# Development of Antenna for Outdoor Wireless Application

## Interim Report

Muhamad Soffi Bin Haroon

13190

Dr. Zuhairi B Hj Baharudin

# ABSTRACT

The project describes a dielectric resonator antenna (DRA) design using cylindrical shape of DRA (CDRA) with microstrip feed technique method. Due to current transmission of data via point-to-point antenna are required for long distance, a high gain antenna is one of the solution to the problem. Therefore, the usage of CDRA may result in low loss compare to other shape such as rectangular. The microstrip shall give offer more freedom in impedance matching which is not available to other excitation modes. The project objectively investigates and designs the antenna (DRA) for WLAN application with a high gain. The antenna design are fabricated and tested for their performance. The design of DRA shall be under scope of frequency at 5.6GHz and gain of 10dBi above. The design simulations are conducted using Computer Simulation Technology (CST) software and tested by Agilent Network Analyzer.

# TABLE OF CONTENT

# ABBREVIATION

| | |
|---|---|
| DR | - Dielectric Resonator |
| DRA | - Dielectric Resonator Antenna |
| CDRA | - Cylindrical Dielectric Resonator Antenna |
| RDRA | - Rectangular Dielectric Resonator Antenna |
| HDRA | - Hemispherical Dielectric Resonator Antenna |
| CST | - Computer Simulation Technology Simulation Software |
| WLAN | - Wireless Local Area Network |
| Agilent NA | - Agilent Network Analyzer |
| EM | - Electromagnetic |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

In communication system, antenna plays important roles to make a data transmission succeed. An antenna provided the user with capability to send data in long range wirelessly in form of electromagnetic (EM) wave at specified frequency [1, 2]. Besides, antenna may also be a receiver. Many applications had been develop from the usage of the antenna such as on mobile phone communication, data transmission for television (TV) and radio, wireless fidelity (Wi-Fi) and etc. For this project, it will be focus on development of antenna for outdoor wireless point-to-point (directional) application by using dielectric resonator antenna (DRA).

Figure 1: Dielectric Resonator in Various Shapes

Currently, the DR antenna design produces a low gain frequency radiation. These gain unable to support wireless communication for long distance purpose. With these disadvantages, there are limitations on the usage of the antenna that required a high gain application. The current technology for time being was focus on the DRA design that could enhance the performance of antenna. There are many designs being proposed to overcome the limitation such as implementation of mutual and aperture coupling for DRA, usage of variation of feed element and variation shape design – *see* Figure 1. This project aim to propose a new design for the antenna that could improve the efficiency and gain of the antenna greater than 10dBi using cylindrical DRA (CDRA) with reflector for IEEE 802.11a wireless local area network (WLAN).

## 1.2 Problem Statement

Recently, due to fast moving development on the communication technology such smartphone, tablet and others data gadget, the demand on stable data communication with high capability on the coverage is keep on increasing day to day. Therefore, vigorous development had being done on antenna field of studies especially on the DRA due to its advantages over other conventional material to fulfill on the demands.

Despite of their advantages, there shall be improvement on DRA as currently, single element of DRA design only capable to produce gain up to 5dBi. Due to this, the antenna is not capable being use to cover long distance point-to-point data transmission that usually required a higher gain greater than 10dBi with higher efficiency. Combination of cylindrical DRA with annular aperture coupled technique and reflector yet to be developed.

## 1.3 Objective

The project will focus objectively on the development of designing and fabricate a prototype of DRA with high gain (>10dBi) at frequency of 5.6GHz. From the design, the project prototype shall be able to test to obtain the desired result and measured the performance of DRA in point-to-point wireless application. The objectives of the project can be summarized as follows;

- To study on antenna design architecture and working principles for WLAN application using CST simulation software.
- To design and fabricate a prototype of antenna with high gain (>10 dBi) at frequency of 5.6GHz.
- To test and measure the antenna performance in wireless application using Agilent Network Analyzer.

## 1.4 Scope of Study

The development of this antenna shall focus on computer simulation technique where the recommendation design will be simulated by using CST software. This scope of study shall be achieving the objective to design to create an antenna with high gain (>10dBi) and efficiency at frequency of 5.6GHz. The design will focus on the usage of CDRA which has high capability in bandwidth and gain. The design also includes usage of reflector as catalyst to enhance the gain of transmit signal.

The simulation design of the antenna should be fabricate according to the design simulation and tested. Agilent Network Analyzer shall be used to analyze the transmit signal during the test. The implementation of the antenna shall be on the directional area where the transmitter antenna will be facing directionally to the receiver. The antenna will be ideal for data sharing or transfer from one point to another point. The testing of the antenna shall be conducted on open area (directional to receiver) where the data is transmit at 5.6GHz frequency and the send data shall be retrieved back at the same frequency.

## 1.5 Relevancy and Feasibility of the Project

The project will be studies regarding the antenna design specification to obtain the required gain with integrating of the usage of antenna reflector to increase the gain to higher. Within time frame of 28 weeks, the project is reliable to complete with the time frame with a proper key milestones.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction on Antenna

In wireless communication, antenna is essential due to its capabilities to radiate or pick up data signal from one point to another point since the first development of antenna on 1901 by Guglielmo Marconi [2]. Basically, the radiated signal was in form of EM wave. In an antenna, there will be EM transducer that will function to convert a data signal (guided wave) into free-space wave for to be transmitted in free space. For receiver antenna, the process is vice versa where the free-space wave shall be converted back into guided wave form [2].

