

# Faculty of Electrical and Electronic Engineering Technology



**Bachelor of Electronics Engineering Technology (Telecommunications) with Honours** 

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Design of a Broadband Reflectarray Antenna For X-Band Radar Application

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A project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours



# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

# **DECLARATION**

I declare that this project report design of a broadband reflectarray for X-Band radar application is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in

candidature of any other degree.

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# APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

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### **DEDICATION**

### Thanks to Allah,

For give me a good health and strength while making this report.

# My beloved father and mother,

Rumli Bin Kamis & Jamilah Binti Ahmad,

Who has always been our epitome of love and always pray for my strength to finish up this

report. My beloved relatives, My siblings, Thank you for your support and pray. The person who has been very understanding and helpful, DR. Muhammad Inam Abbasi

For the support and guidance. Hope that I always be remembered.

My unforgettable friends,

My housemate, my course mate and all BEET student's intake June 2019,

my struggle not yet ends.

Finally, friends that always together during this fourth years study,

Hopefully achieved what we aspired.

### ABSTRACT

A unit cell antenna for the X-band is a type of antenna designed to function within the Xband frequency range, which is commonly classified as 8-12 GHz. These antennas are commonly employed in radar and communications systems, as well as other applications requiring high-frequency signal transmission and reception. Next, the patch antenna, which is made up of a flat, metallic patch suspended above a ground plane, is a typical type of Xband unit cell antenna. A microstrip transmission line often feeds the patch, allowing the antenna to be integrated into a larger system or device. Patch antennas are distinguished by their tiny size, low profile, and good performance at X-band frequencies. The slot antenna is another type of X-band unit cell antenna that is made out of a rectangular slot cut into a metallic sheet or waveguide. Besides that, the slot antenna which is often fed by a coaxial transmission line, is notable for its large bandwidth and strong gain at X-band frequencies. A unit cell antenna's performance in the X-band can be measured using a range of metrics, including gain, directivity, and efficiency. These parameters can be shown on a graph to demonstrate how the antenna operates throughout a range of frequencies or under various operating situations. However, one of the limitations of the reflectarray antenna is its narrow bandwidth that limits its use in many applications. This work provides the design characterization and analysis of reflectarray antennas for bandwidth enhancement and its use in the X-band radar applications

### ABSTRAK

Antena sel unit untuk jalur-X ialah sejenis antena yang direka bentuk untuk berfungsi dalam julat frekuensi jalur-X, yang biasanya dikelaskan sebagai 8-12 GHz. Antena ini biasanya digunakan dalam sistem radar dan komunikasi, serta aplikasi lain yang memerlukan penghantaran dan penerimaan isyarat frekuensi tinggi. Seterusnya, antena tampalan, yang terdiri daripada tampalan logam rata yang digantung di atas satah tanah, ialah jenis antena sel unit jalur-X yang tipikal. Talian penghantaran jalur mikro sering menyalurkan tampalan, membolehkan antena disepadukan ke dalam sistem atau peranti yang lebih besar. Antena tampalan dibezakan oleh saiznya yang kecil, profil rendah dan prestasi yang baik pada frekuensi jalur-X. Antena slot ialah satu lagi jenis antena sel unit jalur-X yang diperbuat daripada slot segi empat tepat yang dipotong menjadi kepingan logam atau pandu gelombang. Selain itu, antena slot yang sering disalurkan oleh talian penghantaran sepaksi, terkenal dengan lebar jalur yang besar dan keuntungan yang kuat pada frekuensi jalur-X. Prestasi antena sel unit dalam jalur-X boleh diukur menggunakan julat metrik, termasuk perolehan, arahan dan kecekapan. Parameter ini boleh ditunjukkan pada graf untuk menunjukkan cara antena beroperasi sepanjang julat frekuensi atau di bawah pelbagai situasi operasi. Walau bagaimanapun, salah satu batasan antena reflectarray ialah lebar jalur sempit yang mengehadkan penggunaannya dalam banyak aplikasi. Kerja ini menyediakan pencirian reka bentuk dan analisis antena reflectarray untuk peningkatan lebar jalur dan penggunaannya dalam aplikasi radar jalur X

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> اونيۈم سيتي تيڪنيڪل مليسيا ملاك UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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### **CHAPTER 1**

### **INTRODUCTION**

### 1.1 Background

Reflectarrays have been utilized in high-gain antenna designs since Hertz discovered electromagnetic wave propagation in the latter decades of the 19th century. The purpose of this project is to design a unit cell to create a broadband reflectarray antenna for X-band radar application. The advantages of reflectarray antennas, including as low profile, simplicity of production, and pattern sculpting, have piqued people's curiosity. Besides, the primary design of areflectarray is defined by an array of components arranged on a flat surface to reflect theoccurrence signals from an appropriately distant feed. Next, such as their low profile, ease of construction, and ability to shape patterns, have sparked a lot of interest.

### **1.2 Problem Statement**

Reflectarray antenna is a recently evolved antenna that combines the advantages of the high gain parabolic reflectors and electronically beam scanning phased array antennas. Conventionally, parabolic reflectors and phased array antennas are used for high gain beam shaping and beam scanning applications. Moreover, the reflectarray has the potential to be a low cost and simple solution in many high gain antenna applications including military and civil radars. However, one of the limitations of the reflectarray antenna is its narrow bandwidth that limits its use in many applications. Therefore, this work focuses on the design characterization and analysis of reflectarray antennas for bandwidth enhancement and its use in the X-band frequency range (8GHz-12GHz) radar applications.

# 1.3 Project Objective

The main aim of this project is to design A Broadband Reflectarray Antenna For X-Band RadarApplication.

Specifically, the objectives of this works are to:

- 1. Design reflectarray unit cells within X-band frequency range (8GHz-12GHz).
- 2. Optimize the unit cell design to achieve wider phase range.
- Utilize the proposed unit cell design to create a broadband reflectarray antennafor Xband radar applications.

# **1.4 Scope of Project**The scope of this project are as follows:a) Unit cell design using CST software.

- b) Analyze the reflection loss and reflection phase results of unit cells.
- c) Fabricate unit cells and perform scattering parameter (S11) measurement.
- d) Design the periodic reflectarray antenna and perform far-field analysis.

### **CHAPTER 2**

### LITERATURE REVIEW

### 2.1 Introduction

Reflect array antenna commonly known as have an array of unit cells, illuminated by feeding antenna and also it usually a horn then with the advantages, including as low profile, ease of production, and pattern shaping, reflect array antennas have generated a wide acceptance[1]. The primary architecture of a reflectarray antenna is defined by an array of elements assembled on a flat surface to reflect incident signals from an appropriately distant feed[2]. Besides, the primary design of a reflect array is defined by an array of components arranged on a flat surface to reflect the occurrence signals from an appropriately distant feed. Next, such as their low profile, ease of construction, and ability to shape patterns, have sparked a lot of interest.

Previously, rectangular unit cells were used in the design of the reflectarray antenna. The simple rectangular cells, on the other hand, have a limited range of reflection phase angles thatare less than 360 degrees. As a result, some waves may not be reflected at the proper angle, resulting in a phase mistake. The antenna's performance will suffer as a result[3]. The majority of reflectarrays are made using a flat substrate and a microstrip reflecting element of variable length or size. However, the microstrip element's fundamental disadvantage is its limited bandwidth, which is mostly driven by the resonance phenomena. Multiple resonances have been generated utilising stacked layers in a variety of experiments to enhance the bandwidth of the reflectarray[4].



Figure 2.0.1: The unit cell and single-offset reflectarray.

Figure 2. 1: shows the unit cell and single-offset reflectarray. The reflectarray is made upof a number of reflecting unit cells and is planar. In the XZ plane, the feed phase Centre is located at  $\vec{r} \rightarrow f$  each reflectarray element has a different incidence angle[5].

