DIELECTRIC RESONATOR ANTENNA WITH REFLECTOR

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
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for the Degree
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(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Nur Jalilah binti Johar

ABSTRACT

Antenna is a vital role in the transmitting and receiving data and signal over unguided media like wireless communication network. In this entire project, the main focus is on dielectric resonator antenna with reflector which invented using low-loss power of dielectric constant substrate. This project is looking into advantages of dielectric resonator antenna compared to the traditional low-gain antenna types such as microstrip patches, monopoles and dipoles. The attractive characteristics of dielectric resonator antenna provide a strong reason for this antenna to go further in communication area as a versatile and high design flexibility antenna. The project required Computer System Tool (CST) Studio Suite for designing and fabricating the antenna architecture. This report consist of an introduction, problem statement, objectives, literature review and methodology used to ensure this project goes well to the end as planned.

ACKNOWLEDGEMENTS

First and for most, praise to Allah the Almighty for his guidance and giving me strength to undergo this 8 months Final Year Project (FYP), which start from January to September 2012. I do not think I would make it this far without Him. Special credit goes to my beloved family and friends for all of their support and motivation.

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LIST OF ABBREVIATIONS

DRA	Dielectric Resonator Antenna
CST	Computer Simulation Technology
MSDRA	Multisegment Dielectric Resonator Antenna
PCB	Printed Circuit Board
IEEE	Institute of Electrical and Electronics Engineering
WLAN	Wireless Local Area Network

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Recently there is been a huge explosion and revolution in wireless communication area. Most of the communication devices required an antenna which can be integrated into small size of equipment. Hence, numbers of researches are come out with a new solution of compact size antenna which capable to radiate at high radiation bandwidth known as dielectric resonator antenna (DRA). In fact, numerous attractive characteristics of DRA such as small size, high radiation efficiency, wide bandwidth and high power capability made this type of antenna is versatile in shape and very useful as a radiator application. Reflector is another device which is corporate with antenna to perform reflection of radiation that comes out from the antenna itself. The purpose of having a reflector is it allows modification of electromagnetic wave from the radiating element. Besides, the usage of reflector in antenna application offers the radiated electromagnetic wave to travel over a great distance.

1.2 Problem Statement

1.2.1 Problem Identification

Nowadays, people are demanding on thin and small size of portable and handy wireless devices. However, it is very challenging for technologists and engineers to invent antenna which can be integrated into those devices with high radiation efficiency, thus fulfill the requirement of wireless consumer. A typical requirements on the antenna design, regardless of the frequency, include low cost, low profile, and in most applications, a large operating bandwidth [1].

For application required wide gain and bandwidth radiation pattern, for example, radar communication, it is not very practical for the antenna to operate alone by itself. Another mechanism should be installed together with the antenna to improve gain and bandwidth of radiated element.

1.2.2 Significance of Project

The aim for this project is to construct dielectric resonator antenna with reflector. For applications needing low antenna profiles, the dielectric resonator antenna can be made very thin, and by using a high dielectric constant, the other dielectric resonator antenna dimensions can be kept small [2]. In addition, most shapes of dielectric resonator antenna can be adjusted while maintaining the same resonant frequency at a constant dielectric material. This is very applicable to implement for handy and portable wireless devices technology.

By applying reflector antenna with dielectric resonator antenna, it provides a highest gain, widest bandwidth, and best angular resolutions at the lowest costs [3]. Reflector antennas commonly used in long distance communication since the capability of this antenna to achieve high gain and bandwidth.

1.3 Objective and Scope of the Project

1.3.1 The Objective of the Project

- To conduct a simulation of dielectric resonator antenna with reflector using Computer Simulation Technology (CST) Studio Suite.
- To design and fabricate a small dimension of dielectric resonator antenna with reflector which produce gain greater than 5dB.
- To evaluate the performance of the designed antenna in term of gain, bandwidth and radiation pattern.

1.3.2 Scope of the Project

This project will begin with some literature review related to dielectric resonator antenna and also theory on reflector antenna. Next step will be simulation design of this type of antenna using CST Studio Suite which later on will be realize in the form of prototype. Further testing will be carried out to produce a small size of antenna with greater efficiency of radiation.

1.4 Relevancy of Project

Since the fast growing technology in modern communication system, it is very relevance for engineers to come out with smaller size of DRA which can be integrated into the handy and portable devices. There are numerous application, especially for wireless consumer, required a compact size of antennas to be integrated into small packages, such as cell phones, laptops or other portable devices [2]. Another important aspect is that the proposed DRA is suitable to operate for various category of wireless application such as 802.11 a/b/g.

1.5 Feasibility of Project

Duration to complete the whole project is two semesters which include areas of simulation, fabrication and testing on the prototype. The aimed of this project is to design a dielectric resonator antenna with reflector that has excellent performance for emerging broadband or ultra wideband system. CST Studio Suite will be used throughout this project to construct the DRA architecture. Next, with the help of GA and lab technician, the design can be fabricated based on required specification. Therefore, it is very clear that this project is able to carry out within the time frame.

CHAPTER 2
LITERATURE REVIEW

2.1 Dielectric Resonator Antenna

Dielectric Resonator Antenna (DRA) is fabricated from low-loss and high relative dielectric constant material of various shapes whose resonant frequencies of predominantly a function of size, shape and material permittivity [4]. This antenna was designed to produce an efficiency DRA using dielectric substrate, to improve some parameters such as bandwidths or gain, or to manufactured compact or low profiles antenna. One of the main advantages of the DRA is its high degree of flexibility and versatility, allowing the designs to suit a wide range of physical or electrical requirements of varied communication applications [5].

2.2 Shapes of Dielectric Resonator Antenna

There are three basic shaped of DRA which are commonly used: hemispherical, cylindrical and rectangular, depending on the desired characteristic of DRA. Each of these shapes has different mode configuration that are used to determine the resonant frequency, radiation Q-factor and radiation pattern of DRA.

2.2.1 Hemispherical DRA

The hemispherical DRA is the basic shape that has been studied earlier. The Figure 1 shows the geometry of hemispherical DRA which can be characterized by a dielectric constant ε_r and a radius of a. This kind of shape is very complex to construct and does not have any degree of freedom in selecting the preferable design parameter.

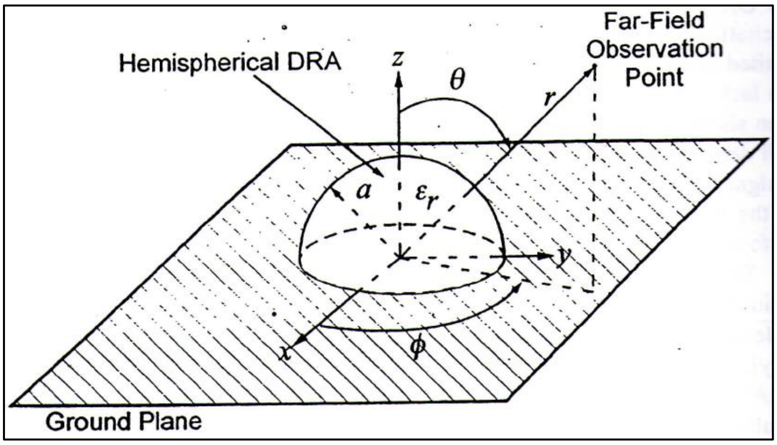


Figure 1 Hemispherical dielectric resonator antenna [5]

2.2.2 Cylindrical DRA

Cylindrical-shaped dielectric resonator has been used efficiently as a circuit application in the design of filter and oscillator due to their high Q-factor and compact size. The finding of cylindrical dielectric resonator radiation properties were first developed by examining the radiation characteristics of a probe-fed cylindrical DRA [5][6]. In Figure 2 below shows the geometry of the cylindrical DRA along with the parameters used to describe the characteristics of this shape.

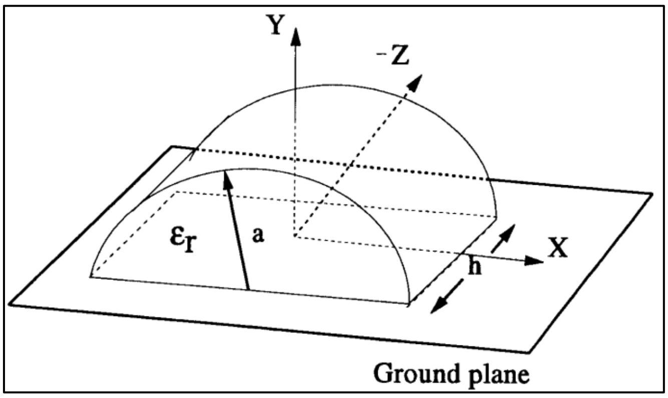


Figure 2 Cylindrical dielectric resonator antenna

For this shape, the resonant frequency and the Q-factor are controlled by the ratio of *radius/height*. Thus, for a given dielectric constant and resonant frequency, different Q-factors can be identified by varying the DRA's sizes. This design flexibility allows the designers to choose the most preferable ratio to perform the desired frequency and bandwidth.

2.2.3 Rectangular DRA

Among of these three basic shapes, rectangular is the most versatile of the shape. The geometry of rectangular DRA is shown in Figure 3. This shape can be characterized by a height *h,* width *w*, depth *d,* and dielectric constant, ε_r.

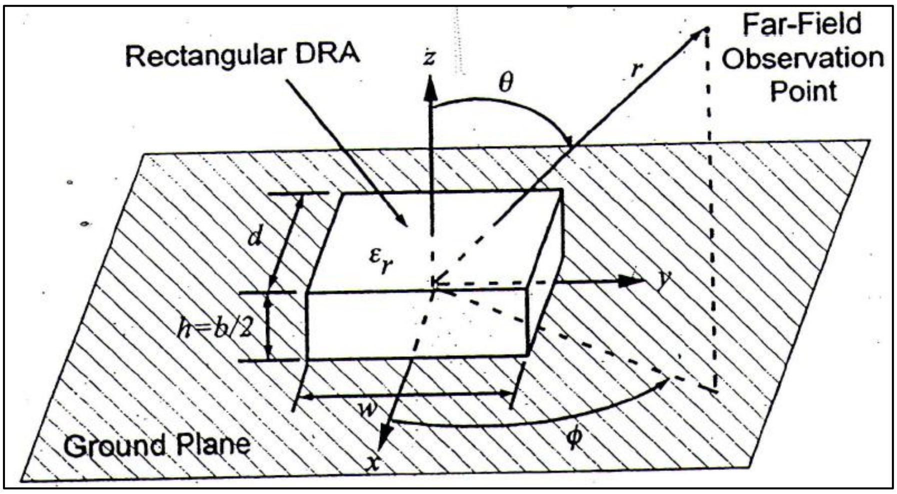


Figure 3 Rectangular dielectric resonator antenna [5]

This shape of DRA offers second degree of freedom more than hemispherical DRA and one more than cylindrical DRA. For a given dielectric constant, the ratios of width/height and width/depth of rectangular DRA are controlling resonant frequency and radiation of Q-factor in order to obtained required specification and bandwidth characteristics. Thus, DRA with rectangular in shape offers a greater design flexibility.