There are varieties of antenna are available in term of their size variation, gain, resonant frequency and other specifications based on their desired function. The project shall focus on the point-to-point (one transmitter antenna communicate with one receiver antenna directionally) transmitter antenna. There are a lot development that had being done recently to improvise the specification and ability of the antenna. One the field of study is regarding designing of the antenna by using DR material or called as Dielectric Resonator Antenna (DRA).

## 2.2 Dielectric Resonator Antenna

DRA is made up of dielectric material with low-loss in term of microwave signal radiation that causes DRA are able to increase the bandwidth and gain of the signal [3, 4]. This property made the antenna become favorable to the researcher to further develop an antenna in order to enhance the communication field since 1960s (at first as a filter) and the first DRA were propose on 1980s by [5, 6]. The DRA also offer other attractive characteristic that acted as added value for further research on DRA. Among the advantages of DRA is it shall offer the antenna with high efficiency and quality factor compare to other material due to its dielectric material property that almost not experienced any surface and conduction wave losses due to the direct contact with the ground plane of the substrate [7]. In term of design, usage of DRA gives freedom to user to design the DRA according to their requirement as the frequency can be varies from 0.7-35GHz with wide range of permeability (ε) [8, 9]. In addition, the properties of the DRA that can be feed by various materials such as microstrip line, coaxial probe, slot and others give good point of view on considering DR as antenna. Among the advantages of are as follows [3-8, 10, 11];

- Low ohmic losses
- Variation of size and shape design
- Good radiation factor
- Variation of dielectric constant ( $\varepsilon_r$ = 6 -100)
- Tolerance on noisy object
- Control over the bandwidth and frequency (0.7 – 35 GHz)
- Variation on excitation modes

The resonant frequency and the dielectric constant can be calculated using the formula as follows [4];

$$f_r = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{2\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{2b}\right)^2} \qquad (1)$$

$$\lambda = \frac{c}{f_r\sqrt{\varepsilon_r}} \qquad (2)$$

Where, $f_r$ = resonant frequency

$c$ = speed of light $(3 \times 10^8)$

$\varepsilon_r$ = dielectric constant

a = radius of dielectric

b = height of dielectric

Compare over other type of antenna such as microstrip patch antenna (MPA), DRA shall give more advantages in gain and bandwidth. According to Petosa et al, DRA offer an improved gain compare to MPA with high performance in bandwidth [12]. In addition, DRA had overcome the limitation on the MPA in term of conductor losses in millimeter-wave frequency and sensitivity to the tolerance in the antenna [13].

## 2.3 Shape of DRA

The DRA are able to be shaped in varies form such as rectangular, hemispherical, cylindrical, tetrahedral and others – *see* Figure 2 & Figure 3 for illustration. The basic shaped only consists of hemispherical, cylindrical and rectangular. Each form these form have their own advantages and the selected design shall be followed the user design specification. From [7, 14], to design a small size shape antenna, the dielectric constant shall be adjust at high that may result in low bandwidth.

For hemispherical shape, there are advantages and disadvantages on using it in design an antenna. For hemispherical, the user shall has advantage on manipulating the radius to obtain the desired efficiency, gain, Q-factor and resonant frequency. But, the user is not able to control the bandwidth of the antenna due to its limitation on the degree of freedom in dimensioning the shape. In addition, hemispherical design is difficult to be fabricated compare to rectangular and cylindrical shape due to it hemispherical property [10].

Cylindrical shape shall offer the user with one more degree dimension to be manipulated compare to hemispherical shape, which is the height. In designing a CDRA, user had control on the ratio of “a” (radius) over “h” (height) to be able to obtained desired frequency and Q-factor. To excite the CDRA, the process should be more easy compare to hemispherical due to its structure was design in a simple mode. The radiation pattern of CDRA is more directional and suitable in designing point-to-point antenna. [8, 10]

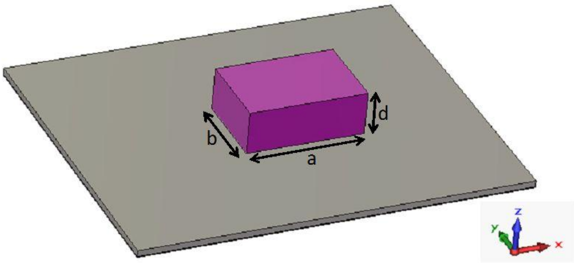


Figure 2: Rectangular DRA Design using CST[15]

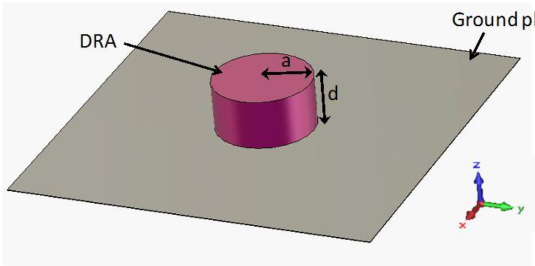


Figure 3: Cylindrical DRA Design using CST[15]

For rectangular shape DRA, the design flexibility is more flexible compare to CDRA and HDRA where the user shall have control on three different dimensions (height, width and length). In term designing, the property of RDRA that can avoid the mode of degeneracy shall give degree more advantage to RDRA as it can enhance the level of the cross-pol and increase the performance of the antenna [14]. Despite of all the advantages, RDRA has a drawback due to its shape nature that made off of many edges that could lead to additional losses [8].