A waveguide is a high-frequency signal feed line made of electromagnetic material. Microwave communications, aerospace, radars, telecommunications, and other highfrequency applications all make use of them. Depending on the wave frequency, waveguides can be made ofdielectric or conductive materials. Horns and reflector antennas commonly use circular waveguidefeeds, but the majority of the microwave system requires a more standard rectangular waveguide. There are several methods for transforming between a circular waveguide propagating the mode and a rectangular waveguide transmitting the mode [6].







(b) Figure 2.2: *the structure of a waveguide* 

Figure 2.2 shows depicts the structure of a waveguide simulation in which electric fields are stimulated in the Y-direction, resulting in E-walls on the upper and bottom walls of the cavity. As a result, H-walls form on the interior cavity of the waveguide simulator's left and right walls. (b) In the waveguide aperture, there is a reflectarray patch element[7].

### 2.2 Unit cell

A unit cell element with minimal loss is the best choice for efficient reflectarray antenna performance. However, the loss and phase range performance of the reflectarray unit cell elementmust be balanced. The choice of a unit cell is the initial step in the construction of a reflectarray. Both a waveguide and then a microstrip resonator can be used to make the unit. cell. Waveguide cells did not discover use in the centimeter's wavelength region due to their large size the optimumchoice for efficient reflectarray antenna performance is a unit cell element with low loss. However, there is a compromise between the reflectarray unit cell element's loss and phase range performance.[8] Reflection response (magnitude and phase) and polarization purity are the most important unit cell features. To achieve perfect reflected field is nearly equal to that of the incident field. [9]. The unit-cell is made up of microstrip lines connected to a circular microstrip patch. A circular ring is also constructed around the central structure to achieve additional resonance and minimize unit-cell size. [10]





(C)

Figure 2.3: (a) Measurement setup for scattering parameter measurements; (b) fabricated square patch unit cell elements; (c) top and side view of the square patchelement.[11]



Figure 2.4: Reflection response of a variable-length square patch unit cell element at 26 GHz.

Figure 2.4 (a) shows the total measurement setup, which uses the waveguide's open end to keep the two-patch-unit cell element The waveguide simulator is designed to assess the scatteringcharacteristics of a reflectarray unit cell with infinite boundary conditions. Figure 2(b) depicts themanufactured two-patch-unit cell elements with varied patch lengths displayed on each sample. Figure 2.1 compares the simulated and measured outcomes of unit cell elements. It is clear that thesimulated and measured data follow the same pattern, with a progressive phase range of 330 and a phase inaccuracy of 30. Phase inaccuracy has a direct impact on the reflectarray antenna's gain and efficiency performance. [11]. Its impact can be reduced if the reflectarray antenna is precisely built. It has the same resonance performance as the predicted loss, the observed loss was around 1dB greater. This additional loss is produced by the waveguide simulator's cable, connections, and propagation effects. This extra loss is unavoidable for unit cell measurements. It can, however, beoverlooked in the study of the reflectarray antenna when the cable, connections, and waveguide are not present.[11]

### 2.2.1 Reflection loss



Figure 2.5 shows the reflection loss curve for a 0.127-mm thick substrate utilized in reflectarray design, as measured and simulated. This can be seen. At 10.6 GHz, the observed reflection loss exceeds the calculated reflection loss as shown in Figure 2.6, but the trend of the two curves is the same. The difference between what was measured and what was really measured. The loss in the connectors and wave guide simulator can be blamed for the simulated reflection loss [5].

### 2.2.2 Reflection phase



Figure 2.6: Measured and simulated results for 0.127-mm thick substrate.

Reflection phase curve

Figure 2.6 indicates that reflection phase curves are already in strong agreement, indicating that the measured values are legitimate. Since the substrate used in the reflectarray design is so thin, the slope of the reflection phase curve in Figure 3 is rather steep. This causes several energy bounces in the substrate region, resulting in an extremely high reflection loss and a narrow bandwidth. [5].

### 2.3 Array (Periodic array)

An array is a collection of similar components stored in contiguous memory regions and accessible separately by an index to a unique identifier. To construct and analyze reflectarray antennas, a numerical code has been built that calculates the radiated far field using the equivalent currents technique, technique. The algorithm uses cubic fourdimensional interpolation to calculate the reflection coefficients of the individual reflectarray elements[21].



Figure 2.7: The reflectarray with square and hexagonal patch elements (a) Square and (b)hexagonal[12].



Figure 2.8: Simulated radiation patterns for the reflectarrays with square and hexagonal patch elements (a) Square and (b) hexagonal[12].

Figure 2.8 depicts reflectarrays with square and hexagonal patch elements. Figure 4.1 depicts the simulated radiation patterns of the reflectarrays with square and hexagonal patch elements. The sidelobe level of the hexagonal patch is thought to be superior than that of thesquare patch in this case[12] [22].

# 2.4 SUMMARY

Table 2.1: Reflectarray unit	ell patch elements	for highly efficient	operation [11]
------------------------------	--------------------	----------------------	----------------

Element Type		Loss (dB)	Phase Range	Aperture	Efficiency
	Design		(°)	Size $(\lambda^2)$	(%)
Hexagonal[12]		N.A	360	69.4	60
Bow-tie[13]	*	-0.4	360	39	57
I-Shaped[14]		N.A	360	75.7	50
Dual Rings[15]	0	N.A	360	250	52
Parallel Dipoles[16]		-0.2	360	180	65
Two Rings and Patch[17]		N.A	مىبى بى <del>م</del> 360	اويبونري 130	64
Three Rings[18]		N.A	1ALAT SIA 1 500	163	66
Split Ring[19]		-0.3	360	187	55
Fractal[20]		-0.45	700	54.5	66
Ring with Phase Delay Lines[8]	$\bigcirc$	-0.05	460	78	57.3

### N.A = not available.

Based on table 2.1, it shown most of the elements described in Table 1 have a reflection phase range of 360 or greater, with a reflection loss of less than 1 dB (wherever specified), and areused to achieve a high operating efficiency ( $(\geq 50\%)$ ). According to [12], a hexagonal element withcross slots is proposed to decrease loss with a large reflecting surface and to achieve a wide reflection phase range with the help of cross slots. A circular polarization operation can also improve the efficiency of the reflectarray antenna. Bow-tie [13] and Ishaped [14] elements can be utilized for this purpose. Due to the integration of more than one element in a single unit cell, themulti-resonance technique for phase augmentation, as used in dual rings [15], three parallel dipoles [16], two rings with patches [17], and three rectangular rings [18], is also required for low loss operation. A dipole element is a suitable option for low loss operation, and a split ring is typically employed to generate a smooth phase span; both of these are used in [19] to improve the reflectarray antenna's efficiency. A combination of elements used for multi-resonance might causemutual coupling and decrease reflectarray performance. Since it is a single element employed forwideband and low loss operation, a fractal element [20] can eliminate the issue of mutual coupling. A ting element's loss performance can be improved by using numerous phase delay lines, as shownin [8], where the phase delay lines are also responsible for achieving the wide phase range. The fundamental challenge with low loss and wide reflection phase range elements is their high designcomplex, which prevents it from using at millimeter wave frequencies.

### **CHAPTER 3**

### METHODOLOGY

### 3.1 Introduction

Reflectarray antenna is a recently evolved antenna that combines the advantages of the high gain parabolic reflectors and electronically beam scanning phased array antennas. The reflectarray has the potential to be a low cost and simple solution in many high gain antenna applications including military and civil radars. However, one of the limitations of the reflectarray antenna is its narrow bandwidth that limits its use in many applications. Therefore, the purpose of the project is to design of broadband reflectarray antenna for X-band radar applications. The mainobjective of this project is to design a reflectarray of unit cells within X-band frequency range (8GHz-12GHz) and also to optimization the unit cells design to achieve wider phase range

### 3.2 Methodology

This thesis presents the process in creating a reflectarray antenna in X-band frequency range (8GHz-12GHz). The strategy employed in this project is focused on developing, analysing, and fabricating. The selected approach is based on simulation in CST Studio Suite. The experimental method (design) makes use of empirical modelling and a statistical methodology. Following that, Figure 3.1 depicts the thesis's research design.