2.3 Dielectric Resonator Antenna Exciting Techniques

The selection of most suitable feeding mechanism play an important role as it will affect the performance of DRA. Usually coupling is required in optimizing the excitation of DRAs. Coupling can be implemented by locating the feed line correctly with respect to the DRA. This, in turn, gives an impact to the radiation characteristics of DRAs and frequency response of the input impedance [5]. Several techniques found to exciting a DRA as discussed below:

2.3.1 *Aperture coupling*

Aperture is one of the convenient coupling technique to excite DRA. In this type of technique, the commonly used aperture is the small rectangular slot [8]. The smallest size of slot used capable to minimize the amount of radiation underneath the ground plane. For the purpose of fed cylindrical DRAs, annular slot can be used [9], whereas circular polarization can be excited by cross-shape or C-shape slots [10]. On the other hand, the aperture can itself be excited by a transmission line or waveguide [11].The feed line is placed below the ground plane to avoid the radiating aperture associate with unwanted coupling. Figure 4 shows aperture shapes and feeding techniques.

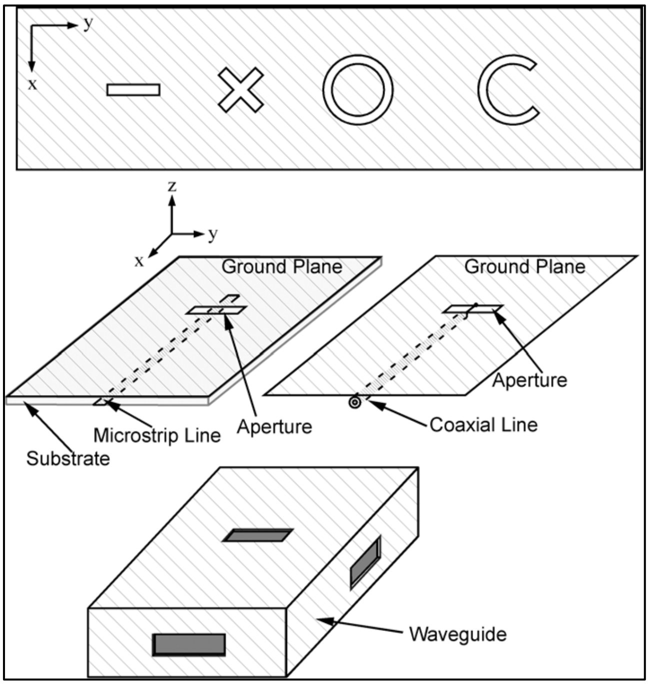


Figure 4 Various slot apertures [5]

2.3.2 *Probe coupling*

DRA also can be fed with a probe, which consists of coaxial line transmission line that bonded to the ground plane. At the center of coaxial line, there is coax center-pin as shown in Figure 5. In other cases, coaxial transmission line can be connected to a flat metallic strip. Assuming the probe having vertical electric source current, it should be located at a region where DRA got high electric fields to yield strong coupling [5]. Besides that, changing the probe height and DRA location also can produce great performance of DRA.

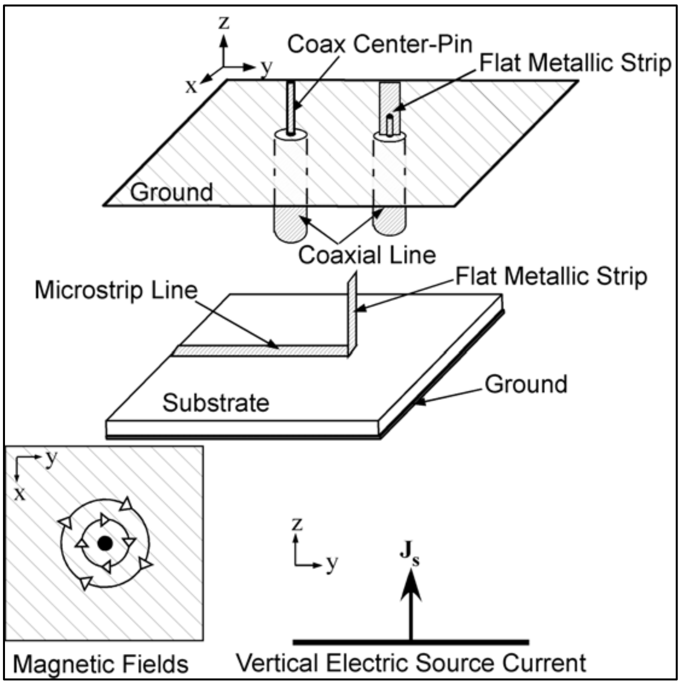


Figure 5 Vertical probe sources [5]

2.3.3 Microstrip Lines Coupling

Another common feeding technique used is coupling DRA with microstrip lines. Figure 6 shows microstrip feeding technique applies to DRA [12]. The value of s as can be seen, related to the amount of microstrip line coupling. For this method, dielectric constant value is quite related to the coupling capability, hence, high value of dielectric constant $\varepsilon_r > 20$ provides strong matching of DRA. Nevertheless, only application with a narrow bandwidth can implement this coupling technique since the radiation Q-factor directly proportional to the dielectric constant.

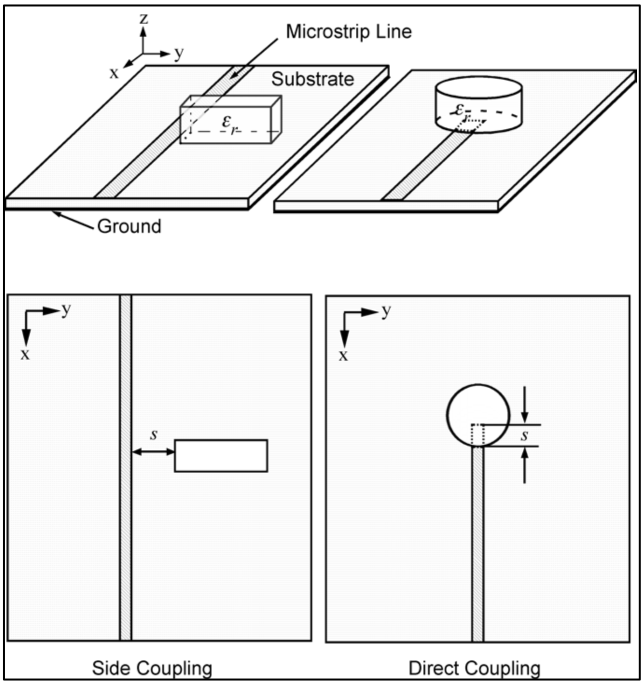
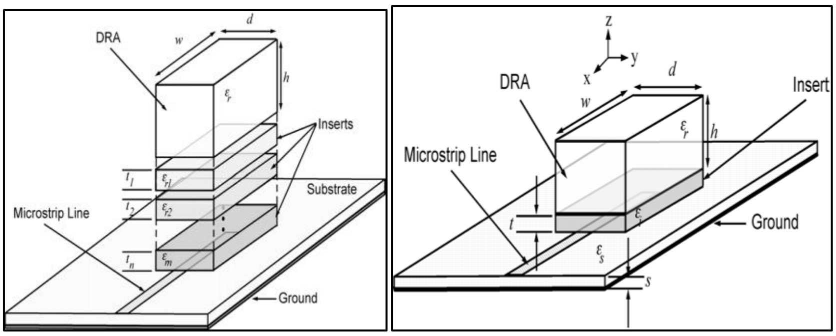


Figure 6 Microstrip coupling to DRAs [5]

2.3.4 The Multisegment DRA

Mutisegment DRA is an alternative way to provide strong coupling with a lower dielectric constant [13]. As shown in the Figure 7 below, the multisegment DRA is layered by multi-level thin segment of different dielectric constant substrates with dielectric resonator antenna attached on top of the layer. Hence, adding the substrates significantly improves coupling performance by transforming the impedance of DRA to the microstrip line and concentrating the field beneath the DRA. However, this technique is spent a lot of money and consumed time. So, designer come out with the simple multisegment with a single insert as shown in Figure 7 (b).



(a) (b)

Figure 7 (a) The multisegment DRA (b) MSDRA with a single insert [5]

2.3.5 Coplanar Coupling

Another method of exciting DRA is coplanar coupling. The example of this technique is illustrated in Figure 8 below. The picture shows three examples of coplanar feeds; open-circuit line, stub-loaded lines and coplanar loops. Open-circuit line can be fed directly to the DRA, while adding stub-loaded lines at the end of the line, the impedance matching of DRA can be adjusted. Whereas, putting DRA over the coplanar loop, allows the coupling level to be controlled. Although the dimension of coplanar feed should be chosen large enough to ensure proper coupling, the small size also should be considered to avoid excessive radiation in the backlobe [5].

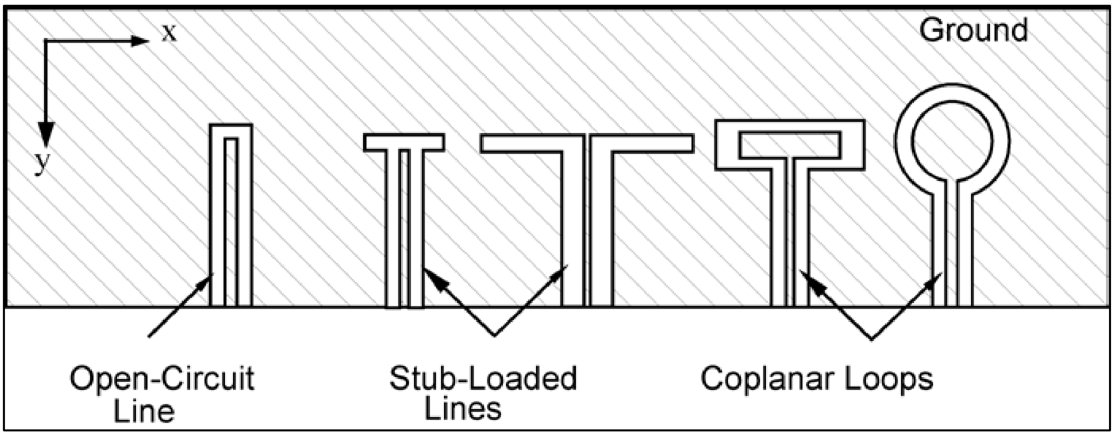


Figure 8 Various coplanar feeds for coupling to DRAs [5]

2.3.6 Dielectric image guides

Last but not least, dielectric image guide is a one of the way to excited DRA. Similar to the microstrip line matching, to obtain strong coupling of DRA, high value of dielectric constant is needed. On the other hand, dielectric image guides provide an advantage over the microstip at millimeter-waves frequency because they do not experience conductor losses in transmission line. As a consequences, this type of feeding technique is the best series feed to a linear array of DRA. The Figure 9 below shows the dielectric image guide feeds.

