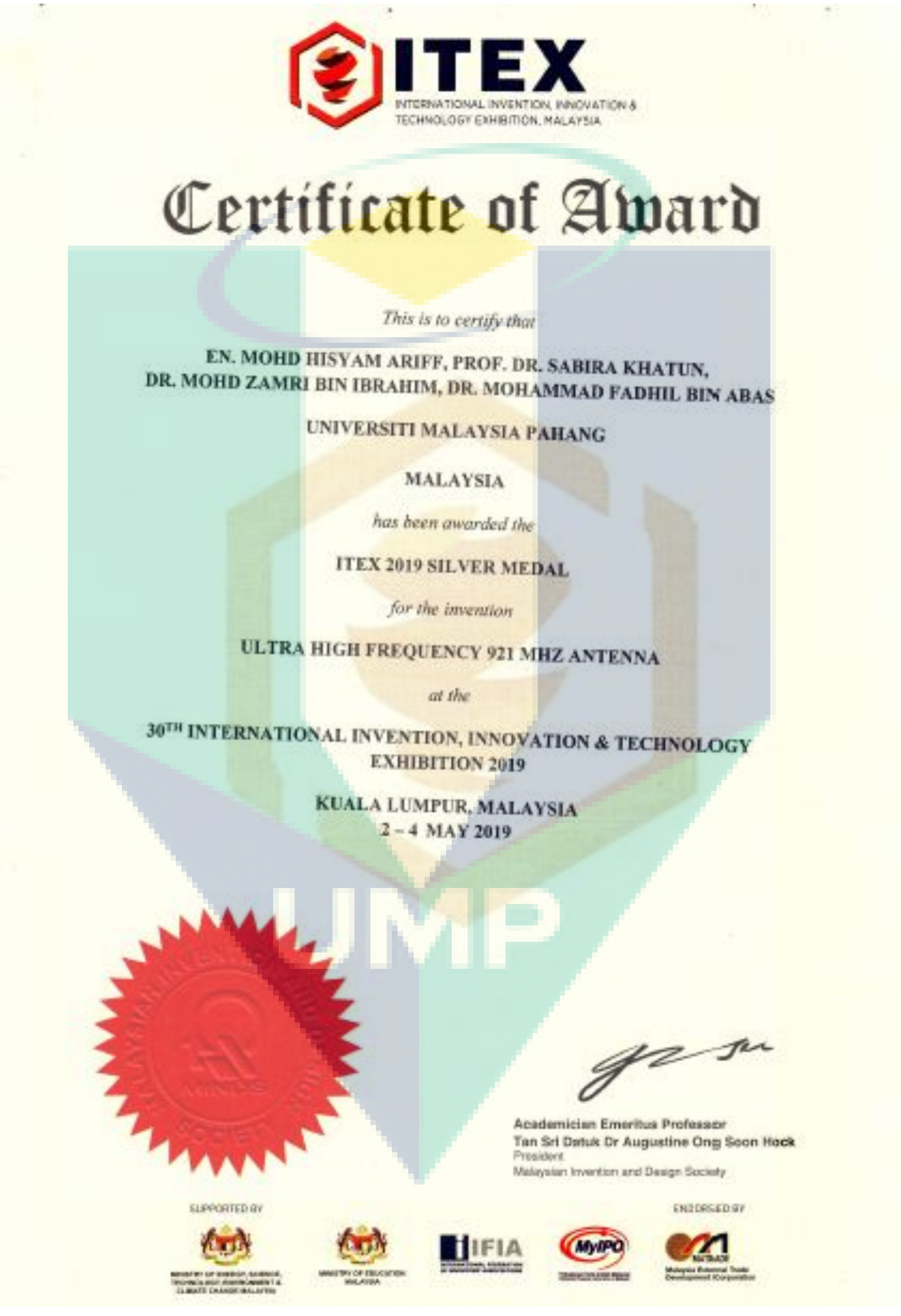
Name	UHF RFID Antenna 
Model and Size	Model: UMP RFID 001 Antenna Size: 12 cm x 12 cm x 0.16 cm Case Size: 14.5 cm x 14.5 cm x 2 cm
Frequency	UHF 921-923 Malaysian Standard
Gain	5.9 dBi
Read range	1 cm - 200 cm (depending on application/ reader/ antenna/ install sites)
Work tag type	ISO/ IEC 18000-6C/ 6B, EPC Class1 Gen2 UHF
Polarization	Circular Polarization
Antenna cable connector	SMA
Cable	10-15cm (default)
Impedance (Ω)	50
VSWR	<1.3
Use for reader	Portable UHF reader, desktop reader, fixed reader & multi ports reader
Using the environment	Temperature: - 40~ + 80 ℃
Lightning Protection	DC ground
Wide application	Books library, door control access, asset inventory, logistics warehouse, school, students, sports, race timing ,club , clothing, vehicle car parking, shop, store, etc.
Antenna Material	FR-4

APPENDIX C – AWARDS/CERTIFICATE

1) **Silver Medal:**
Ultra High Frequency 921 MHz Antenna.
30th International Invention, Innovation & Technology Exhibition 2019 (ITEX 2019).

2) **Gold Medal:**
Ultra High Frequency 921 MHz Antenna with Circular Polarization for RFID Reader.
Creative, Innovation, Technology & Research Exposition (Citrex 2019).

ITEX -2019 – Silver Award.



ITEX
INTERNATIONAL INVENTION, INNOVATION & TECHNOLOGY EXHIBITION, MALAYSIA

Certificate of Award

This is to certify that

EN. MOHD HISYAM ARIFF, PROF. DR. SABIRA KHATUN,
DR. MOHD ZAMRI BIN IBRAHIM, DR. MOHAMMAD FADHIL BIN ABAS

UNIVERSITI MALAYSIA PAHANG

MALAYSIA

has been awarded the

ITEX 2019 SILVER MEDAL

for the invention

ULTRA HIGH FREQUENCY 921 MHZ ANTENNA

at the

30TH INTERNATIONAL INVENTION, INNOVATION & TECHNOLOGY EXHIBITION 2019

KUALA LUMPUR, MALAYSIA
2 – 4 MAY 2019

Academician Emeritus Professor
Tan Sri Datuk Dr Augustine Ong Soon Hock
President
Malaysian Invention and Design Society

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Citrex -2019 – Gold Award.

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CITReX | CREATION, INNOVATION, TECHNOLOGY & RESEARCH EXPOSITION (CITREX)

Certificate of Award

GOLD MEDAL

This Certificate of Award is presented to

Mohd Hisyam Bin Mohd Ariff, Mohammad Fadhil Bin Abas, Dr. Mohd Zamri Bin Ibrahim, Professor Dr. Sabira Khatun

For the invention entitled

Ultra High Frequency 921 Mhz Antenna With Circular Polarization For RFID Reader

CREATION, INNOVATION, TECHNOLOGY & RESEARCH EXPOSITION 2019
12th – 13th February 2019, Universiti Malaysia Pahang

PROFESSOR TS DR. KAMAL ZUHAIRI ZAMLI
DEPUTY VICE CHANCELLOR (RESEARCH & INNOVATION)
UNIVERSITI MALAYSIA PAHANG