Figure 3.1: Unit cells reflectarray design estimation general process flow.

### 3.2.1 Experiment setup

This project present a new integrated analytical approach to create a new unit cell reflectarray design. As a result, the focus of the study is on the design, characterization, and analysis of reflectarray antennas for bandwidth increase in X-band (8GHz-12GHz) radar applications.

### 3.2.1.1 Equipment

### 3.2.1.1.1 Simulation



Figure 3.2: The CST Microwave Software

In technology used in this project, a circularly polarized microstrip antenna for UWB applications has been designed. First, CST microwave software was used to develop an ultrawide band antenna, then CST microwave software was used to construct a circular polarization antenna optimize the design antenna.

### 3.2.1.2 Fabrication

To conduct x mirror on the logo, picture, or any text for the group name, check that the size of the circuit matches the positive board size before printing. Only tick bottom copper, boardedge, scale 100 percent rotation x horizontal, and reflection normal when performing a border on the circuit to select the area that will be used. Monochrome color scheme is used.



Figure 3.3: PCB Developer Machines

To turn on the mains, the PCB developer uses a chemical procedure. Set the temperature to 40°C and the time of the development to 2 minutes. After that, wash it with water and dry it with tissue paper. This method necessitates the use of safety equipment such as gloves, goggles, and an apron.



Figure 3.4: Etching Developer Machines

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The massive electronics of the etcher machines (model FAPC 300). At the input roller, assign the +VE board. Then, keep the temperature between 40°C and 46°C. Depending on thesize of the board, the etching procedure may be repeated 2-4 times. However, once the etchingprocess is complete, the surrounding copper in the non-circuit area will no longer be visible.

Wear safety equipment such as gloves, goggles, and an apron before beginning this activity.

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Figure 3.5: Photoresist Stripper Machines

The photoresist stripper chemical is used by the etcher machine Mega electronics (model PA320) to assign the +VE board in the nets and execute up and down soaking. The circuit line willbe made from green lining to copper lining at the end of the process. When doing this procedure, wear safety equipment such as gloves, goggles, and an apron.



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This printed circuit board (PCB) cutter need to ensure the board is dry before cutting process. Align the unwanted PCB area to towards the cutting area and move the cutter handler down fast to ensure smooth cutting. When the process cutting make sure to not move to slow since board edge will be crack. Need to wear the safety protection materials such as goggle during this process. When it finishes need to throw away the balance portion into the dustbin and ensure the workstation clean
### 3.2.1.3 Measurement



Figure 3.7: Vector Network Analyzer Machines

The principle of monitoring transmitted and reflected waves while a signal flows through a device under test is used by the vector network analyzer. To do this, the transmitted and reflected signals must be measured across the band of interest and often beyond, allowing the device's characteristics to be identified.

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Calculation for Patch

The width (W) is calculated as follows:

$$w \frac{c}{2 \times fr \sqrt{\frac{\varepsilon r + 1}{2}}}$$
(3.1)

The Effective Dielectric Constant is calculated. This is estimated based on the patch antenna'sheight, dielectric constant, and predicted width:



The length extension  $\Delta L$ :

$$\Delta L = 0.412(h) \frac{(\varepsilon erff + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon erff - 0.258)(\frac{W}{h} + 0.8)}$$
(3.4)

The actual length of patch:

$$Lp = Leff - 2 \Delta L \tag{3.5}$$

#### 3.3 Summary

The proposed methodology is presented in this chapter in order to offer a new, effective, and integrated approach to waveguide cos and size optimization. The primary purpose of the suggested technique is to get a simple, less rigorous, and effective estimation that does not result in a significant loss of accuracy in the findings. The strategies also aimed to make use of publiclyavailable and restricted network and load data from power utilities. The method's ultimate purpose to achieve efficiency, ease of use and manipulation, and the flexibility to deploy on a large-scaledistribution network, rather than maximal accuracy.



### **CHAPTER 4**

### **RESULT AND DISCUSSION**

### 4.1 Introduction

In this chapter, its present the results and analysis on the advancement of X-band radar application that will be the potential to be a low cost. Then, the designing the unit cells are to establish a methodology to estimate the frequency range that needed. Next, based on this case studies, it will perform radiation pattern, S-parameter (S1,1) result and the gain results. In fact, this project used CST Studio suite to create and simulate a unit's cells. By that the results will be supported from the series simulation.

## 4.2 Result and Analysis

4.2.1 FR4 (lossy) material

4.2.1.1 Square shape of unit cells using FR4 (lossy)material.





(b)

Ground



Figure 4.1: The design of square unit cells using FR4 (lossy)material.

Figure 4.1 shown (a) front and (b) perspective view of square shape of unit cells using FR-4 material. Figure 4.1 (c) is a unit cell with port 1 and (d) the boundaries condition of unit cell of square shape of unit cells using FR-4 material. Ports are used in unit cell design in CST software to define the boundary conditions for EM simulation, to apply excitation, and to monitor the power, voltage, and current levels inside the structure.

Calculation of FR4:  

$$\varepsilon r = 4.3, \ f_r = 10 GHz, \ c = 3 \times 10^8, \ h = 1.6 \ mm}$$

$$w \frac{c}{2 \times fr \sqrt{\frac{\varepsilon r + 1}{2}}}$$
(4.1)

$$w \frac{3 \times 10^8}{2 \times 10 Ghz \sqrt{\frac{4.3+1}{2}}}$$

= 0.0092144m

= 9.2144*mm* 

$$\varepsilon_{reff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2} \left[ 1 + 12 \frac{h}{w} \right]^{-\frac{1}{2}}$$
(4.2)

$$\varepsilon_{reff} = \frac{4.3 + 1}{2} + \frac{4.3 - 1}{2} \left[ 1 + 12 \frac{1.6}{9.2144} \right]^{-\frac{1}{2}}$$

$$= 3.5896$$

$$L_{eff} = \frac{c}{2 \times fo \sqrt{\varepsilon reff}}$$

$$3 \times 10^{8}$$
(4.3)

$$L_{eff} = \frac{3 \times 10}{2 \times 10 GHz \sqrt{3.5896}}$$

=0.0079171m

$$\Delta L = 0.412(h) \frac{(\varepsilon erff + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon erff - 0.258)(\frac{w}{h} + 0.8)}$$
(4.4)  
$$\Delta L = 0.412(1.6) \frac{(3.5896 + 0.3)(\frac{9.2144}{1.6} + 0.264)}{(3.5896 - 0.258)(\frac{9.2144}{1.6} + 0.8)}$$
=0.7067 mm

$$L_p = L_{eff} - 2\Delta L$$
(4.5)  
= 7.9171 - 2(0.7067)  
= 6.5037 mm

$$Wg = Lg = \frac{c}{2fo}$$

$$Wg = Lg = \frac{3 \times 10^8}{2(10GHz)}$$

$$= 15mm$$
(4.6)

$$DL = \frac{Ls}{2} - \frac{Lp}{2}$$
$$DL = \frac{15}{2} - \frac{6.5037}{2}$$

=4.248mm

Parameters	Theoretical Calculation Value (mm)	Simulation Value (mm)
Patch Height, Hp	0.035	0.035
Substrate Height, Hs	1.600	1.600
Patch Length, Lp	6.5037	6.219
Patch Width, Wp	9.2144	6.219
Substrate Width, Ws	15	15
Substrate Length, Ls	ىتى تىكنىكى	15 او نبو مر س

Table 4.1: Comparison value of parameters u	using J	FR4
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(4.7)

In table 4.1, it shows the comparison value of parameters value in theoretical calculation and the simulation value by using FR4 material. Theoretical Calculation Value and Simulation Value are two different methods to solve a problem, where Theoretical calculation value is based on mathematical models and assumptions, while Simulation value is based on numerical methods and approximations. The results obtained from the two methods should agree within a certain level of accuracy, and it's not always necessary that the result should be exactly the same, the difference between them depend on the complexity of the problem, the accuracy of the models and approximations used.