## 2.4 Feed Methods

The DRA shall be stimulated with low voltage in order to make it radiate the frequency and transmit the data signal. In order to feed it, there are varies of exciting modes technique may be applied. Among the modes available are microstrip line feeding, co-planar lines, probe, coaxial, slot, waveguide slot and dielectric image guides where the effective methods are using microstrip and probe [6, 14]. The usage of coaxial line for feed the DRA are not recommended due to its property that unable to sustain for high frequency application [16].

Due to the limitation, most researchers are currently preferred the other method such as microstrip line feed that may overcome problem with high frequency application within millimeter waveband operation range [16]. In addition, the low-profile microstrip lines that come into place since 1970's also give a lot other advantages such as simple fabrication, light and cheaper. Despite of its advantages, microstrip line come with drawback such as low in efficiency, bandwidth and handling capabilities [2].

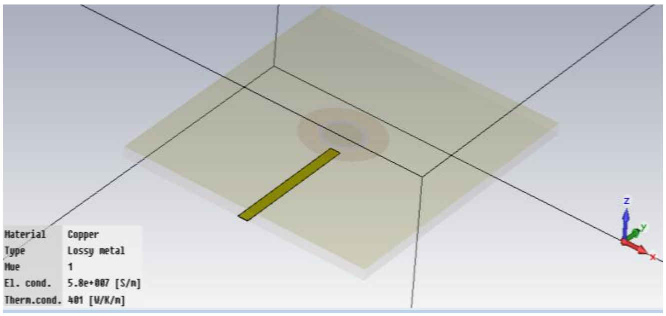

Figure 4: CDRA Design with Microstrip Line using CST

The feed shall be placed on area which the electric field is strong to obtain a strong coupling based on the formula (3) [10].

$$\chi \propto \int_V (E_{DRA} \cdot J_s)\, dV \qquad (3)$$

Where,

| | |
|---|---|
| $\chi$ | = amount of coupling within DRA |
| $E_{DRA}$ | = electric field |
| $J_s$ | = electric source |
| $V$ | = volume occupied by source |

## 2.5 Coupled Methods

The coupled technique such as aperture coupled also may take into consideration due to its significant effects on the result in term of bandwidth and frequency. Aperture technique basically is just an introduction of air gap (vacuum) between the feed and DRA make sure there is no direct contact occur between both surface [17]. The aperture technique may increase the frequency of DRA but this method has a drawback of extra volume consumption and more support needed for the DRA [18]. To overcome this disadvantage, a small area of air gap shall be introduced such as annular shape aperture that have advantage on easy excitation on circularly polarized field [17].

Other than that, the aperture coupled also radiates a large amount of radiation the lead to poor front-to-back radiation pattern but this drawback may be overcome with few improvements. The effective improvements that shall be done are adding on the microstrip antenna element as internal reflector [19]. From [11], mutual coupling shall be taken into consideration due to its significant on impedance frequency.

For an array antenna, the configuration will result in high gain compare to single element [11]. Therefore, there are few design being propose by [9] from their research finding on the effect of DRAs arrangement. The best design was 4-elements linear array that constructed by arranging all 4 DRAs in straight line. While, 4-elements planar array result in low gain compare 4-elements linear array but higher than the 2-element broadside array.

## 2.6 Reflector

One ways on design antenna with high gain by introducing a reflector to reflect and amplified the signal. There are basically a few type of reflector such parabolic reflector, active-corner reflector, retro reflector and elliptical reflector. The parabolic reflector was popular in high gain application such as point-to-point antenna due to good cross-polarization in its radiation pattern [20-22]. For the active corner reflector, the reflector design is varies due to the freedom in manipulating the "α" angle. The "α" may vary less than 180º. While the retro reflector, the  angle shall be at 90º [20, 21]. Elliptical reflector consists of ellipsoidal dish where there are 2 focal points that control the gain of the radiate signal. The first focal locate at the center dish exactly at the source. While the second focal point locate at distance of $2D^2/\lambda$ (D = aperture diameter) [23].

## 2.7 Summary

For the project, the cylindrical DRA (CDRA) will be used in designing an antenna with high gain and efficiency. The usage of CDRA will give an advantage of the low losses due to its smooth edge property compares to rectangular DRA (RDRA). CDRA shall not experience any edge losses (increase the efficiency) compare to RDRA even though RDRA give advantages in term high degree freedom on dimensioning the DRA. Besides, CDRA are more directional and it was an ideal property in term developing a point-to-point antenna.

In term of coupling, aperture technique with annular design shall be used to design the antenna. The annular design will keep the air gap area small in size that makes it able to minimize the radiation spilling between ground plane and any unwanted coupling as there will no continuous ground plane in this technique [10]. For the DRA excitation modes, microstrip lines will be used as feed to the CDRA. Microstrip lines offer more freedom in impedance matching which is not available to other excitation modes such as waveguide. The parabolic reflector shall be using to increase the gain.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Project Methodology

### 3.1.1 Development of Antenna for Outdoor Wireless Application

The project starts on understanding the project background through literature review of the previous development project and other reference that related to the subject. From the literature review finding, the data collection part shall be conducted to obtain required data and tools that needed. The data shall be collected based on the design requirement to produce DRA antenna with high gain and efficiency at 5.6GHz. The data shall be cover on the selected shape of DRA, formulation on the dimension, bandwidth and frequency, coupling method, feed method and reflector type.

The design study on the simulation software should be performed during on the next stages. Simulation shall be done by using CST simulation software. The CST design shall be developed based on the result of literature review and data collection. The dimension of the antenna is design in CST to obtain the theoretical result before the fabrication process taking places. The detail on CST design will be explained on the next section.