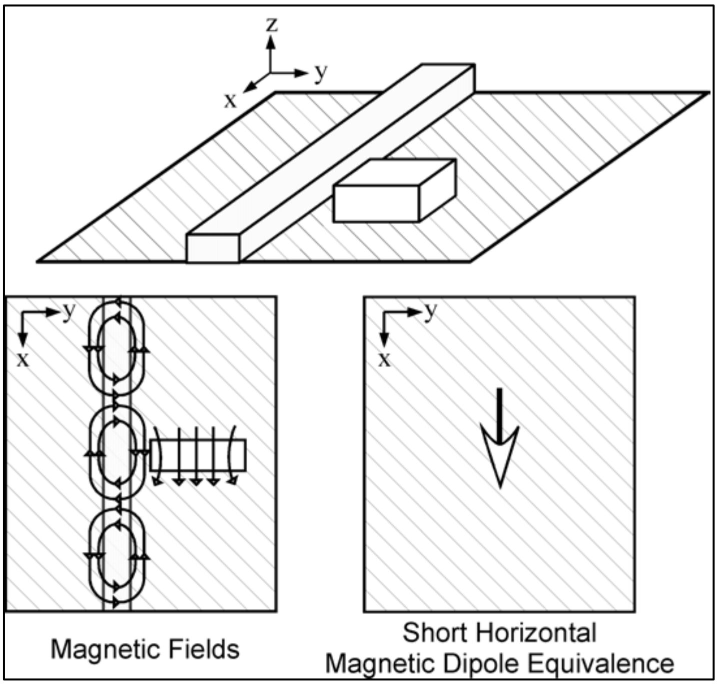


Figure 9 Dielectric image guide feed for DRAs [5]

2.4 Reflector Antenna

Reflector antenna is a device utilizes some sort of reflecting surface to modify the antenna radiation pattern, whether to change or concentrate flux of electromagnetic wave [14]. A typical reflector antenna required feeding mechanism to excite the antenna, thus, will result on obtaining desired radiation pattern. Reflector antenna widely used in high frequency and high gain application [15]. There are four most common types of reflector antenna as follow:

2.4.1 Parabolic Reflector

The most popular reflector is parabolic reflector. Parabolic reflector is able to yield high gain with low side lobes and great cross-polarization characteristics in radiation pattern [16]. This type of reflector produces a minimum beamwidth of radiation pattern called as "pencil beam". Deformation of parabolic reflector is shown in Figure 10.

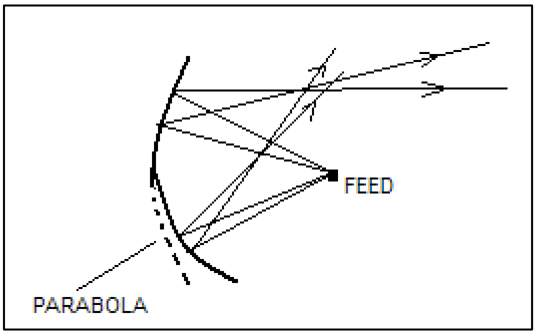


Figure 10 Geometry of parabolic dish antenna [16]

2.4.2 Active Corner reflector Antenna

Another type of reflector antenna is active corner reflector antenna. It consists of two flats surface intersecting to each other with the angle of $a < 180^o$ [17]. A small beamwidth is produced parallel to the x-axis. The Figure 11 represents the geometry of active reflector antenna.

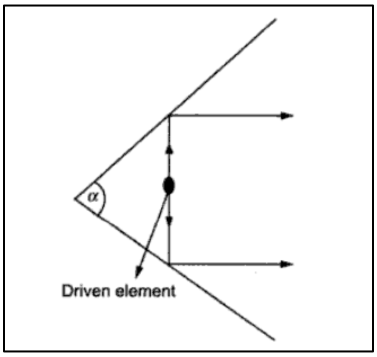


Figure 11 Geometry of active corner reflector antenna [16]

2.4.3 Retro-reflector antenna

Similar to the active corner reflector antenna, retro-reflector antenna also required two flat surfaces to radiate electromagnetic wave. However, those two flat surfaces must be perpendicular and intersecting to each other with constant value of $a, (a = 90^o)$ [18]. Therefore, the driven wave is being reflected back directly towards the source. Figure 12 below shows a retro-reflector antenna.

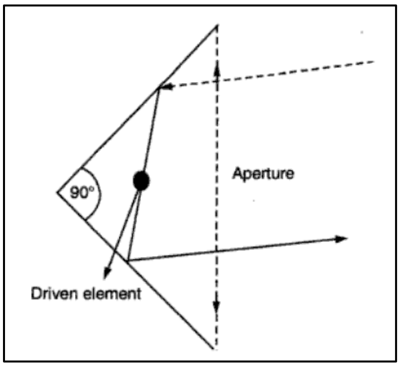


Figure 12 Geometry of retro-reflector antenna [16]

2.4.4 Elliptical Reflector Antenna

An elliptical reflector antenna is shown in the Figure 13. From the figure, it shows that elliptical reflector antenna has two focal points which represent as F_1 and F_2. Feeding structure of antenna is fixed at focus $F_1$and the entire radiated beams passing through focus point, F_2 [18].

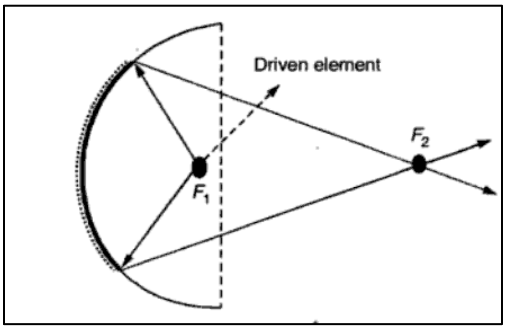


Figure 13 Geometry of elliptical reflector antenna [16]

2.5 Reflector Antenna Exciting Techniques

As mentioned earlier, reflector antenna consists of coupling antenna to optimize performance and reflector surface. The feed antenna can be located on the front of reflector antenna or can be fed from the back, depending on the requirement of radiation pattern [19]. Although several types of reflector antenna feeding techniques are shown in Figure 14 below, only two of them will be discussed more.

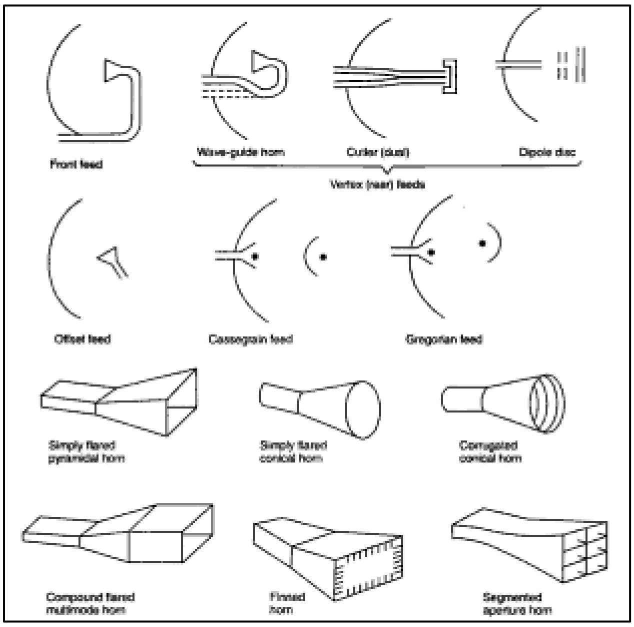


Figure 14 Various types feed for reflector antenna [18]

2.5.1 Cassegrain

One of the well-known feeding technique of a reflector is Cassegrain feed system [20]. In general, the feeding structure of this exciting technique is mounted behind the parabolic reflector surface (main dish) and a convex hyperboloid reflector (sub-reflector dish) is taken place in front of the main dish. A typical feed radiator used is horn antenna. When horn antenna radiates wave towards sub-reflector dish, the main dish receives illuminated that exactly the same from the feeder, then parabolic dish reflects the radiated wave to produce the desired beam [21]. The geometry of Cassegrain feed technique is shown in the Figure 15. In some cases, especially for a small dimension of parabolic dish, some of the radiation from the main dish is blocked by the convex hyperboloid reflector [22].

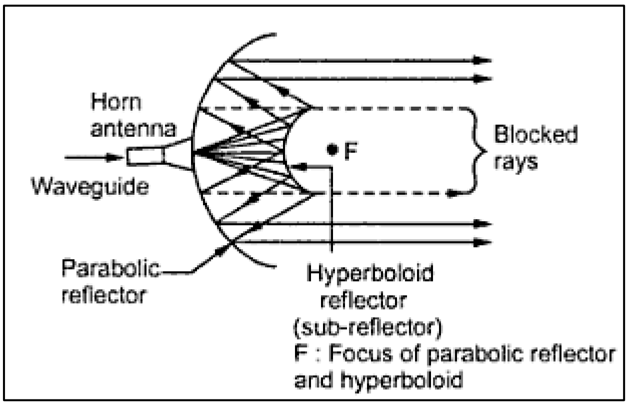


Figure 15 Geometry of Cassegrain feed antenna [18]

2.5.2 Offset

Offset feeding technique offers an advantage over Cassegrain feeding system. Refer to Figure 16 below, the feeder is located in front of the parabolic reflector, hence, the beams radiate properly without any blockage area as in Cassegrain technique [21].