Figure 4.2: S-Parameter S11 of FR4

In figure 4.2 it shows the measured and the result of simulation for reflection loss curve by using value 6.839mm for length and width patch used for reflectarray design. It can be observed from Figure 4.3 that the measured return loss -4.4128077 dB this shows that the system or antenna being measured is operating more effectively and loses less power to reflection. Next, the exact significance of these reflection loss values will rely on the application's requirements as well as the context in which they are measured. A smaller reflection loss number is, however, typically desirable as it denotes higher performance and efficiency.



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Figure 4.3: Parameter sweep for (a)reflection loss and (b) reflection phase of FR-4 material.

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In figure (a) it shows the results of simulation for parameter sweep using FR-4 material with the results of return loss by using different value of length patch. In general, an antenna's reflection loss is influenced by its impedance and how well it matches the transmission line's impedance. By using different length patch by range values between 5.6, 5.9, 6.2, 6.5, 6.8, 7.1, 7.4, 7.7, 8 and 8.3 being used to see how its impact the results of reflection loss. Changes in the patch's length and width may influence the antenna's impedance, which will then change the reflection loss. Generally, a larger patch antenna may have reduced reflection loss due to the superior matching that the larger surface area can provide to the transmission line. A larger patch antenna may also have lower gain and a more constrained operational bandwidth, thus there is a cost to consider. Figure 4.3 (b) show the reflection phase, at a certain point in a transmission line, is a measurement of the phase difference between the incident and reflected waves. It is often expressed in degrees and is correlated with the system's VSWR rating. A strong antenna-to-transmission line match and little power loss are indicated by the reflection phase being typically near to 0 degrees



Figure 4.4: Parameter sweep VSWR for of FR-4 material

Figure 4.4 shows the optimum VSWR number is 1:1, which indicates an almost perfect fit between the antenna and the transmission line. A VSWR value of 1.15963 is incredibly low and very close to this ideal value. A system's antenna will have little power loss and great efficiency at this VSWR rating. This level of VSWR is regarded as the antenna's remarkable performance, and it is likely to satisfy the requirements of most of the radar or communication systems. It is crucial to remember that the performance is dependent on the overall antenna and transmission line design. The performance of the antenna will not be completely realized if the rest of the system is not tuned for it.



(a)



(b)

WALAYSIA

Figure 4.5: (a) E-field and (b) H-field for of FR-4 material

In figure 4.5 it is a representation of the electric field that influences the current density. Based on e-field value frequency at 10 GHz the maximum plot value is 182161V/m in this simulation. Then, for h-field it shows at frequency 10GHz the maximum value is 406.583A/m.

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### 4.2.1.2 Square shape of two element patch of unit cells using FR4 (lossy)material.





Figure 4.6: The design of two element of patch unit cells using FR4 (lossy)material.

Figure 4.6 shown (a) front and (b) perspective view of square shape of unit cells using FR-4 material. Figure 4.8 shown (c) unit cell with port 1the port represents an opening in the structure through which EM waves can enter or exit and (d) the boundaries condition of two element of patch in unit cell of square shape with square slot using FR-4 material. It shows how boundaries assigning the appropriate boundary conditions to the selected shapes, such as electric or magnetic boundary conditions in simulation using CST software.







Figure 4.8: the simulation of (a) reflection loss and (b) reflection phase using Sweep parameter for FR4 (lossy) material.



Figure 4.9: the simulation of value voltage standing wave radio (VSWR) using Sweep parameter for FR4 (lossy) material.





(b)

Figure 4.10: the simulation of (a) e-field (b) h-field using FR4 (lossy) material.



**4.2.1.3** Square shape of unit cells with square slot using FR4 (lossy)material.

(d)

Figure 4.11: The design of square of unit cell with slot.

Figure shows (a) front and (b) perspective view of square shape of unit cells with slot using FR-4 material. Figure (a) shows a square-shaped opening or gap within the antenna structure is referred to as a slot in a square unit cell antenna. The antenna's radiation characteristics, such as the radiation pattern, directivity, and gain, can be influenced by the size, shape, and position of the slot. Consider a square patch antenna with a part cut out for a square slot antenna unit cell (the square slot). Figure shown (b) unit cell with port 1 and (c) the boundaries condition of two element of patch in unit cell of square shape with square slot using FR-4 material.



Figure 4.12 shows in value of length and width patch 5. 919mm. It is thought that the return loss value of -5.7154 dB, which is close to the ideal value of 0, is an acceptable number. The reference return loss value, which is 0 dB, is regarded as ideal or theoretically perfect, meaning that the antenna is perfectly matched and there is no reflection from it. Most communication systems are thought to be acceptable if the value array show less its reflect.





(b)

Figure 4.13: the simulation of the reflection loss and phase using FR4 materials.

Figure 4.13 Parameter sweep for (a)reflection loss and (b) reflection phase of FR-4 material. A unit cell antenna with a slot would have a reflection loss value of -5.1754187 dB. In general, the reflection loss should be as low as feasible to ensure the greatest performance. A reflection loss value of -5.1754187 dB indicates a rather low power loss nonetheless, it is still crucial to examine the system's design, evaluate the quality of its components, and, if required, retune the system to increase the reflection loss value.



Figure 4.14 Parameter sweep VSWR for FR-4 material

Figure 4.14 show the important data regarding the effectiveness of power transfer between the transmission line and the load can be found in the voltage standing wave ratio (in this case, the antenna). The antenna's bandwidth and operating frequency can be determined by the width and frequency of the dip.



(a)



### (b)

Figure 4.15: (a) E-field and (b) H-field for of FR-4 material

Figure 4.15It represents the e-fields of FR4 material. The simulation's highest value of e-field at 10 GHz is 489665 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel all other charged particles in the field. Then, in figure 4.15 (b) its shows 1125.82 A/m.



(c)

(d)

Figure 4.16: The design of two element patch square of unit cell with slot

Figure 4.16 shown (a) front and (b) perspective view of two element of patch for square shape of unit cells with slot using FR-4 material. Then, in (c) unit cell with port 1the port represents an opening in the structure through which EM waves can enter or exit and (d) the boundaries condition of two element of patch in unit cell of square shape with square slot using FR-4 material.



Figure 4.17: result simulation S 11 Parameter in two elements of patch for square shape of unit cell with slot using FR-4 materials.

Based on this figure 4.17 in generally, Reflectarray antenna is designed to have a low S11 value (or return loss) which is near to 0 dB. This is because a low S11 value indicates a good impedance match between the transmission line and the antenna, which results in minimal power loss and a desired performance. If the simulation results show an S11 value of -5.14767 dB, it indicates that there is a significant mismatch between the transmission line and the antenna. This value is relatively low, but it is not near to 0 dB, which is the ideal value for a Reflectarray antenna. This means that the majority of the power is being transmitted to the antenna, however, there is still significant power loss which is not ideal.

(a)



(b)

Figure 4.18: Parameter sweep for (a)reflection loss and (b) reflection phase of two element patch of unit cell using FR-4 material

Figure 4.18 shows the reflection loss, which is the amount of power reflected to the source when a signal is transmitted through the antenna, is depicted in graph (a). This illustrates how the reflection loss varies over the tested frequency range when plotted against the operating frequency. Typically, the objective is to determine the frequency range where the reflection loss is lowest, suggesting that the antenna is transmitting the greatest power. Next, the reflection phase, which is the phase shift of the reflected wave with respect to the incident wave, is depicted in graph (b). It displays how the reflection phase varies over the tested frequency.