The theoretical design from the CST simulation shall be sent for fabrication process on printed circuit board (PCB) and DRA dimension. On the fabrication part, the DRA will be fabricated according to design before being tested. The testing shall be conducted to obtain the actual result on the resonant frequency, return loss $S_{11}$ and bandwidth before being finalize. Agilent NA is used on this process. Unsuccessful result shall be redesign. The illustration on this methodology process is explained in flow chart as on Figure 5: Flow Chart on Development of Antenna for Outdoor Wireless Application.

### 3.1.2 CST Design Simulation

Figure 6 shows the flow chart on CST design simulation architecture. The design shall be start on the choosing the desired shape of design, coupled technique and feed voltage method. For the project, the CDRA with microstrip line feed were use as main component of the design. The CDRA block design should be constructed using the CST simulation with design parameter obtained from the calculation done based on the literature review. At first place, single element CDRA design was main focus of the study to obtain the desired result with annular aperture coupled technique.

The second design propose for the as contingency plan were to design an array antenna with varies of aperture and mutual coupling technique. The constructed design shall be simulate and test using CST to obtain the result of the antenna bandwidth, frequency and gain. The design shall be redesign if the simulation result does not meet requirement of bandwidth, frequency and gain based on the contingency measurement.

## 3.2 Project Flow Chart

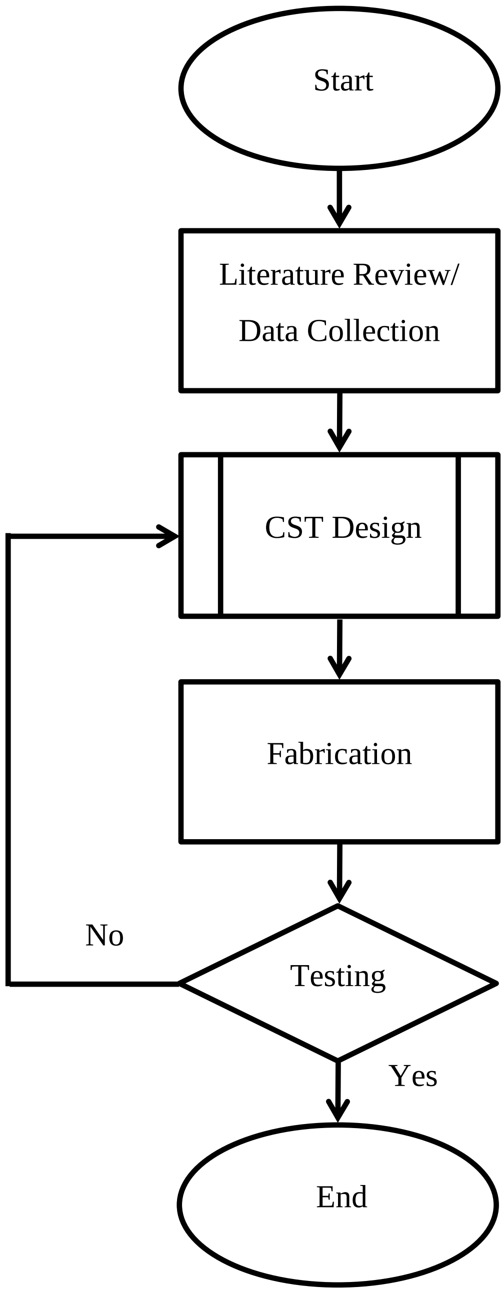


Figure 5: Flow Chart on Development of Antenna for Outdoor Wireless Application

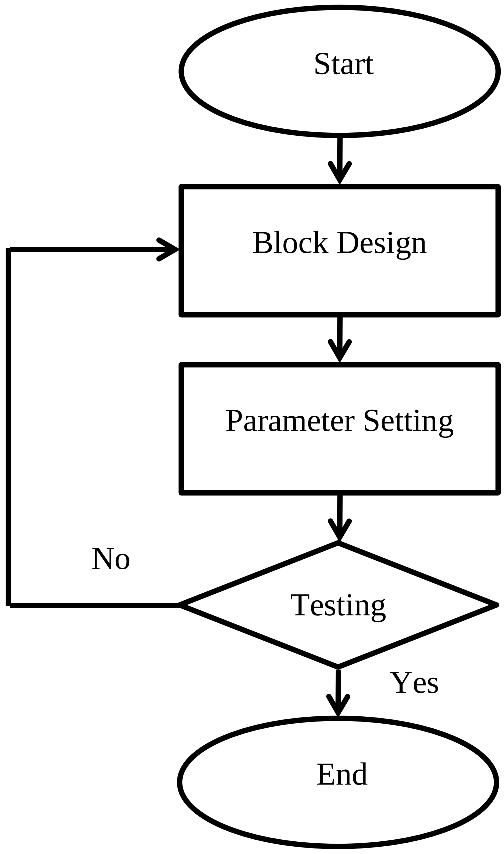


Figure 6: Flow Chart of CST Design Simulation Software

## 3.3 Gantt-Chart

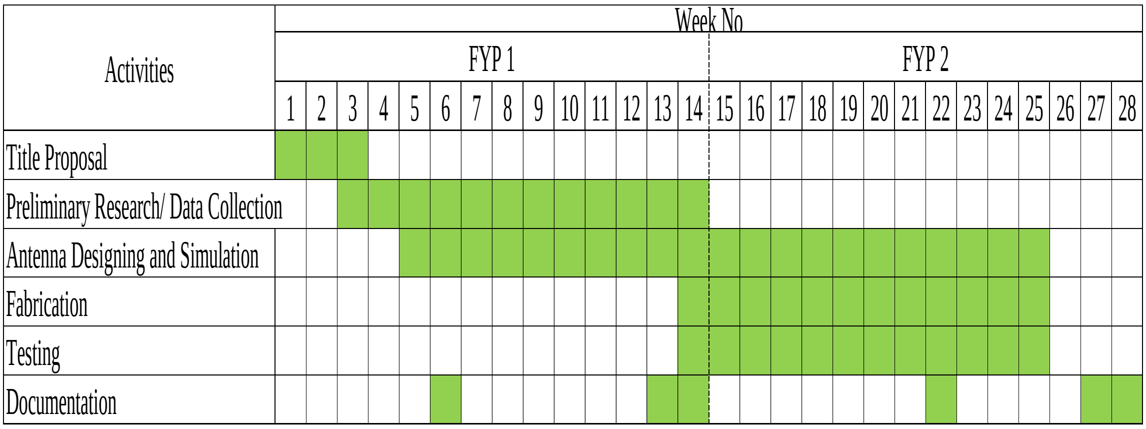


Figure 7: Gantt Chart of Development of Antenna for Outdoor Wireless Application