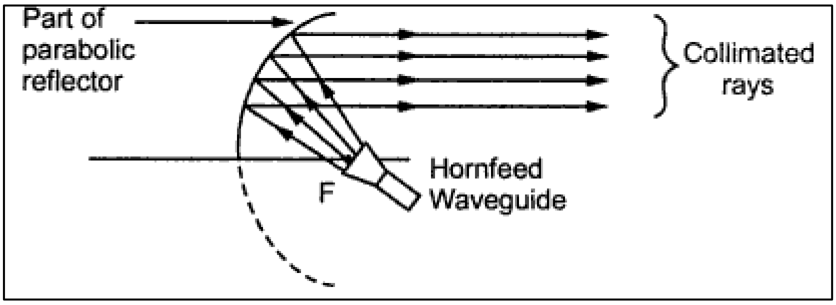


Figure 16 Geometry of Offset feed antenna [18]

CHAPTER 3
METHODOLOGY

3.1 Flow Chart

The following flow chart explains the methodology in executing the project:

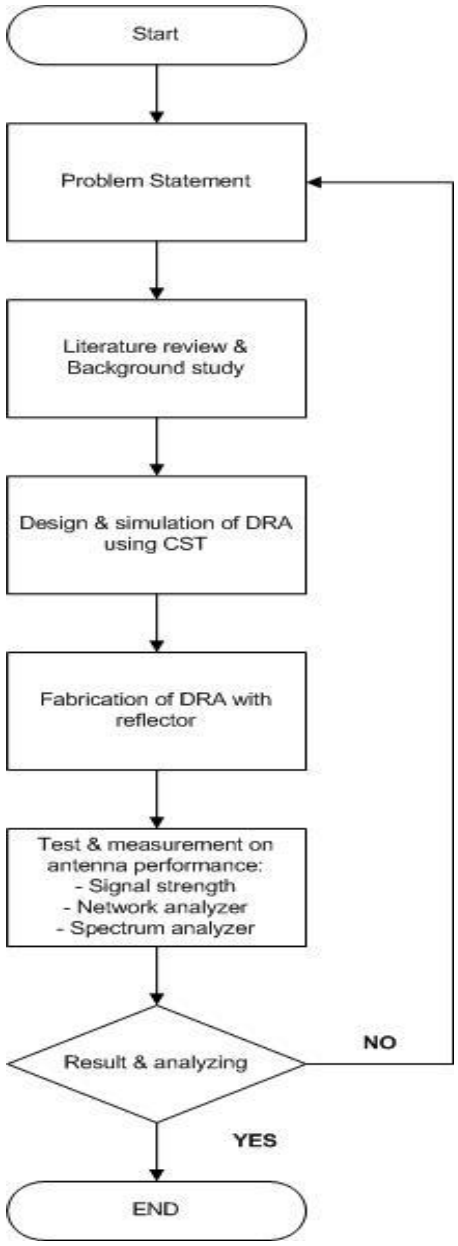


Figure 17 Flow chart

3.1.1 Problem Statement

In the introduction, problem statement is based on dielectric resonator antenna (DRA) is discussed earlier. The aimed is to produce a small size of DRA but high radiation efficiency which can be integrated into small size of devices. Besides, the DRA itself rely on other component to perform high gain and bandwidth over a wide distance.

3.1.2 Literature Review and Background Studies

Then, some researches are conducted on the literature review and background studies about theory of DRA to get familiar with the basic concept of antenna and the effects of the reflectors on the antenna gain and bandwidth. The information from journals, research papers, books and internet is gathered to understand about the topic in detail.

3.1.3 Design and Simulation Using CST

The design and simulation of proposed DRA is constructed using Computer Simulation Technology (CST) Microwave Studio. CST Microwave Studio is software that is popular and widely used in electromagnetic projects. Since CST offers Complete Technology for 3D EM, it has a great flexibility in tackling a wide application range through the variety of available solver technologies [23].

As mentioned earlier, the main focus of this project is to design DRA with reflector. However, at the first stage, the DRA is designed as a single element without reflector structure. In order to design and stimulate antenna devices, one's must be able to master in basic skills of CST such as Geometric Construction Steps, Common Solver Settings, S-Parameter and Farfield Calculation, and also Patch Antenna Array.

After completing on simulation of DRA with reflector, the results for single element DRA and with the existence of reflector are recorded to analyze the performance of the proposed antenna design based on theory understanding. The important data required to be discussed in details which available on CST software are S-Parameter for antenna return loss measurement, farfield of DRA and antenna gain as well.

Here, some details explanation will elaborate more on return loss and farfield.

- Return loss

  Return loss is a ratio measured that compares the power reflected by the antenna to the power that is fed into antenna from the transmission line. The actual value we want to record is transmitted signal which been absorbed by the receiving end. Somehow, there is numbers of signal will be reflected back where the signal will create interference either constructive interference or destructive interference that can cause mismatch. Hence, it is important to measure the return loss in order to determine the exact value of signal received at the receiver end. The S-Parameter graph will be used to calculate the magnitude of loss signal in dB while x-axis shows the frequency when the highest magnitude of loss signal occurred. For the best result of S-Parameter, the magnitude of loss signal should be less than -10dB.

- Farfield

  Farfield is a way of expressing signal scattered before the signal totally disappears to the open space. It illustrates the region where the signal radiation creates uniform pattern at uniform distance from the antenna. The proposed DRA is a directional antenna. Therefore, the front side of antenna has the strongest signal because it capable to concentrate energy when transmitting as well as receiving signal. However, the back side of DRA has weaker signal as direction is opposite of the DRA directivity. Later in the discussion section will shows more on the result of simulation proposed DRA.

The simulation is conducted to record the available data such as S-Parameter for the antenna return loss, farfield of the DRA and as well as the antenna gain. The S-parameters and the farfield of the designed antenna can be calculated using transient and frequency domain solvers. The transient simulation uses a hexahedral mesh whereas the frequency domain calculation is performed with a tetrahedral mesh [23]. For the transient simulation, it is recommended to choose large bandwidth in the range of 20% up to 100%.

The simulation is important to be executed in designing an antenna so that, measured value and actual value can be compared while testing the constructed design. Simulation result also should be analyzed to get optimum results before proceeds to fabrication process.

3.1.4 Fabrication of Dielectric Resonator Antenna with Reflector

After completing design and simulation works, the fabrication on the real components can be preceded. In order to send the proposed DRA for fabrication, the design from CST file must be converted to Gerber file. After converting the specific design, the simple way to view the new file format is 'Online Gerber Viewer' as shown in the Figure 18 below.

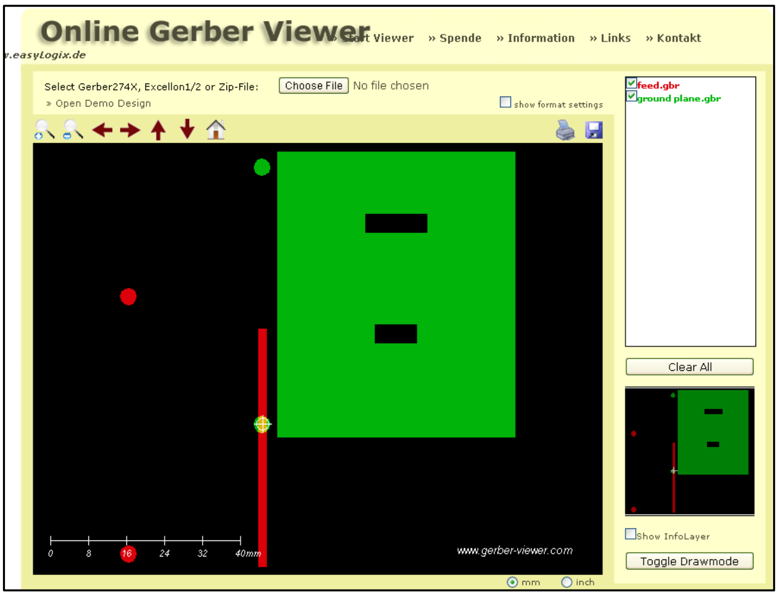


Figure 18 Online Gerber Viewer interface

The specific type and dimension of material such as Printed Circuit Board (PCB) are identified and measured prudently. In fabricating the components, the process must be done accordingly to avoid any error that might affect the performance of the DRA. Therefore, observation and evaluation should be conducted regularly to ensure high performance and high quality of DRA with reflector is produced.

3.1.5 Test and Measurement

The final step is testing and measurement on the fabricated design. This is the most important part to determine the potential of DRA with reflector in the wireless communication area. The purpose of testing the components is to compare the result value of simulation and measurement. If the result shows large value of error, it means some improvements need to be done to obtain high performance and high quality of DRA. The performance of DRA can be analyzed based on signal strength, network analyzer and spectrum analyzer. All of the results and data must be recorded for further discussion and explanation.

Here, some details explanation on tools required in test and measurement process.

- Transceiver

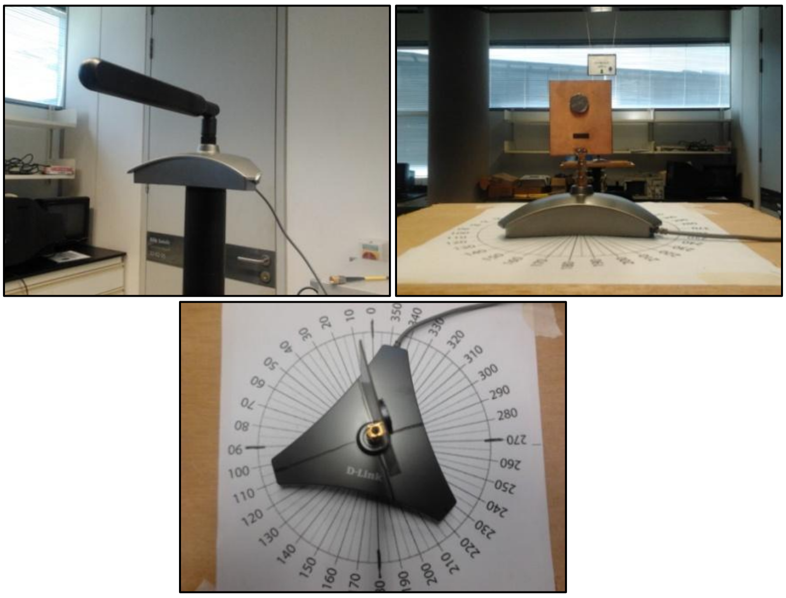


Figure 19 Transmitter and receiver antenna

Transceiver is a device used to transmit or receive the signal. It has the ability to produce differential reception capability from the controller and differential transmission the network. During the test and measurement process, specific 2.4GHz antenna is used to transmit the signal and fabricated DRA is chose to be the receiver. Meanwhile, the fabricated DRA is placed on the positioning paper for the purpose of controlling the position of DRA [24]. The overview is shown in the Figure 19.