Figure 4.19: Parameter sweep for (a)reflection loss and (b) reflection phase of two element patch of unit cell using FR-4 material

Figure 4.19 shows the reflection loss, which is the amount of power reflected to the source when a signal is transmitted through the antenna, is depicted in graph (a). This illustrates how the reflection loss varies over the tested frequency range when plotted against the operating frequency. Typically, the objective is to determine the frequency range where the reflection loss is lowest, suggesting that the antenna is transmitting the greatest power. Next, the reflection phase, which is the phase shift of the reflected wave with respect to the incident wave, is depicted in graph (b). It displays how the reflection phase varies over the tested frequency.



Figure 4.20: Parameter sweep VSWR for two patch element of unit cell using FR-4 material.

The VSWR is a measurement of the antenna's or another RF component's compatibility with the transmission line or other power source. It is commonly measured as a ratio without units and is defined as the greatest voltage to minimum voltage on the transmission line. In this simulation the result for voltage standing wave radio is 3.4728831.







Figure 4.21: show (a) E-field and (b) H-field two element patch of unit cell using FR-4 material.

Figure 4.21 represents the FR4 material's e-fields and h-field. Because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field, the simulation's maximum value of e-field at 10 GHz is 42737.6 V/m. Then, it shows 158.097 A/m in figure (b).

**4.2.1.5** Square shape of unit cells using FR4 (lossy)material.



Figure 4.22: The design square of unit cell with circle slot Figure 4.22 Shown (a) front and (b) perspective view of square shape of unit cells with circle slot using FR-4 material. In figure (c) its is the port 1 view and (d) is the boundaries condition of this unit cell.



Figure 4.23: S-Parameter S11 of unit cell with circle slot using FR-4 materials

Figure 4.23 shows a square unit cell antenna for x-band radar with a return loss value of -9.524786 dB is well-matched to the transmission line or other source of power and to have good performance. As a result, the majority of the power is being transmitted through the system rather than being reflected to the source. The optimum value is -10 dB, and this figure is near to that. A lower return loss number is preferable since it indicates that less power is being reflected, allowing for more system power transmission. Return loss, however, is only one facet of constructing and optimizing an antenna; in order to obtain the greatest performance for the particular application, other parameters like directivity, gain, and efficiency must be considered as well.



(a)





Figure 4.24: E-field and (b) H-field for circle slot in unit cell using FR-4 material.

In figure 4.24 (a) shows the reflection loss value of -9.5247865 dB and the reflection phase value of -120.93408 degrees in a unit cell antenna for x-band radar are considered to be relatively good values. The low reflection loss value of -9.5247865 dB indicates that the antenna is well-matched to the transmission line and has good performance, and the reflection phase in figure 4.24 (b) value of -115.909 degrees shows that the reflected wave is almost completely out of phase with the incident wave, which is a desirable characteristic in an antenna. These values suggest that the antenna is designed well and has good performance in the x-band frequency range.

**4.2.1.6** Square shape of unit cells using FR4 (lossy)material.



Figure 4.25: The design square of unit cell with circle slot

Figure 4.25 Shown (a) front and (b) perspective view of square shape of unit cells with circle slot using FR-4 material. In figure (c) its is the port 1 view and (d) is the boundaries condition of this unit cell.



Figure 4.26: S-Parameter S11 of unit cell with circle slot using FR-4 materials

Figure 4.26 shows a square unit cell antenna for x-band radar with a return loss value of -9.524786 dB is well-matched to the transmission line or other source of power and to have good performance. As a result, the majority of the power is being transmitted through the system rather than being reflected to the source. The optimum value is -10 dB, and this figure is near to that. A lower return loss number is preferable since it indicates that less power is being reflected, allowing for more system power transmission. Return loss, however, is only one facet of constructing and optimizing an antenna; in order to obtain the greatest performance for the particular application, other parameters like directivity, gain, and efficiency must be considered as well.





(b)

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Figure 4.27: E-field and (b) H-field for circle slot in unit cell using FR-4 material.

In figure 4.27 (a) shows the reflection loss value of -9.5247865 dB and the reflection phase value of -120.93408 degrees in a unit cell antenna for x-band radar are considered to be relatively good values. The low reflection loss value of -9.5247865 dB indicates that the antenna is well-matched to the transmission line and has good performance, and the reflection phase in figure 4.27 (b) value of -115.909 degrees shows that the reflected wave is almost completely out of phase with the incident wave, which is a desirable characteristic in an antenna. These values suggest that the antenna is designed well and has good performance in the x-band frequency range.



Figure 4.28: Voltage standing wave radio (VSWR)circle slot in unit cell using FR-4 material.

A unit-less ratio is commonly used to assess the transmission line's highest voltage to minimum voltage, which is what the value of VSWR 2.0030528 in a unit cell antenna refers to.



(b)

Figure 4.29: It represents the (a) e-field and (b) h-field of the FR4 material.

The simulation's highest value of the e-field at 10 GHz is 242330 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field. Then, it displays 993.828 A/m (b).

**4.2.1.7** Square shape of two element of patch in unit cells with circle slot using FR4 (lossy)material.



Figure 4.30: The design of two element patch square of unit cell with circle slot.

Figure 4.30 Shown (a) front and (b) perspective view of two element of patch for square shape of unit cells with circle slot using FR-4 material. Then, in (c) unit cell with port 1the port and (d) the boundaries condition of two element of patch in unit cell of square shape with square slot using FR-4 material.



Figure 4.31: S-Parameter S11 of two element patch of unit cell with circle slot using FR-4 materials.

For a reflectarray antenna, it is generally desirable to have the S11 parameter value as close to 0 dB as possible, as this would indicate a perfect match between the transmission line and the reflectarray antenna, resulting in minimal power loss and the highest possible efficiency. A value of -9.524786 dB is relatively low and is considered a good value. It indicates that the majority of the power is being transmitted to the reflectarray antenna, rather than reflected back, resulting in minimal power loss and a good match between the transmission line and the reflectarray antenna.





Figure 4.32: Parameter sweep for (a)reflection loss and (b) reflection phase of two element patch of unit cell with circle slot using FR-4 material.

Figure 4.32 shows the graph illustrates the reflection loss, which is the amount of power reflected to the source when a signal is delivered via the antenna (a) -9.534697 dB at 10 GHz. Plotting the reflection loss versus the operating frequency demonstrates how it fluctuates over the tested frequency range. Finding the frequency band with the least reflection loss, which indicates that the antenna is transmitting with the most power, is the usual goal. Next, a graph shows the reflection phase, which is the phase difference between the incident and reflected waves in figure 4.32 (b) the value is -125.32476 deg. When plotted against the operating frequency, it shows how the reflection phase changes over the tested frequency range.



Figure 4.33: Voltage standing wave radio (VSWR) circle slot for two element patch in unit cell using FR-4 material.

The VSWR measures how well an antenna or other RF component works with a transmission line or other power source. It is frequently expressed as a ratio without units and is determined by comparing the transmission line's highest voltage to its lowest voltage. The voltage standing wave radio result in this simulation is 2.0013357.



(b)

Figure 4.34: It represents the (a) e-field and (b) h-field for two elements of patch in unit cell with circle slot using the FR4 material.

The simulation's highest value of the e-field at 10 GHz is 169746 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field. Then, magnitude field, it displays 737.958 A/m in figure 4.34(b).

### 4.2.2 Rogers RT5880 (lossy) material.



**4.2.2.1** Square shape of unit cells using 2 Rogers RT5880 (lossy) material.



(d)

Figure 4.35: The design of square of unit cell using Rogers RT5800 material.
Figure 4.35 Shown (a) front and (b) perspective view of square shape of unit cells using Rogers (lossy) material. Next, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell.