## 3.4 Key Milestones

Toward the project research, few key milestones being set up to accomplish the desired design. The key milestones are as follows:

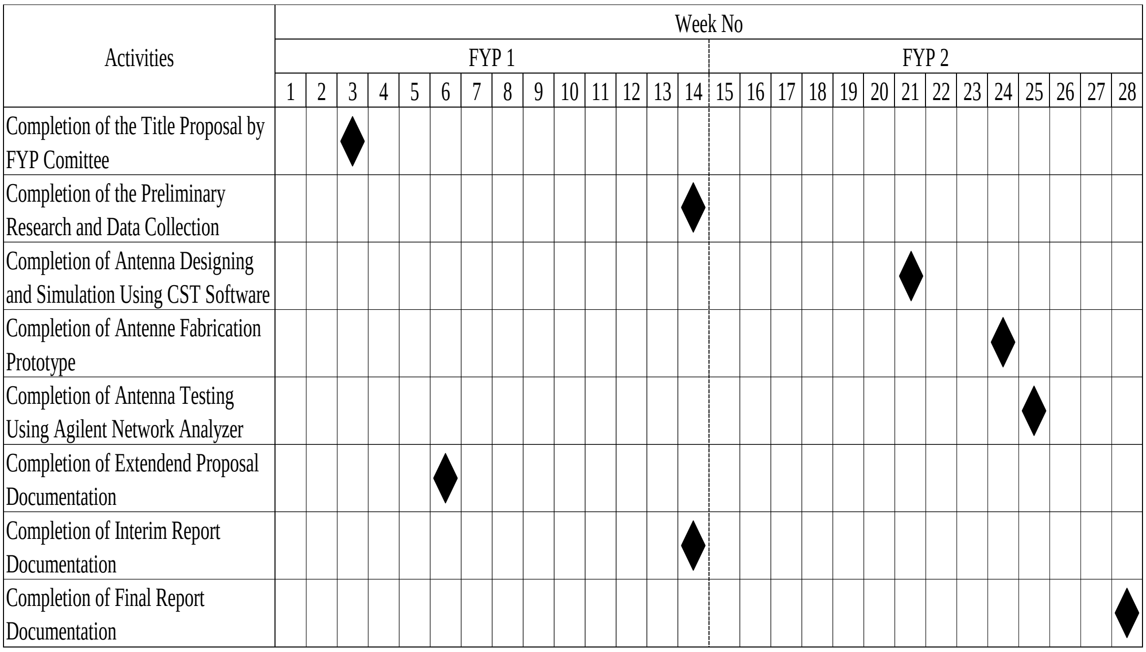


Figure 8: Key Milestones for Development of Antenna for Outdoor Wireless Application

## 3.5 Tools and Equipment

The project on the antenna designing shall require knowledge on the antenna design, fabrication, testing and measuring the result output. To achieve the key milestones for each stage, tools and equipment are required to conduct the project works. The tools and equipment shall be divided into 4 sections as follows;

### 3.5.1 Consumable

**Solder Lead** – Solder lead used to make connection between the SMA bulkhead connector and microstrip line.

### 3.5.2 Software

**Computer Simulation Technology (CST)** - CST Microwave Design software shall be used on designing of the antenna which allowed the user to perform simulation design on the antenna. Specific dimension and material property can be manipulated to obtain the theoretical result before the fabrication step be conducted.

### 3.5.3 Fabrication

**Cylindrical Dielectric Resonator Antenna (CDRA)** - CDRA is the main component of the antenna designing to radiate the signal. CDRA will be shaped into the specific dimension based on the design simulation during the fabrication process.

**Microstrip** – Microstrip lines shall be used on the antenna design to feed the CDRA. The size of the microstrip is vary depend on the requirement and the fabrication of the microstrip is done using printed circuit board (PCB) technology.

**Reflector** – Reflector is the component used to as catalyst to increase the gain of the signal. The reflector will be design using aluminium to desired dimension based on the simulation design to reflect the signal from the CDRA.

**SMA Bulkhead Connector** – Bulkhead connector used as to interface to feed the microstrip line with voltage to stimulate the CDRA to radiate signal.