- Network Analyzer

Figure 20 Network Analyzer

Network analyzer is an Agilent instrument that measure S-parameter of electrical network. This instrument is provided in CommLab at Academic Building block 22 to measure S-parameter and return loss of fabricated antenna. Network analyzer is often used at higher frequencies, which operate at the range from 9kHz up to 110GHz. Based on the objective of this project to design DRA which can operate at 2.4GHz and 5GHz, this equipment is suitable for testing and measuring the fabricated DRA. Figure 20 is the overview of Network Analyzer.

- Spectrum Analyzer

Figure 21 Spectrum Analyzer

Spectrum analyzer as shown in the Figure 21 is another instrument to measure the magnitude power of spectrum signal in dBm. Similar to the Network Analyzer, this equipment has two axis; magnitude on the vertical axis and frequency displayed on horizontal axis and. The radiation pattern for E-field and H-field of fabricated antenna is determined based on the magnitude power displayed on the monitor. In order to determine radiation pattern of the fabricated antenna in every angle, the DRA is placed on a flat surface area and the transmitted power of the DRA for every 5^o, starting from 0^o to 360^o is recorded and plotted in the formulated spreadsheet.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Dielectric Resonator Antenna without Reflector

4.1.1 Antenna Structure

The antenna structure without reflector is illustrated in Figure 22 below. The antenna is printed on FR-4 lossy material board as substrate, which has a dielectric constant (ε_r) of 4.45, dielectric loss tangent (tanδ) 0.025 and thickness of 1.6mm. The feeder is made from copper, which designed to have 50mm length, 1.8mm width and thickness is 0.05mm.

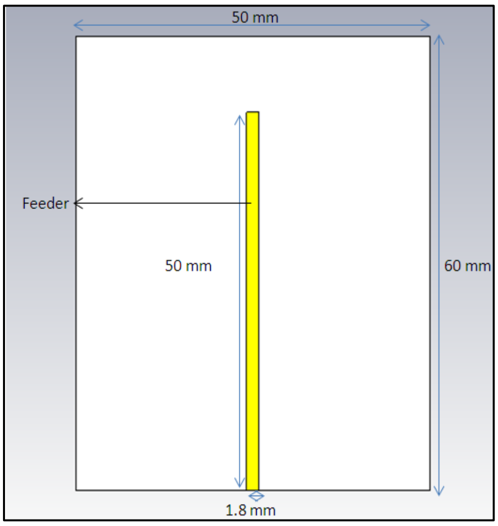


Figure 22 Front view of DRA

On the other side of FR-4 material, 0.05mm height of copper is covering the ground plane with 60mm length and 50mm width of the antenna structure. Two different rectangular slots are cut off from the ground plane; slot 1 is placed 19.8mm from the top with length and width is designed to be 9mm and 4mm respectively, meanwhile the position of slot 2 is approximately 12.3mm from bottom with length and width is designed to be 13mm and 4mm respectively. The parameter is illustrated in Figure 23 below.

In this project, the chosen technique to excite the cylindrical DRA is aperture slots in the ground plane. The benefit of applying aperture coupling as it can prevent the radiating apertures from any unwanted coupling or spurious radiation from the feed [Aperture coupling]. Size of slot must be kept as small as possible to reduce the amount of radiation beneath the ground plane. Moreover, the position of slot is designed to be at the center of cylindrical DRA to achieve strong coupling [27].

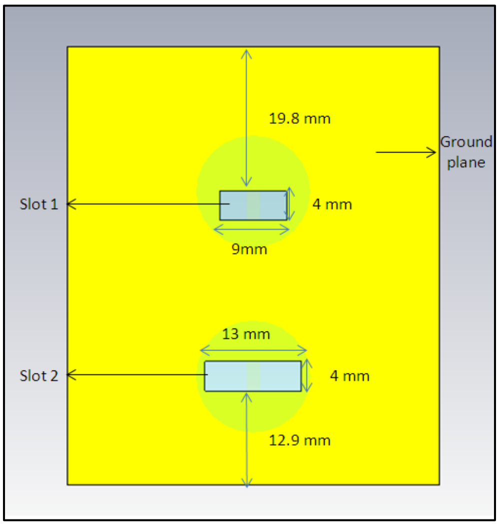


Figure 23 Ground plane of DRA

Two identical cylindrical DRA is mounted on the ground plane covering both slots is shown in the Figure 24. The material for both CDRA is CCTO ($CaCu_3Ti_4O_{12}$) which has dielectric constant (ε_r) of 55. The diameter of DRA is chosen to be 15.3mm with 2mm height. CDRA 1 is placed 12.18mm from the top while the position of CDRA 2 is 7.21mm from the bottom.

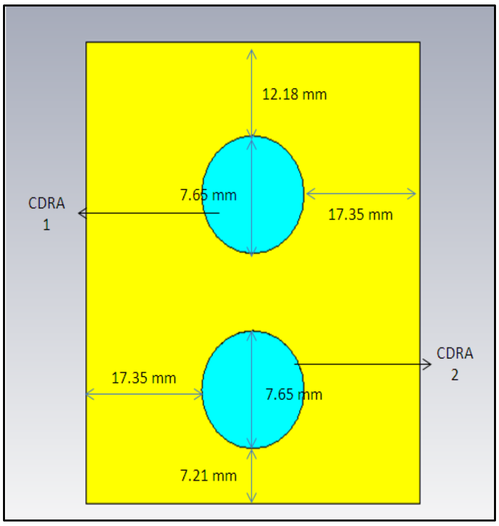
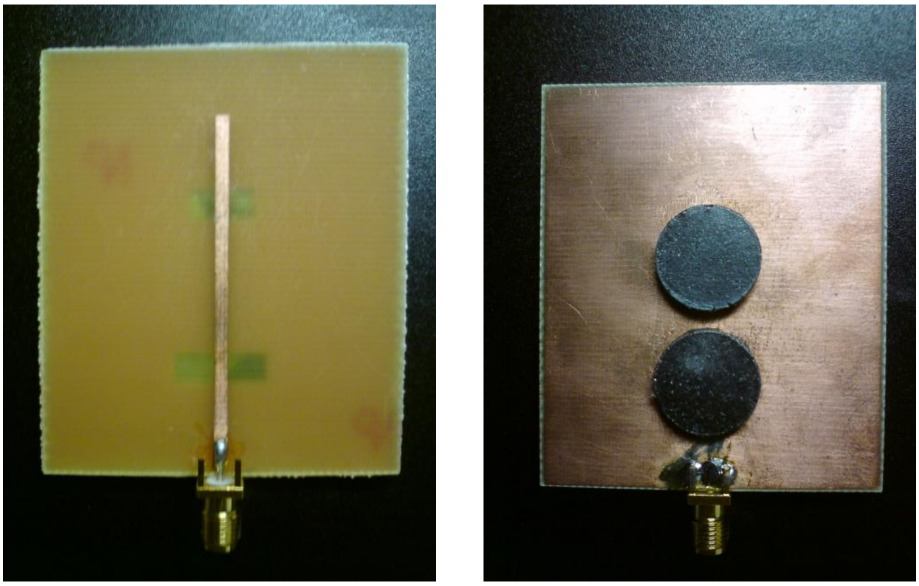


Figure 24 Two CDRA covering slots

The geometry of fabricated DRA without reflector is shown in the Figure 25. The design of proposed antenna was sent to the PCB lab to be printed out. It takes approximately three weeks to complete the fabrication process and completely done by respective lab technician.



(a) (b)

Figure 25 Geometry of fabricated DRA structure (a) Feed network (b) Ground plane

4.1.2 Results for Dielectric Resonator Antenna without Reflector

First, the comparison of the simulation and experimental results are evaluated for the CDRA without reflector. The S-11 parameter is measured using Network Analyzer which provided in the Communication Laboratory. The simulated and fabricated return losses vs. frequency are shown in the Figure 26 below. The antenna mainly resonates at 5 GHz frequency bands which covering 5.2GHz to 5.8GHz. Based on the S-11 Parameter graph, the fabricated antenna produce broader bandwidth approximately 600MHz while in the simulation produce only 390MHz bandwidth. Minimum return loss value is -23.4628 dB at frequency 5.47 GHz.

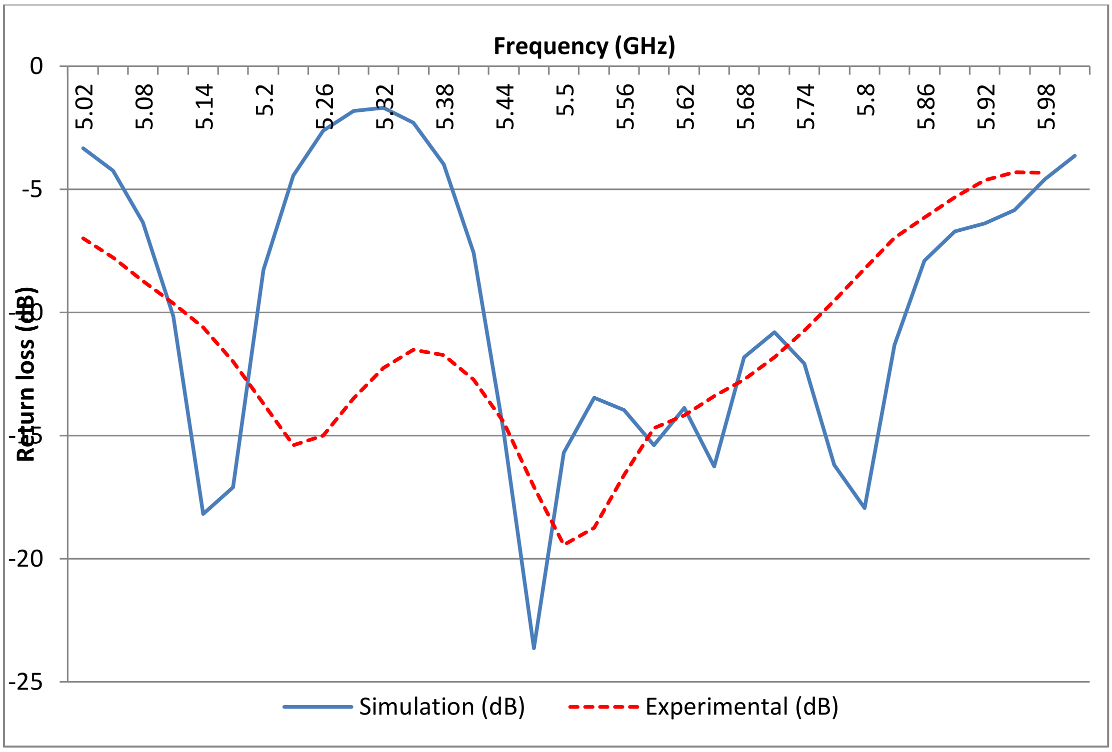


Figure 26 S11 Parameter for DRA without Reflector

DRA without reflector 3D farfield are shown in the Figure 27. This result is captured from the CST Microwave Studio Suite. It shows that, region with red in color have stronger signal strength which is the gain is up to 5.98 dBi.