## Calculation for ROGGERS

=2.2

 $f_r = 10GHz$ , Zo = 50ohm



$$= 2.0751$$

$$L_{eff} = \frac{c}{2 \times fo\sqrt{\varepsilon reff}}$$

$$L_{eff} = \frac{3 \times 10^8}{2 \times 10 GHz\sqrt{2.0751}}$$
(4.10)

$$\Delta L = 0.412(h) \frac{(\varepsilon erff + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon erff - 0.258)(\frac{W}{h} + 0.8)}$$
(4.11)



$$Wg = Lg = \frac{3 \times 10^8}{2(10 GHz)}$$

=15mm

$$DL = \frac{Ls}{2} - \frac{Lp}{2}$$

$$DL = \frac{15}{2} - \frac{9.7958}{2}$$

$$= 2.6021 mm$$
(4.14)

Parameters	Theoretical Calculation Value (mm)	Simulation Value (mm)
Patch Height, Hp	0.035	0.035
Substrate Height, Hs	0.5880	0.5880
Patch Width, Wp	11.859	9.36
Patch Length, Lp	9.7958	9.36
Substrate Width, Ws	15	15
Substrate Length, Ls	15	15

Table 4.2: Comparison value of parameters using Rogers RT5880

Table 4.2 shows the parameter comparison between simulation results using Rogers RT5880 and values from theoretical calculations. The theoretical calculation value and the simulation value differ significantly, according to the numbers in the table. Furthermore, the distinction between theoretical and experimental probability is that the former is founded on understanding and mathematics, whilst the latter is founded on observation. When performing this simulation, it is also affected by the sensitivity of human error and numerical error.



Figure 4.36: S11 parameter value of square shape of unit cells using Rogers (lossy) material.

Based on figure 4.36 for reflection loss it shows the value of return loss in 10 GHz is-0.654385 dB in this simulation. The length and width patch that being used in this simulation is 9.36 mm.



Figure 4.37: S11 parameter value of square shape of unit cells using Rogers (lossy) material.

Figure 4.37 shows the S11 parameter value of -0.654385 dB and phase -118.93554 degrees for a reflectarray antenna indicate a good match between the transmission line and the reflectarray antenna, resulting in minimal power loss and relatively high efficiency. The S11 value is very close to 0 dB which is considered an excellent value for the S11 parameter. However, the phase value is not as close to zero as desired, which could affect the antenna's performance. It is important to note that the acceptable S11 value and phase will depend on the specific application and requirements of the system, as well as the operating frequency and the reflectarray antenna design. It's important to check the design requirements and compare the results to them, to ensure that the performance of the antenna is optimal for the specific application.



Figure 4.38: Voltage standing wave radio (VSWR) square shape of unit cells using Rogers (lossy) material







Figure 4.39: It represents the (a) e-field and (b) h-field of square patch of unit cell using Rogers 5880 (lossy) material.

In this simulation's highest value of the e-field at 10 GHz is 97377.7 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field. Then, magnitude field, it displays 364.731 A/m in figure 4.39(b).



## 4.2.2.2 Square shape of unit cells with square slot using Rogers RT5880 (lossy) material



Figure 4.40: the design of square shape of unit cells with slot using roger RT5880 material.



Figure 4.41: Front and prespective view of square shape pf unit cells with slot

Figure 4.41 shown (a0 front and (b) perspective view of square shape of unit cells with slot using Rogers 5880 (lossy) material. Next, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell.





(b)

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Figure 4.42: S11 parameter sweep value of reflection loss and reflection phase square shape of unit cells using Rogers (lossy) material.

Based on this figure 4.42 S11 parameter sweep value of (a) reflection loss and (b) reflection phase square shape of unit cells using Rogers (lossy) material. A unit cell antenna's return loss value of -1.152138 dB is a measurement of the amount of power that is reflected back to the source during radio frequency (RF) signal transmission through the antenna. A negative value means that less power is being reflected to the source; it is commonly measured in dB. Its show the parameter sweep using Rogers's material with different value of return loss in single element of patch with square slot. It is because by using different value of length patch it will show different value of return loss. So, in that simulation the value of return loss was, at 10 GHz for return loss is -1.521dB and the phase value -120.422 deg.



Figure 4.43: Voltage standing wave radio (VSWR) square shape of unit cells with slot using Rogers (lossy) material.



(a)



Figure 4.44 it shows the electric field and magnetic field of this unit cell.

It represents the (a) e-field and (b) h-field of square patch of unit cell with slot using Rogers 5880 (lossy) material. This simulation's highest value of the electric field at 10 GHz is 107609 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field. Then, magnitude field, it displays 885.919 A/m in figure 4.44 (b).

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**4.2.2.3** Square shape of unit cells with circle slot using Rogers RT5880 (lossy) material

Figure 4.45: the design of square shape of unit cells with slot using roger RT5880 material.

Figure 4.45 shown (a) front and (b) perspective view of square shape of unit cells with circle slot using Rogers 5880(lossy) material. Next, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell.



Figure 4.46: S11 parameter of square shape of unit cells with circle slot using Rogers 5880 (lossy) material. At 10 GHZ the value s11 is





Figure 4.47: S11 parameter sweep reflection loss and reflection phase of square shape of unit cells with circle slot using Rogers 5880 (lossy) material

Figure 4.47 S11 parameter sweep (a) reflection loss and (b) reflection phase of square shape of unit cells with circle slot using Rogers 5880 (lossy) material. The S11 parameter value of -1.4284836 dB and phase -101.69819 degrees for a reflectarray antenna indicate a relatively good match between the transmission line and the reflectarray antenna, resulting in minimal power loss and high efficiency. The S11 value is close to 0 dB, which is considered an excellent value for the S11 parameter. However, the phase value is not as close to zero as desired, which could affect the antenna's performance.



Figure 4.48: S11 parameter sweep of VSWR of square shape of unit cells with circle slot

Figure 4.48 S11 parameter sweep of VSWR of square shape of unit cells with circle slot using Rogers 5880 (lossy) material. The value at 10GHz shown 11.81959 for voltage standing wave radio (VSWR) in this simulation.



(b)

Figure 4.49 shows the value of E-field and H-field in simulation using Rogers 5880 (lossy) material.

Based on figure 4.49 this simulation's highest value of the electric field at 10 GHz is 124904 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field. Then, magnitude field, it displays 853.592 A/m in figure 4.49(b).

**4.2.2.4** Square shape of two element of patch in unit cells with square slot using Rogers RT5880 (lossy) material





Figure 4.50 the design of square shape of unit cells with two element patch slots using roger RT5880 material.

Figure 4.50 Shown (a) front and (b)perspective view of two element of patch for square shape of unit cells with slot using Rogers 5880 (lossy) material. Then, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell.



Figure 4.51: S11 parameter of square shape of unit cells with slot using Rogers RT5880 (lossy) material.





Figure 4.52: Parameter sweep for reflection loss and reflection phase of two element patch.

Figure 4.52 Parameter sweep for (a)reflection loss and (b) reflection phase of two element patch of unit cell using Rogers 5880 (lossy) material. In figure 4.52 a reflection loss value of -1.2045998 dB and a reflection phase value of -126.27575 in a unit cell antenna for x-band radar are relatively low values, but not optimal. A reflection loss value of -1.2045998 dB means that a relatively high amount of power is being reflected to the source. This would result in poor performance and reduced efficiency. Similarly, a reflection phase value of -126.27575 degrees indicates that the reflected wave is almost completely out of phase with the incident wave, which is a desirable characteristic in an antenna, but it is not as good as -180 degrees phase shift.

14.44431, -1.2045998, -126.27575



Figure 4.53: S11 parameter sweep of VSWR

Figure 4.53 S11 parameter sweep of VSWR of square shape of unit cells with square slot using Rogers 5880 (lossy) material. The value at 10GHz shown 14.44431 for voltage standing wave radio (VSWR) in this simulation.