### 3.5.4 Testing

**Agilent Network Analyzer** – Network analyzer shall be used to measure the signal transmitted by the fabricate antenna. Network analyzer served to test the result on the frequency, bandwidth and gain of the transmitted signal by antenna.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Antenna (DRA) Design Structure

Figure 9, Figure 10, Figure 11 and Figure 12 shows the design of DRA proposed for the development of antenna for outdoor wireless application. From Figure 9 and Figure 10, the design shall be single element antenna with microstrip feed method. For the antenna design, few parameters are set up to control the output in order to meet the design requirement to achieve 5.6GHz resonant frequency with high gain (>10dBi). The design parameter consider for the antenna design are radius ($R_D$) and height ($H_D$) of the CDRA, the microstrip dimension (length ($L_m$), height ($H_m$) and width ($W_m$)) and annular coupling radius ($R_{1C}$ and $R_{2C}$) and height ($H_C$) as shown in Figure 11 and Figure 12.

Figure 9 shows the substrate surface that made of FR-4 (lossy) material with ground (yellow colour surface) extruded from one of it the surfaces. The ground plane shall be made up of copper material on the top side of FR-4 substrate while microstrip line shall be fabricated on the bottom side. The microstrip line was fabricated with the same material as ground plane which is copper. The annular coupling slot as show in Figure 10 (yellow circle) is fabricated as vacuum compartment. The DRA use are from dielectric material with $\varepsilon_r$ = 55.

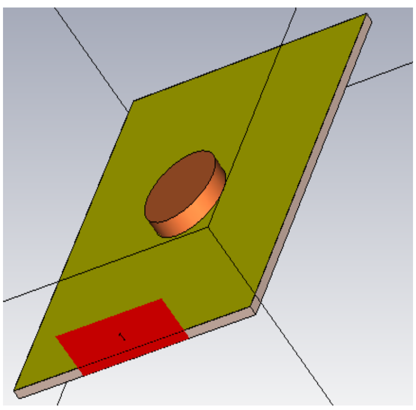

Figure 9: CDRA Design with CST

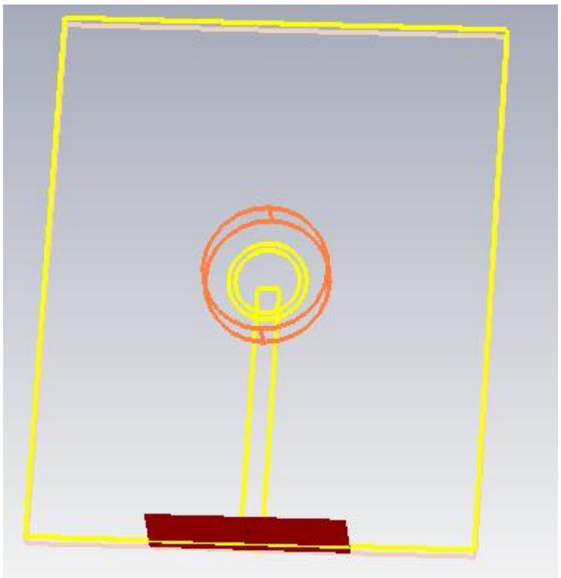

Figure 10: CDRA Design with CST (Wide frame Mode)

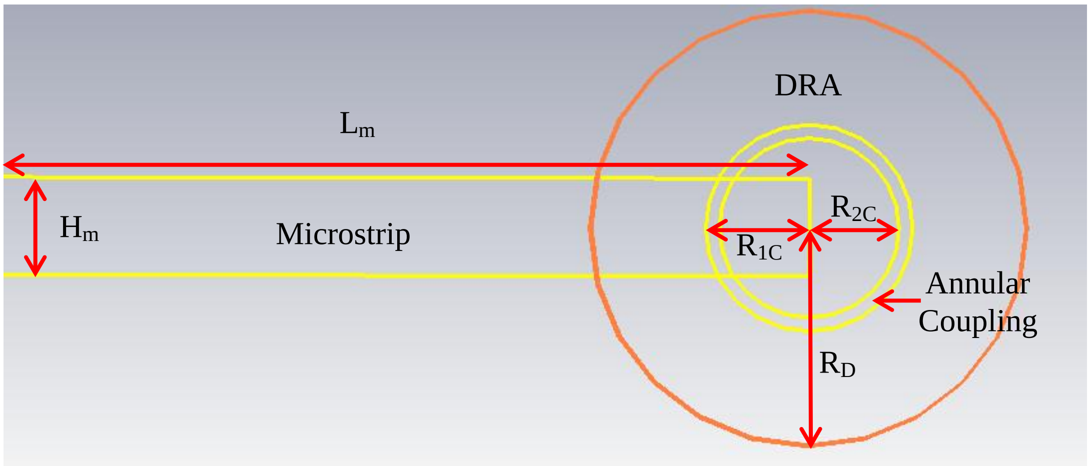


Figure 11: Design Parameters for CDRA

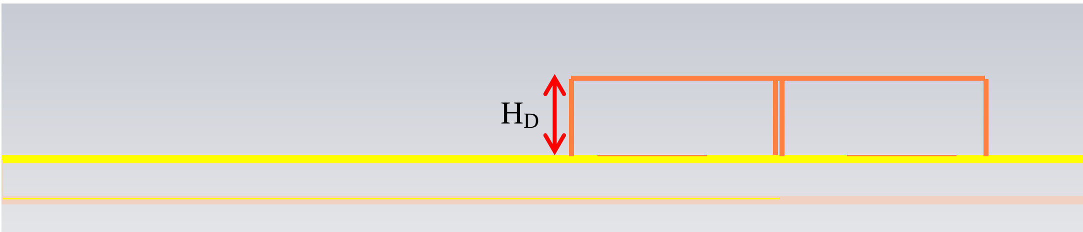


Figure 12: Design Parameters for CDRA

The placement of each element (microstrip, annular coupling and CDRA) is varied and for the period of 14 weeks, the placements are fixed for the entire element on the center of the substrate according to the define parameter design. The dimension of the substrate and the ground are defined at value of 60mm X 50 mm where CDRA and annular coupling are place on the center of substrate with distance of 30mm from waveguide port feed (see Figure 9 labeled as 1 on red colour). The height of microstrip and annular coupling are fixed at 0.034mm.