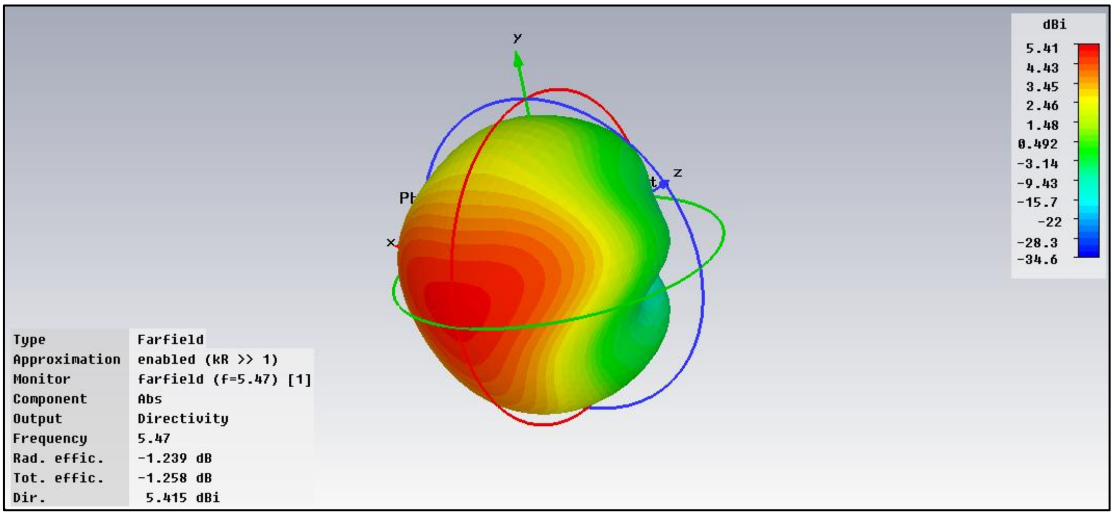


Figure 27 3D farfield of DRA without reflector

The e-field is illustration of radiation pattern in x-z plane. Figure 28 shows the e-field radiation pattern in polar view for antenna without reflector. The main lobe magnitude is 5.4 dBi with angular width 99.7^{o}. The side lobe level for this creature is -13.3 dB.

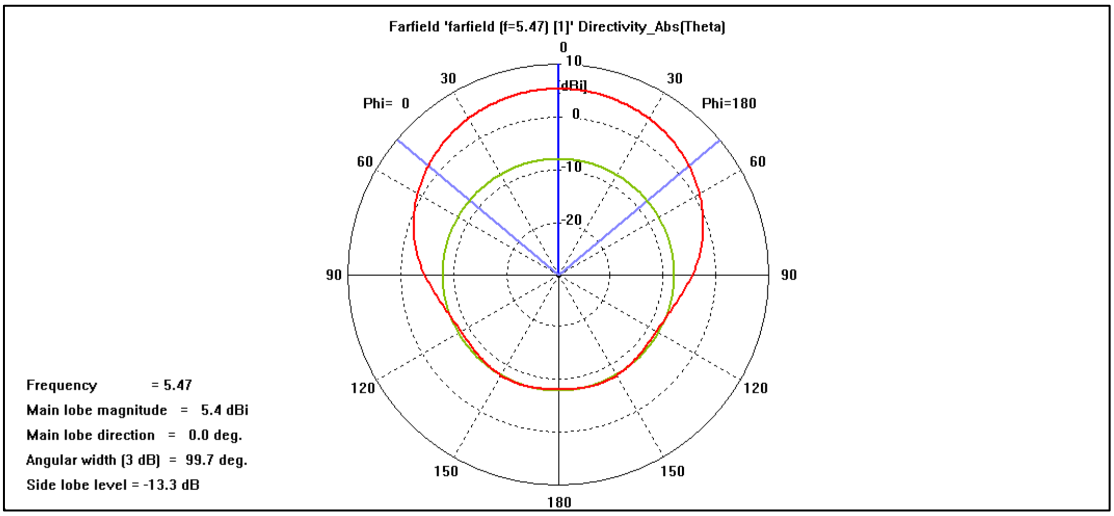


Figure 28 E-field Radiation Pattern of DRA without Reflector

In order to have a view of h-field radiation pattern, the radiation can be captured in y-z plane. As shown in the Figure 29, h-field radiation pattern in polar view of DRA without reflector covered 123.0^{o} at gain 6.0 dBi.

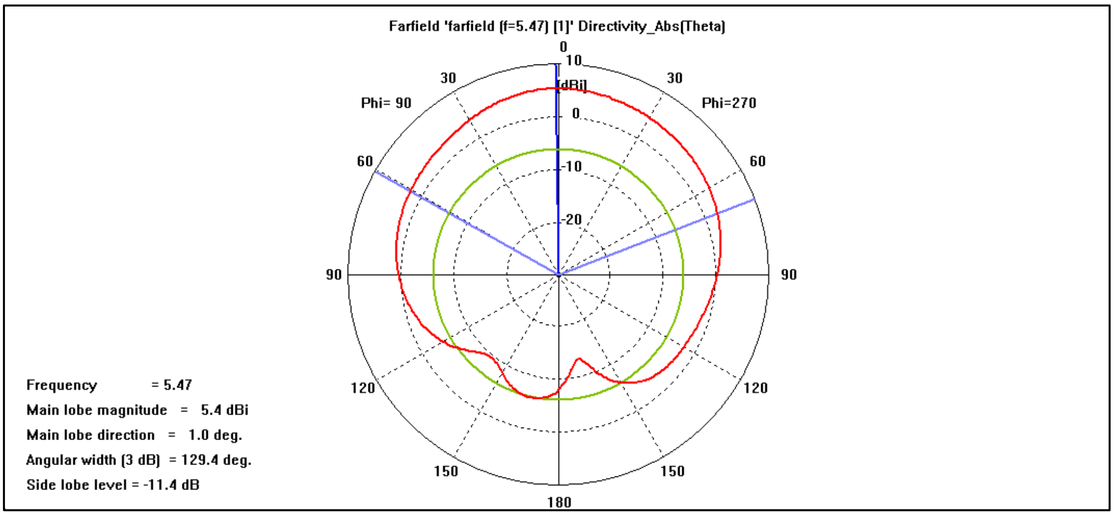


Figure 29 H-field Radiation Pattern of DRA without Reflector

4.2 Dielectric Resonator Antenna with Reflector

4.2.1 Antenna Structure

In order to minimize backward radiation, reflector is placed at the backside of DRA [28]. The reflector consists of copper material in the front while FR-4 board is at the back side. The thickness of copper is 0.05mm and the thickness of FR-4 is 1.6mm. In [28] stated that the larger air gap between both two structure, it may reduce antenna gain. Besides, the length of reflector may affect the backward radiation of antenna. In addition, to obtain the finest bandwidth, the width must be wide enough but no too much [29]. Hence, the reflector size is chosen to be 78.15mm length and 84.55mm width as illustrated in the Figure 30.

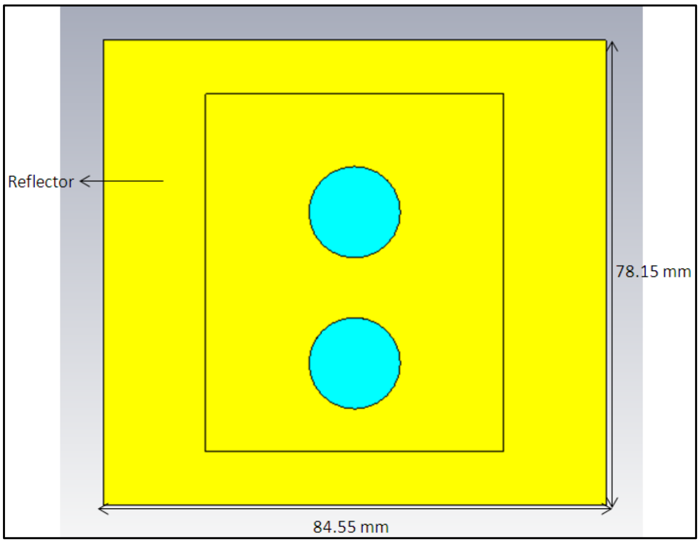


Figure 30 Dimension of reflector

To evaluate the performance of reflector, the reflector is placed at three different positions from the CDRA structure. The results are investigated based on bandwidth, return loss and also radiation pattern recorded from simulation in CST. The position of reflector is illustrated in the Figure 31 below. Moreover, the geometry of fabricated DRA with reflector at 3mm spacing gap is shown in the Figure 32.

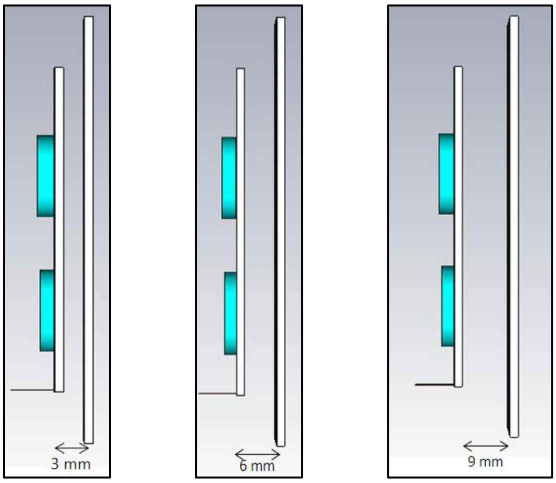


Figure 31 Position of reflector structure

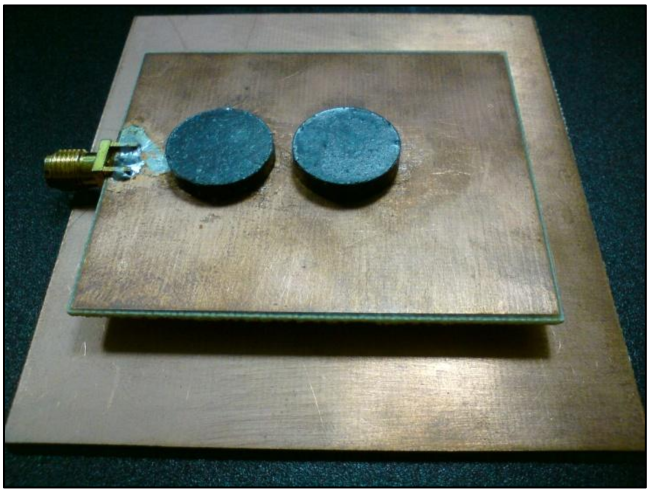


Figure 32 Geometry of fabricated CDRAs with reflector

4.2.2 Results for DRA with Reflector

Second, the comparison between simulation and experimental results are evaluated for CDRAs with three different position of reflector also. Similar technique and equipment are applied to measure return loss, resonant frequency and radiation pattern of CDRAs with reflector.