(b)



Based on figure 4.54 this simulation's highest value of the electric field at 10 GHz is 76159.3 V/m because it surrounds electrically charged particles and interacts with them to either attract or repel other charged particles in the field. Then, magnitude field, it displays 322.391 A/m in figure 4.54(b).

**4.2.2.5** Square shape of two element of patch in unit cells with circle slot using Rogers RT5880 (lossy) material



Figure 4.55: the design of square shape of unit cells with c two element circle patch slots using roger RT5880 material.

Figure 4.55 Shown (a) front and (b)perspective view of two element of patch for square shape of unit cells with slot using Rogers 5880 (lossy) material. Then, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell.



Figure 4.56: result of S-parameter of two element of patch for square shape of unit cells with circle slot using Rogers RT5880 (Lossy) material.

Figure 4.56 Shown (a) front and (b)perspective view of two element of patch for square shape of unit cells with circle slot using Rogers RT5880 (Lossy) material.







(b)

Figure 4.57: Result of reflection loss and reflection phase of two element of patch for square shape of unit cells with circle slot using Rogers RT5880 (Lossy) material.

The slope value of -1.5271662 dB/GHz for reflection loss and a reflection phase value of -151.66957 degrees in a unit cell antenna made of Rogers RT5880 material for X-band radar at 10GHz are considered to be good values. The slope value of -1.5271662 dB/GHz for reflection loss indicates that the amount of power reflected back to the source is decreasing as the frequency increases, it means that the antenna is well-matched to the transmission line, and it is consistent across the intended frequency range. The reflection phase value of -151.66957 degrees indicates that the phase of the reflected wave is almost completely out of phase with the incident wave which is a desirable characteristic in an antenna. These values suggest that the antenna is performing well, and it is well-matched to the transmission line which in turns results in minimal reflection.



Figure 4.58: simulations of VSWR for two elements of patch in unit cell using Rogers RT 5880 material.

Based on figure 4.58 the value of VSWR 12.811141 in a unit cell antenna made of Rogers RT5880 material for X-band radar at 10GHz is considered to be a high value, indicating a poor match between the antenna and the transmission line. This high value suggests that a significant amount of power is being reflected to the source, resulting in poor performance and reduced efficiency. The goal is to achieve a VSWR value as close to 1 as possible to get the best performance and efficiency in the X-band radar.



(a)



(b)

Figure 4.59: (a) e-field and (b) h field for two element patch of unit cell antenna.

Since electrically charged particles are surrounded by the electric field, which interacts with them to either attract or repel other charged particles in the field, the simulation's electric field at 10 GHz has a maximum value of 107943V/m (based on figure 4.59). The magnitude field in figure 4.51 then shows 425.291A/m (b).

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## 4.2.3 Rogers RT6006 (lossy) material.



Figure 4.60: the design of square shape of unit cells using roger RT6006 material.

Figure 4.60 Shown (a) front and (b) perspective view of square shape of unit cells using Rogers (lossy) material. Next, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell.

## **Calculation of ROGERS RT6006:**

$$\varepsilon r = 6.45$$
,  $f_r = 10GHz$ ,  $c = 3 \times 10^8$ ,  $h = 1.6 mm$ 

$$w \frac{c}{2 \times fr \sqrt{\frac{\varepsilon r + 1}{2}}} \tag{4.15}$$

$$w \frac{3 \times 10^8}{2 \times 10 Ghz \sqrt{\frac{6.45 + 1}{2}}}$$

$$= 0.007772m$$

$$= 7.772mm$$

$$\varepsilon_{reff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2} [1 + 12\frac{h}{w}]^{-\frac{1}{2}}$$

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$$= 10.457$$

$$(4.16)$$

$$L_{eff} = \frac{c}{2 \times fo\sqrt{\varepsilon}reff}$$
$$L_{eff} = \frac{3 \times 10^8}{2 \times 10GHz\sqrt{10.457}}$$

(4.17)

=0.004639m

=4.639mm

$$\Delta L = 0.412(h) \frac{(\varepsilon erff + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon erff - 0.258)(\frac{w}{h} + 0.8)}$$
(4.18)

$$\Delta L = 0.412(1.6) \frac{(4.639 + 0.3)(\frac{7.772}{1.6} + 0.264)}{(4.639 - 0.258)(\frac{7.772}{1.6} + 0.8)}$$

=0.9452 mm

(4.19)

$$L_p = L_{eff} - 2\Delta L$$
  
= 4.639 - 2(0.94527)  
= 2.7485 mm



=6.126mm

Parameters	Theoretical Calculation Value (mm)	Simulation Value (mm)
Patch Height, Hp	0.035	0.035
Substrate Height, Hs	1.600	1.600
Patch Length, Lp	2.7485	4.886
Patch Width, Wp	7.772	4.886
Substrate Width, Ws	15	15
Substrate Length, Ls	15	15
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Table 0.3: Comparison value of parameters using Rogers RT5880

Table 4.3 displays the parameter comparison between simulation results using Rogers RT6006 and values from theoretical calculations. The theoretical calculation value and the simulation value differ significantly, according to the numbers in the table. Furthermore, the distinction between theoretical and experimental probability is that the former is founded on understanding and mathematics, whilst the latter is founded on observation. When performing this simulation, it is also affected by the sensitivity of human error and numerical error.



Figure 4.61: S11 parameter for unit cell using Rogers RT6006

The value of figure 4: using the value of length and width patch 4.886mm and the return loss value in this simulation is -0.738387 dB.



(b)

Figure 4.62: value of S11 parameter sweep for reflection phase and reflection loss.

The values provided for slope reflection loss -0.73838665 dB and reflection phase - 123.05492 degrees for rogers RT6006 material may indicate that the antenna design is wellmatched to the transmission line, and that minimal power is being reflected back to the source, however these values should be evaluated within the context of the specific application, and in comparison to the performance goals and requirements of the antenna



A VSWR (Voltage Standing Wave Ratio) value of 23.540837 for a reflectarray antenna using Rogers RT6006 material10GHz.





(a)

(b)



(c)

(d)

Figure 4.64: the design of square shape of unit cells with slots using roger RT6006 material.

Figure 4.64 Shown (a) front and (b) perspective view of square shape of unit cells with slot using Rogers (lossy) material. Next, (c) is the port 1 that being used in the design and (d) is the boundaries condition of the design of unit cell



Figure 4.65: S11 parameter for unit cell with slot

This value of figure 4: using the value of length and width patch 4.889mm and the return loss value in this simulation is -0.85189952 dB.



Figure 4.66: value of S11 parameter sweep for reflection phase and reflection loss.

Figure 4.66 shows a: value of S11 parameter sweep for (a) reflection phase and (b) reflection loss by using two element patch antenna with slot. The values provided for the slope reflection loss of -0.85189952 dB and the reflection phase of -121.19588 degrees for Rogers RT6006 material may suggest that the antenna design is well-matched to the transmission line and that little power is being reflected back to the source, but these values should be assessed in the context of the particular application and in comparison, to the performance objectives and requirements of the antenna.



Figure 4.67: S11 parameter sweep of VSWR using Rogers RT6006 material.

A VSWR (Voltage Standing Wave Ratio) value of 20.408163 for a reflectarray antenna using Rogers RT6006 material at 10GHz.

اونيۈم سيتي تيڪنيڪل مليسيا ملاك UNIVERSITI TEKNIKAL MALAYSIA MELAKA **4.2.3.1** Square shape of two element of patch in unit cells with square slot using Rogers RT6006 (lossy) material



Figure 4.68: the design of square shape of unit cells with slots using roger RT6006 material.

Figure 4.68 Unit cells with slots in a square form made of Rogers (lossy) material are shown in (a) front and (b) perspective views. Following that, (c) describes the port 1 utilized in the design, and (d) describes the boundary condition used in the design of the unit cell.



Figure 4.69 shows the result that by using the value of length and width patch 4.681mm and the return loss value in this simulation is -0.85358344 dB







Figure 4.70: value of S11 parameter sweep for reflection phase and reflection loss.