## 4.2 CST Simulation

Table 1: Simulation Result by using CST Software

| No. | Parameters (mm) | | | | | | | | Result | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cylindrical DRA | | Aperture Coupling (Annular) | | | Microstrip | | | Frequency (GHz) | Gain (dBi) |
| | $R_D$ | $H_D$ | $R_{1C}$ | $R_{2C}$ | $H_C$ | $L_m$ | $W_m$ | $H_m$ | | |
| 1 | 7.5 | 1.67 | 4.4 | 3.6 | 0.034 | 30 | 2.4 | 0.034 | 4.582 | - |
| 2 | 8 | 0.002 | 4.4 | 3.6 | 0.034 | 27.89 | 2 | 0.034 | 7.426 | - |
| 3 | 7 | 2 | 4.4 | 3.6 | 0.034 | 60 | 2 | 0.034 | 4.356 | - |
| 4 | 7 | 3 | 4.4 | 3.6 | 0.034 | 60 | 2 | 0.034 | 4.26/5.55 | 5.6/ 3.9 |
| 5 | 7 | 3 | 4.4 | 3.6 | 0.034 | 30 | 2.4 | 0.034 | 4.13/5.42 | 5.3/ 7.2 |
| 6 | 7 | 3 | 4 | 3.6 | 0.034 | 30 | 2.4 | 0.034 | 4.35/5.42 | 1.7/ 6.1 |
| 7 | 7 | 3 | 4.4 | 3.7 | 0.034 | 30 | 2.4 | 0.034 | 5.37/5.51 | 5.7/ 4.6 |
| 8 | 7 | 3 | 2.4 | 1.6 | 0.034 | 30 | 2.4 | 0.034 | 5.224 | - |
| 9 | 7 | 3 | 3.1 | 3 | 0.034 | 30 | 2.4 | 0.034 | - | - |
| 10 | 7 | 3 | 3.2 | 3 | 0.034 | 30 | 2.4 | 0.034 | 5.95 | - |
| 11 | 7 | 3 | 3.4 | 3 | 0.034 | 30 | 2.4 | 0.034 | 5.912 | - |
| 12 | 7 | 3 | 3.8 | 3 | 0.034 | 30 | 2.4 | 0.034 | 5.846 | - |
| 13 | 7 | 3 | 3.8 | 3.3 | 0.034 | 30 | 2.4 | 0.034 | 5.618 | 5.4 |
| 14 | 7 | 4 | 3.8 | 3.3 | 0.034 | 30 | 2.4 | 0.034 | 4.968 | 7.2 |
| 15 | 10 | 1 | 3.8 | 3.3 | 0.034 | 30 | 2.4 | 0.034 | 4.922 | 3.4 |
| 16 | 10 | 1 | 3.8 | 3.3 | 0.034 | 30 | 2.4 | 0.034 | - | - |
| 17 | 7 | 3 | 3.8 | 3.3 | 0.034 | 30 | 3.6 | 0.034 | 5.624 | 5.6 |
| 18 | 8 | 3 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 5.466 | 3.6 |
| 19 | 9 | 3 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 5.3 | 5.2 |
| 20 | 6 | 3 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 5.832 | 4.5 |
| 21 | 5 | 3 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 4.96 | 4.6 |
| 22 | 7 | 2.5 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 4.712 | 5.7 |
| 23 | 7 | 3.5 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 5.47 | 3.3 |
| 24 | 7 | 4 | 3.8 | 3.3 | 0.034 | 30 | 4 | 0.034 | 5.362 | 5.6 |
| 25 | 8 | 3 | 3.8 | 3.3 | 0.034 | 30 | 2.4 | 0.034 | | |

Table 1 show the simulation result on the CST Simulation software where the parameter varies to observed the output. From the simulation, the gain and resonant frequency are listed. The result shows that the frequency of 5.6GHz is achieved with few variations on gain depend on the dimension. The highest gain with 5.6GHz of DRA is 5.6dBi for dimension of $R_D$ = 7, $H_D$ = 3, $R_{1C}$ = 3.8, $R_{2C}$ = 3.3, $L_m$ = 30 and $W_m$ = 3.6. On the other hand, the highest gain is 7.2dBi with frequency of 5.4GHz (of $R_D$ = 7, $H_D$ = 3, $R_{1C}$ = 4.4, $R_{2C}$ = 3.6, $L_m$ = 30 and $W_m$ = 2.4) and 5GHz (of $R_D$ = 7, $H_D$ = 4, $R_{1C}$ = 3.8, $R_{2C}$ = 3.3, $L_m$ = 30 and $W_m$ = 4). The gain shall be higher with application of reflector.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

In conclusion, from the initial result obtained up to the date, it shows that the design antenna for 5.6GHz application with gain more than 10 dBi is achievable with further improvement on the design parameter and application of the reflector. The additional design criteria shall also be taking into consideration for accurate result and data with consideration on the limitation of fabrication. Recommendations for future works on the simulation of DRA, the DRA simulation design shall be simulate with application of reflector to obtain the final gain the antenna design. In addition, the design parameter on the simulation shall be revised to investigate the influence of each parameter on the result. The design also shall be revised to make sure the design are in range of fabrication limitation

# REFERENCES


[1] B. Mitchell. (2013, 22 June). *Introduction to Wi-Fi Wireless Antennas*. Available: http://compnetworking.about.com/od/homenetworkhardware/a/introduction-to-wifi-wireless-antennas.htm

[2] C. A. Balanis, "Antenna theory: a review," *Proceedings of the IEEE,* vol. 80, pp. 7-23, 1992.