Figure 33 shows the characteristics behavior of DRA when placing reflector at 3 mm based on S11 parameter. After adding new structure of reflector in the CST, the antenna produces 420 MHz with return loss value as lower as -24.72252 dB operating at resonant frequency 5.474 GHz. However, from measurement of fabricated antenna, the bandwidth is recorded to be 630 MHz with minimum return loss value is -17.6875 dB operating at frequency 5.5 GHz.

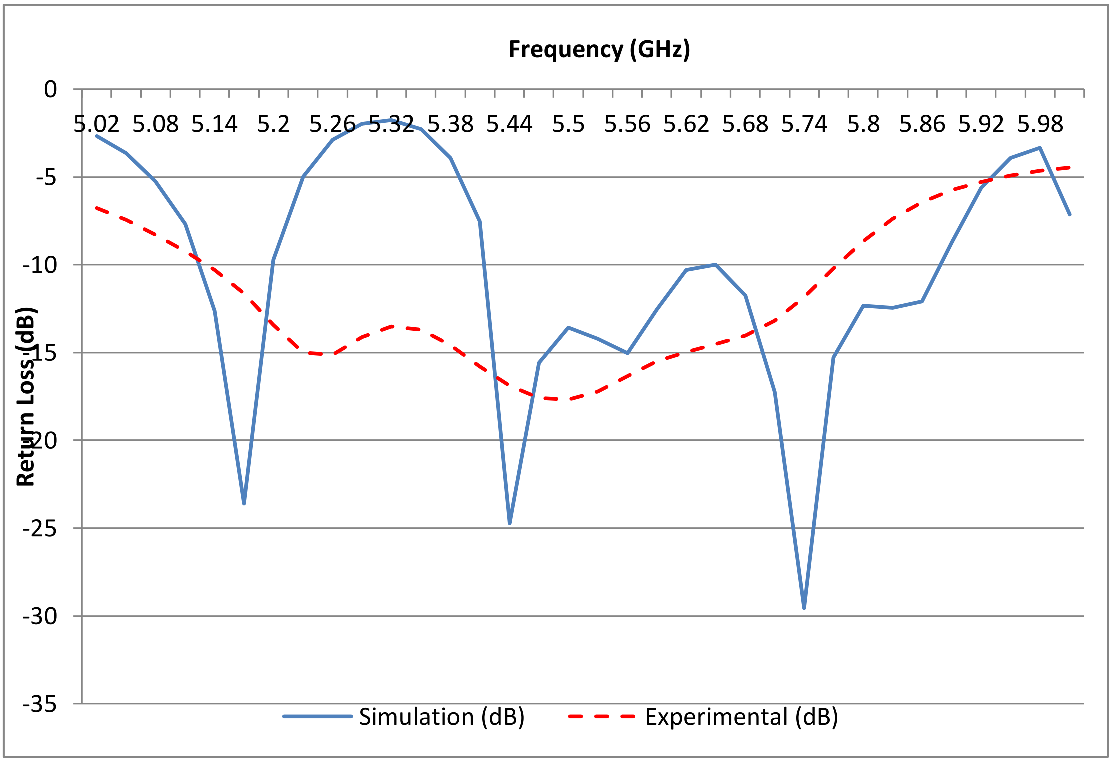


Figure 33 S11 Parameter for 3mm reflector away from CDRAs

S11 parameter of three different position of reflector is plotted and shown in the Figure 34. Curve line in the red color shows the result for spacing gap at 3mm. The bandwidth produce is approximately 420 MHz with return loss value is -33.088 dB at resonant frequency 5.76 GHz. At 6mm spacing gap, return loss value is -27.405 dB at resonant frequency 5.75 GHz. As the value of return loss inversely proportional to the spacing gap, the larger distance of spacing gap produces -21.72 dB at 5.76 GHz.

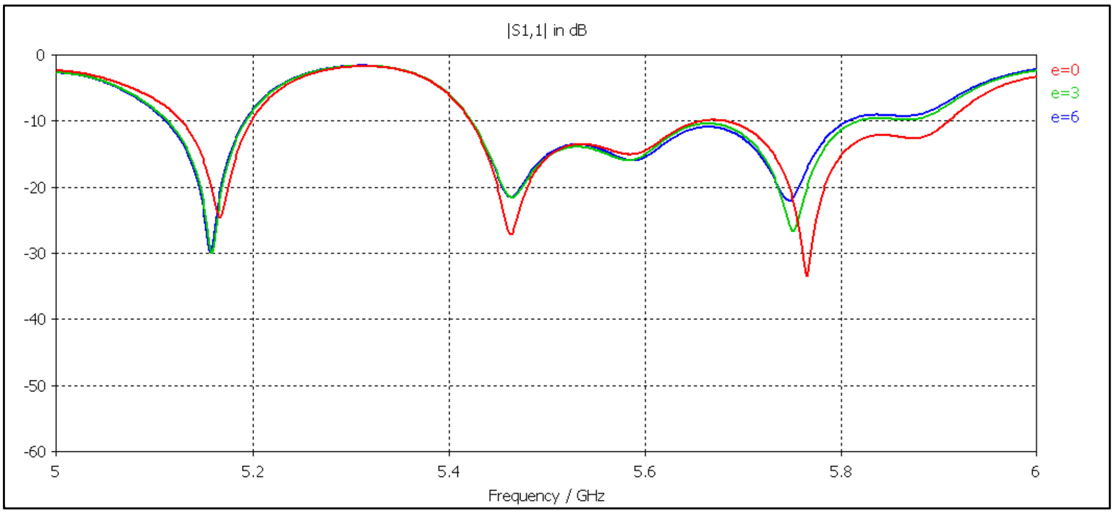
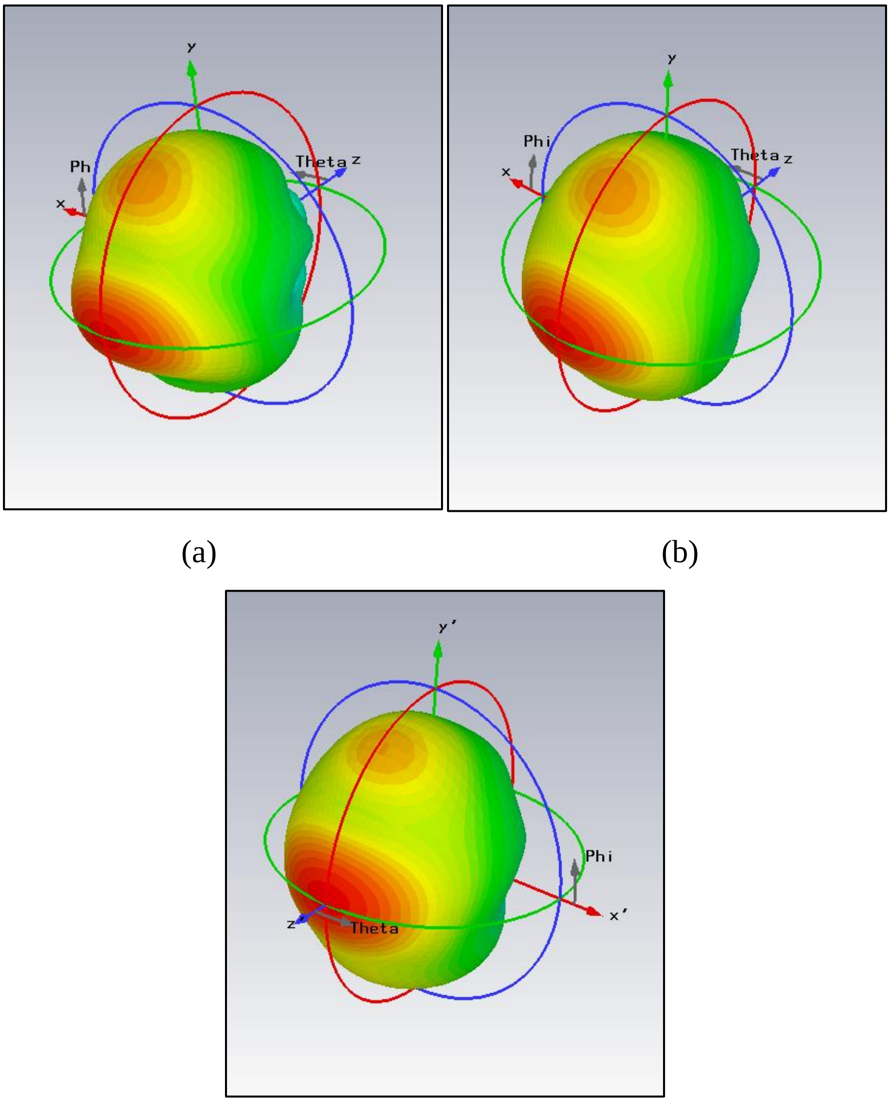


Figure 34 Return loss value at different position of reflector

Result of 3D farfield for DRA with reflector is shown in the Figure 35. When the position of reflector is 3mm away from CDRAs structure, the highest gain produced is 8.65 dBi at frequency 5.47 GHz. Besides, 6mm air gap produces highest gain at frequency 5.47 GHz with magnitude of 7.9 dBi. Meanwhile, adding the reflector 9mm away from CDRAs structure, the highest gain recorded is 7.6 dBi at resonant frequency 5.47 GHz.