In this figure 4.70 S11 parameter sweep for (a) reflection phase and (b) reflection loss of two element of patch with slot. The simulation the values of slope reflection loss -0.85358344 dB and reflection phase -119.34611 degrees for a reflectarray antenna using Rogers RT6006 material are generally indicative of a well-designed antenna. A slope of reflection loss close to 0 dB indicates that the energy is efficiently transmitted, and minimal energy is reflected back, this improves the performance of the antenna as it can provide better directivity, gain, and efficiency. Additionally, a reflection phase of -119.34611 degrees is also within the expected range for a well-designed antenna, it indicates that the energy is being transmitted with minimal phase shift.


Figure 4.71: S11 parameter sweep of VSWR

Based on the figure 4.71, the VSWR (Voltage Standing Wave Ratio) value of 20.367965 for a reflectarray antenna using Rogers RT6006 material at 10GHz.



## 4.2.4 Waveguide







In table 4.4, compare the different between other material it not effecting to much lost of the waveguide value in 10GHz. The reading will be more accurate after putting the unicell together with the waveguide.



Table 4.5: S-Parameters for 1, 5 and 10  $\lambda$ 

Table 4.5 is the result combined for 3 material – Aluminum, Copper, and PEC. This combination will show the different result while running this result.



Table 4.6: unit cell without slot



#### 4.3 Summary

When simulating it with the other 3 material uses, the result in table 4.1 does not indicate a significant difference or cause a lot of lost productivity. In 10GHz, contrast the differences between several materials. It is more accurate to read. A better outcome will be obtained by pairing the waveguide and unit cell. Also, in the x-band frequency range is the unit cell. The size matches the waveguide's intended dimensions.



Figure 0.72: return loss value for two elements of patch unit cell antenna with square slot for each material.

Based on the graph of 3 materials that being used which is FR4, Rogers RT5880 and Rogers RT6006 we can say that the best among the material is Rogers RT5880 because of the return loss at the material was near to '0'. While the FR4 material also can be the good material of this unit cell antenna because of the performance of the material also can be accepted.

Square Shape	FR4	Rogers RT5880	Rogers RT6006
S <sub>11</sub> (return loss)	-4.4128077 dB	-1.2045998 dB	-0.85358dB
Phase	-121.7568°	-126.27575 °	-119.3461°
VSWR	3.4728831V /m	14.44431V/m	20.367965V/m

Table 4.7: The simulation Value of Square shape with slot in each material.

Based on this table the comparison of these three materials will be observe in this table which is the different of return loss in each material and FR4 the value is -4.4128077db, rogers RT5880 is -1.20045998 and lastly Rogers RT 6006 is -08.5358 dB.



Figure 0.73: Return loss of FR4 materials. The figure shows the return loss of FR4 materials by using different shape and with slot .

### 4.3.1 RESULT OF THE FABRICATED

### 4.3.1.1 CORAL DRAW VIEW



From CST software need to convert in coral draw software and color the patch antenna also ground patch into the black color.

# 4.3.1.2 PRINTED ANTENNA DESIGN UNIVERSITI TEKNIKAL MALAYSIA MELAKA



Figure 4.75 : Printed Antenna Design

Antenna design printer found in coral draw on smooth plastic paper.

### 4.3.1.3 UV LASER MARKING



Figure 4.76: UV Laser Marking

Put the FR4 in the UV laser marking to create the blackened antenna design effect. minimizes soot and burrs, prevents surface damage and enables corrosion-resistant marking.



Figure 4.77: PCB Developer Machines in Progress

Put the FR4 that has been marked in the developer machines.

### 4.3.1.5 ETCHING DEVELOPER MACHINES



Figure 4.78: Etching Developer Machines in Progress

FR4 is placed in the etching developer machine to create copper on FR4. The surrounding copper in the non-circuit region will no longer be visible.



Figure 4.79: Photoresist Stripper Machines in Progress

FR4 antenna design is placed in the net found on photoresist stripper machines for the patch line from the green lining to copper lining.

### **4.3.1.7** 4.3.8 PCS CUTTER



Figure 4.80: Cut the FR4 Antenna Based on Used Size After Finish Fabricated





Figure 4.81 : Two element patch of unit cell.

Based on this figure this is the actual size of unit cell that have being fabricated. The actual size of this unit just length 30mm and the width 15mm

### **4.3.1.9** waveguide



Figure 4.82 : Waveguide.

Based on this figure this is the actual size of waveguide that have being fabricated. This reflectarray patch element in waveguide aperture that will be used.

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#### **CHAPTER 5**

#### CONCLUSION

#### 5.1 Conclusion

The dimensions of a patch antenna, such as the length and width of the patch, can have a significant impact on its performance. In general, changing the dimensions of the patch will alter the resonant frequency and bandwidth of the antenna, as well as its gain, directivity, and radiation pattern. If the patch is made longer, the resonant frequency of the antenna will generally shift to lower frequencies, and the bandwidth of the antenna will tend to increase. This can be useful in applications where a wider frequency range needs to be covered. However, increasing the length of the patch can also reduce the gain of the antenna, as more of the incident energy is absorbed by the patch rather than being radiated. If the patch is made wider, the resonant frequency of the antenna will generally shift to higher frequencies, and the bandwidth of the antenna will tend to decrease. This can be useful in applications where a narrow frequency range needs to be covered. However, increasing the width of the antenna, as more of the incident energy is absorbed by the covered. However, increasing the width of the antenna will generally shift to higher frequencies, and the bandwidth of the antenna will tend to decrease. This can be useful in applications where a narrow frequency range needs to be covered. However, increasing the width of the patch can also reduce the gain of the antenna, as more of the incident energy is absorbed by the patch rather than being radiated.

In general, adding slots to a unit cell antenna will tend to decrease its resonant frequency and increase its bandwidth. This is because the slots act as additional resonators, which can resonate at different frequencies and broaden the overall frequency response of the antenna. However, adding too many slots may also decrease the gain of the antenna, as the slots reduce the effective surface area of the patch. The effect of the number of slots on the directivity and radiation pattern of the antenna will depend on the size and shape of the slots, as well as their relative positions within the unit cell. In some cases, adding slots may increase the directivity of the antenna by allowing it to radiate or receive signals more effectively in certain directions. In other cases, the slots may have little effect on the directivity of the antenna. In summary, the number of slots in a unit cell antenna can affect its resonant frequency, bandwidth, gain, directivity, and radiation pattern. The specific effect of the slots will depend on the size and shape of the slots, as well as their relative positions within the unit cell. Next, changing the dimensions of the patch in a patch antenna can have a significant impact on its resonant frequency, bandwidth, gain, directivity, and radiation pattern. Careful consideration of these factors is necessary to optimize the performance of the antenna for a specific application.

#### 5.2 Future Works

Increase the bandwidth: One potential area of improvement for unit cell antennas is to increase their bandwidth, which is the range of frequencies over which the antenna can operate effectively. A wider bandwidth would allow the antenna to detect targets over a larger range of frequencies, improving its performance in radar systems. Improve gain: Another area of improvement for unit cell antennas is to increase their gain, which is a measure of the ability of the antenna to amplify or focus the power of a transmitted or received signal. A higher gain would allow the antenna to detect targets at greater distances, improving its performance in radar systems. Enhance directivity: Another potential improvement for unit cell antennas is to increase their directivity, which is a measure of the antenna's ability to focus the radiation pattern in a specific direction. A more directional antenna would be able to better discriminate between targets in different directions, improving its performance in radar systems. Reduce size and weight: A further area of improvement for unit cell antennas could be to reduce their size and weight, which would make them more suitable for use in portable or remotely deployed radar systems. In summary, there are several ways in which the performance of a unit cell antenna for X-band radar could be improved in the future, including increasing its bandwidth, gain, and directivity, and reducing its size and weight

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