[3] A. Petosa, A. Ittipiboon, Y. M. M. Antar, D. Roscoe, and M. Cuhaci, "Recent advances in dielectric-resonator antenna technology," *Antennas and Propagation Magazine, IEEE,* vol. 40, pp. 35-48, 1998.

[4] M. S. M. Aras, M. K. A. Rahim, A. Asrokin, and M. Z. A. A. Aziz, "Dielectric resonator antenna (DRA) for wireless application," in *RF and Microwave Conference, 2008. RFM 2008. IEEE International*, 2008, pp. 454-458.

[5] S. A. Long, M. McAllister, and S. Liang, "The resonant cylindrical dielectric cavity antenna," *Antennas and Propagation, IEEE Transactions on,* vol. 31, pp. 406-412, 1983.

[6] A. Sharma and S. Shrivastava, "Bandwidth Enhancement Techniques of Dielectric Resonator Antenna," *International Journal of Engineering Science,* vol. 3, 2011.

[7] A. A. Kishk and H. Wei, "Size-Reduction Method for Dielectric-Resonator Antennas," *Antennas and Propagation Magazine, IEEE,* vol. 53, pp. 26-38, 2011.

[8] A. A. Baba, M. A. B. Zakariya, Z. Baharudin, M. H. M. Khir, M. Z. U. Rehman, Z. A. Ahmad, *et al.*, "Aperture and mutual coupled cylindrical dielectric resonator antenna array," *Progress In Electromagnetics Research C,* vol. Vol. 37, p. 11, 2013.

[9] Z. Wu, L. E. Davis, and G. Drossos, "Cylindrical dielectric resonator antenna arrays," in *Antennas and Propagation, 2001. Eleventh International Conference on (IEE Conf. Publ. No. 480)*, 2001, pp. 668-671 vol.2.

[10] A. Petosa, *Dielectric resonator antenna handbook*: Artech House, Incorporated, 2007.

[11] K.-M. Luk, L. Wai-Kee, and L. Kwok-Wa, "Mutual impedance of hemispherical dielectric resonator antennas," *Antennas and Propagation, IEEE Transactions on,* vol. 42, pp. 1652-1654, 1994.

[12] A. Petosa, S. Thirakounc, M. Zuliani, and A. Ittipiboon, "Comparison between planar arrays of perforated DRAs and microstrip patches," in *Antennas and Propagation Society International Symposium, 2005 IEEE*, 2005, pp. 168-175 vol. 2A.

[13] C. Gopakumar, "Development and analysis of a novel isosceles trapezoidal dielectric resonator antenna for wireless communication," 2012.

[14] K. R. Mongia and A. Ittipiboon, "Theoretical and experimental investigations on rectangular dielectric resonator antennas," *Antennas and Propagation, IEEE Transactions on,* vol. 45, pp. 1348-1356, 1997.

[15] L. Huitema and T. Monediere, *Dielectric Materials for Compact Dielectric Resonator Antenna Applications*, 2012.

[16] R. A. Kranenburg and S. A. Long, "Microstrip transmission line excitation of dielectric resonator antennas," *Electronics Letters,* vol. 24, pp. 1156-1157, 1988.

[17] K. W. Leung, W. C. Wong, K. M. Luk, and E. K. N. Yung, "Annular slot-coupled dielectric resonator antenna," *Electronics Letters,* vol. 34, pp. 1275-1277, 1998.

[18] G. P. Junker, A. A. Kishk, A. W. Glisson, and D. Kajifez, "Effect of air gap on cylindrical dielectric resonator antenna operating in TM<sub>01</sub> mode," *Electronics Letters,* vol. 30, pp. 97-98, 1994.

[19] S. D. Targonski and R. B. Waterhouse, "Reflector elements for aperture and aperture coupled microstrip antennas," in *Antennas and Propagation Society International Symposium, 1997. IEEE., 1997 Digest*, 1997, pp. 1840-1843 vol.3.

[20] N. J. Johar, "Dielectric resonator antenna with reflector," Universiti Teknologi PETRONASMay 2012 2012.

[21] Y. Huang and K. Boyle, *Antennas: From Theory to Practice*: Wiley, 2008.

[22] O. Yurduseven and O. Yurduseven, "Compact parabolic reflector antenna design with cosecant-squared radiation pattern," in *Microwaves, Radar and Remote Sensing Symposium (MRRS), 2011*, 2011, pp. 382-385.

[23] X. Shu, S. Altunc, P. Kumar, C. E. Baum, and K. H. Schoenbach, "A Reflector Antenna for Focusing Subnanosecond Pulses in the Near Field," *Antennas and Wireless Propagation Letters, IEEE,* vol. 9, pp. 12-15, 2010.