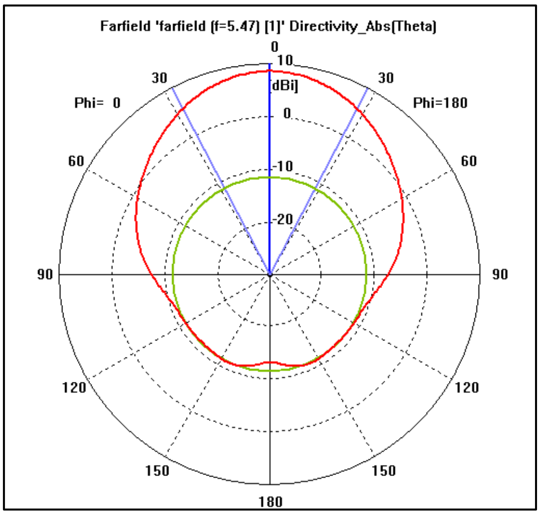


(a) (b)

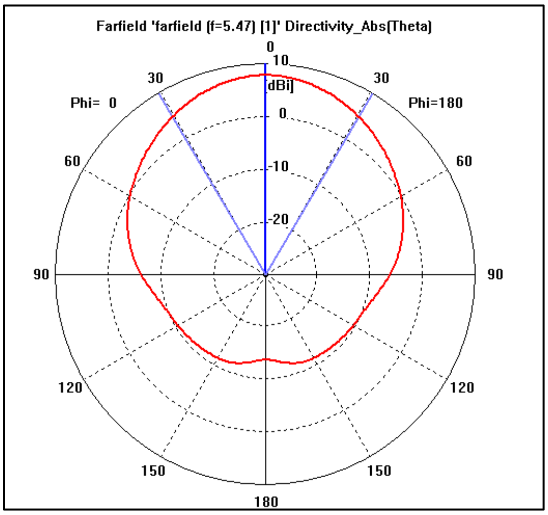
(c)

Figure 35 3D farfield of CDRAs with reflector (a) 3mm (b) 6mm (c) 9mm

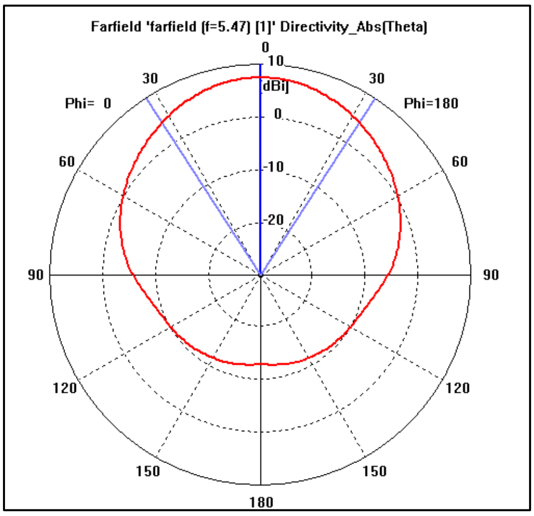
The e-field radiation pattern of DRA with reflector is plotted and illustrated in Figure 36 below. It shows that, adding reflector 3mm at the backside of ground plane produce directivity at 55.7^{o} of angular width and side lobe -20 dB. Meanwhile, 6mm spacing gap between reflector and CDRAs structure produce angular width 61.5^{o}, greater than 3mm spacing gap. The 9mm spacing gap result on 68.5^{o} of angular width which is become less directional.



(a)



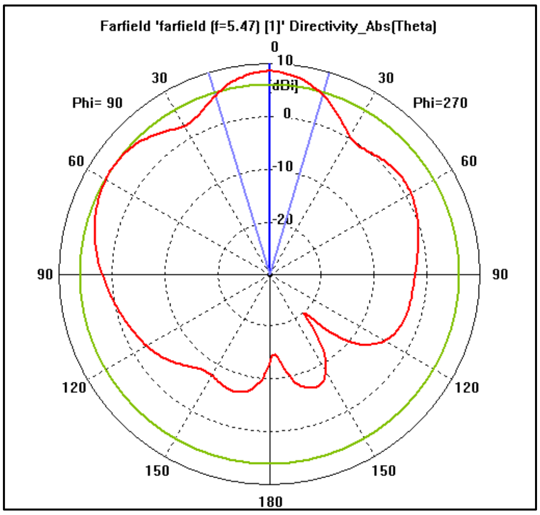
(b)



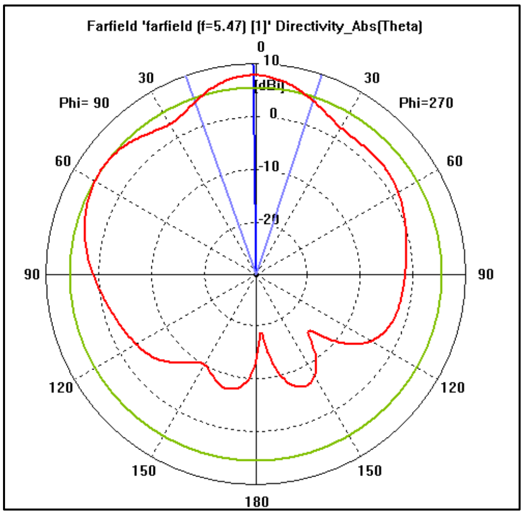
(c)

Figure 36 E-field Radiation CDRAs with reflector (a) 3mm (b) 6mm (c) 9mm

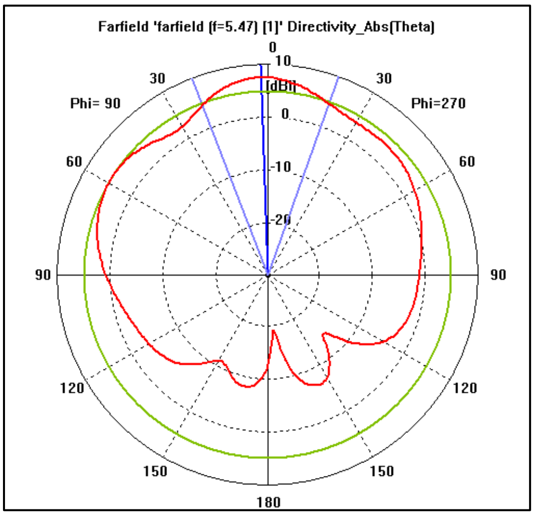
Figure 37 below illustrated h-field radiation pattern of those three different spacing gap between the CDRAs and reflector. The less spacing gap produces angular width of 33.5^{o} with side lobe level -2.4 dB. At 6mm gaps of CDRAs and reflector, the angular width is 37.8^{o} where side lobe level is -2.2 dB. While placing reflector 9mm from the backside of ground plane results on 41.1^{o} and side lobe level is -2.6 dB.



(a)



(b)



(c)

Figure 37 H-field Radiation Pattern of CDRAs with Reflector (a) 3mm (b) 6mm (c) 9mm

4.3 Discussion

In this part, the performance of DRA without reflector as well as affect after adding the reflector will be discussed in details. Besides, behavior and characteristics of antenna is compared in term of bandwidth, return loss value, resonant frequency and gain.

Table 1 Summary of simulation results

	DRA without Reflector	DRA with Reflector		
		3mm	6mm	9mm
Bandwidth (MHz)	390	420	391	380
Return loss (dB)	-23.4628	-33.088	-27.405	-21.72
Frequency (GHz)	5.47	5.47	5.47	5.47
Gain (dBi)	5.41	8.6	7.9	7.6

Simulation result is tabulate in the Table 1 above. From that table, the effect of adding reflector in term of bandwidth, it is increasing approximately 30 Hz of bandwidth of DRA structure only. This bandwidth magnitude is taken from where the -10 dB curve goes down until it rises up at -10dB. The return loss value of CDRAs with reflector also slightly increased compared to structure without reflector. In fact, the return loss value should be as lower as possible to design a good antenna. The highest gain for DRA without reflector is 5.41 dBi which produces at resonant frequency 5.47 GHz. Introducing the reflector structure, although at different position, result on higher gain magnitude. Moreover, it proves that after adding reflector the antenna directivity is increased and become more directional. However, increasing the spacing gap of reflector from the CDRAs structure will turn out on less directional of radiation pattern.

Table 2 Summary on experimental results

	DRA without Reflector	DRA with Reflector
Bandwidth (MHz)	600	630

Return loss (dB)	-19.4379	-17.6875
Frequency (GHZ)	5.5	5.44

The result for experimental is tabulate in the Table 2. The fabricated antenna produces broader bandwidth compared to the simulation. The measured value for bandwidth DRA without reflector is 600 MHz while DRA with reflector produces 630 MHz. On the other side, the return loss value is not as good as simulation results due to interior and exterior factor of fabricated antenna that might give impact on the experimental result. From the measured value, DRA with reflector and without reflector operates at resonance frequency 5.5 GHz and 5.44 GHZ respectively.

CHAPTER 5
CONCLUSSIONS & RECOMMENDATIONS

5.1 Conclusions

As a conclusion, introducing a flat reflector at the back side of ground plane successfully produces gain greater than 5 dBi. Flat reflector is one technique to improve and enhance the performance of CDRAs based on gain and directivity. The simulation and experimental work has validated these antenna characteristics. Somehow, increasing the distance of reflector from CDRAs structure result on less directional of radiated signal and lowering the gain as well. Therefore, the radiation can be efficient by keeping the spacing gap very small. On the contrary, from the observation, there is a lot difference of result in simulation and fabrication. This is happen due to external factor such as mistake while doing the prototype that might affect the performance of antenna and also electrical losses from the antenna structure itself.

In order to be accepted worldwide, the proposed antenna is design to fulfill the requirement of IEEE WLAN standard. This antenna is qualified and compatible for integration with wireless application that operates in range of 5 GHz band frequencies. For instance, 802.11 a/b/g are parts of wireless application category which produced gain greater than 5dBi.

5.2 Recommendation

There are some spaces need to be highlighted for improvement for the future works. A proper room is necessary with ability to absorb the radiating signal to do the measurement setup in order to obtain perfect experimental result. Other than that, an automatic rotational machine can be used to do radiation pattern for fabricated antenna which can rotate the antenna with respect to the respective angle and direction.

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APPENDIX A

GANTT CHART FINAL YEAR PROJECT I

ACTIVITIES	FINAL YEAR PROJECT 1													
	WEEK NO.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research on literature review of DRA with Reflector														
Study on CST software														
Designing DRA with Reflector using CST														
Report writing														

APPENDIX B

GANTT CHART FINAL YEAR PROJECT II

ACTIVITIES	FINAL YEAR PROJECT 2												
	WEEK NO.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Fabrication of the proposed design													
Testing and simulation of the constructed design													
Evaluation and analyze the performance of the constructed design													
Documentation													