THE DEVELOPMENT OF DUAL BAND DRA HYBRID ANTENNA

BY

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FINAL YEAR PROJECT

Dissertation submitted as partial fulfillment of

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CERTIFICATION OF APPROVAL

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Approved by,

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January 2016

CERTIFICATION OF ORIGINALITY

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

Student Signature:

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Lingeshgugan A/L Sanmugam

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Abstract

In wireless technology, Dielectric Resonator Antenna (DRA) is one of the recent technologies that are used to obtain an efficient performance in antenna. In this project a research has been done on the hybrid DRA whereby it consists of cylindrical dielectric resonator and micro-strip patch resonator. The design of the Dual Band Hybrid DRA is created and simulated using the Computer Simulation Technology (CST) software to achieve the desired bandwidth. Parametric studies of the proposed configuration were carried out to characterize the antennas and to verify the simulation result. The expectation of the dual band hybrid DRA is to obtain a wider bandwidth with an operating frequency range at 2.4 GHz to 2.6 GHz and 5 GHz to 6 GHz. To demonstrate the idea, the wireless area network (WLAN) within Industrial, Scientific, and Medical (ISM) band is used to design the Hybrid antenna.

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Abbreviations

PCB	Printed circuit board
DRA	Dielectric Resonator Antenna
CDRA	Cylindrical Dielectric Resonator Antenna
CST	Computer Simulation Technology
GHz	Giga-Hertz
dBi	Decibel of an Isotropic
WLAN	Wireless Local Area Network
ISM	Industrial Scientific and Medical

Chapter 1: Introduction

Antennas are the start and end nodes of a wireless link. Basically they are metallic structure that is designed for radiating and receiving electromagnetic energy. Based to the IEEE standard definition, antenna is meant by radiating or receiving radio waves [22]. In normal cases, antenna acts as a transitional structure or impedance transformer between the guiding devices and the free space. To be more specific antenna is an electromagnetic transducer. In an antenna, charges that are being accelerated by an external source set up a charge flow with oscillating time with produce radiation. Energy will be radiated when the charges reaching the discontinuity or transition in the structure get decelerated [22].

Microwaves are basically not only for information, communication and entertainment transferring but also used for the transfer of energy. This term explains the Industrial, Scientific and Medical (ISM) applications of microwaves [23]. Following are the application using the microwaves under industrial applications which consist of drying, cooking, irradiation, purification, liquefaction, sintering, enzymatic inactivation, sterilization, pasteurization, vulcanization and so on. In the Scientific field microwaves are used in particle accelerators and for semiconductor industry for material characterisation.

The Dielectric Resonator Antenna is fabrication from high dielectric constant materials, high quality factors and mounted on the substrate of lower permittivity [19]. It is a ceramic that radiate energy into the space when it is being excited accordingly [19]. Various compilations of DRAs with different antennas have been proposed for improved bandwidth or dual-band operation [21]. It also has been proposed for the reason of increasing the bandwidth and also to resonate at different frequencies [3]. By selecting particular resonant frequencies of the monopole and also the ring DRA, the combination of the antenna that has been designed is ideally suited for ultra-wideband communication application [7]. Currently, another step is taken which is to create a hybrid DRA that includes dielectric resonator and micro-strip patch resonator whereby the impedance bandwidth of the micro-strip patch can be increased by 10% with proper placement of the DRA [20].

The usage of DR antenna by tightly coupling two dielectric resonators shows that capable to increase the bandwidth. Parasitic elements are introduced to the resonators in order to bandwidth can be increase. There are many advantages of using the dielectric-resonator

(DR) antennas as it can minimize the loss tolerance, low height, low material cost, ease of couple and high bandwidth. There are an applications where performance are given more priority than cost, and DRA generates the result not which is not offered by other radiating elements.

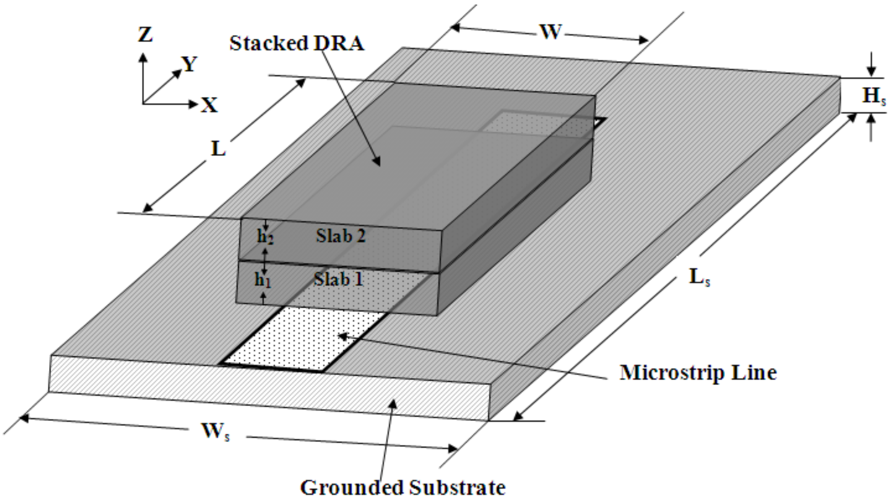

Figure 1.1 Example Coupling of two dielectric resonators

To demonstrate the idea, the dual band hybrid DRA is designed for the Wireless Local Area Network (WLAN) which consists of Industrial Scientific and Medical (ISM) frequencies. There are total of two bands in Industrial Scientific and Medical (ISM) frequencies which are two thousand four hundred megahertz band and five thousand seven twenty five megahertz till five thousand eight hundred fifty megahertz band. The purpose of this project is to gain higher bandwidth from the approach of Hybrid DRA consisting of micro-strip patch and DRA. This project involves the design approach by varying the parameters of the DRA and micro-strip patch and analysis to gain wider bandwidth is analyzed. The Hybrid DRA will be fabricated and measured once it achieves is optimum performance.

1.1 Project Background

The approach of a dual band hybrid-resonator antenna, consist of a micro strip-patch resonant and it is coupled with a dielectric resonator pallet. It is also one of the important approaches for wireless applications. The resonant of dielectric resonator is located nearby the resonant patch resonator. As a result, the combinations of the resonances are tuned to produce a prototype of dual band hybrid antenna with frequency range from 2.4 GHz to 2.6 GHz and 5

GHz to 6 GHz. The hybrid antenna can be applied in Wireless Local Area Network (WLAN) applications.

1.2 Problem Statements

The size reduction of the hybrid antenna design with requirement of wider bandwidth becomes a major challenge for antenna design in wireless application within Industrial, Scientific, and Medical (ISM) band. The detail designs and analysis of the development for the particular antenna had shown a good capability of achieving the needs thorough analytical works and characterization of the design criterion such as substrate, ground plane and dielectrics resonators properties.

1.3 Objectives

There are several objectives for this project:

- To develop the design of Dual Band Hybrid Dielectric resonator antenna in 3D simulation design.
- To characterize the design parameter CST software.
- To fabricate the design and performs the testing and measurement of the antenna design.

1.4 Scope of study

The project begins with 3D simulation using CST software for the design of Dual Band Hybrid Dielectric Resonator antenna. During the designation period the design parameters for the dielectric resonator are characterize. The operated frequency range of the design selected to be within 2.4 GHz to 2.6 GHz and 5 GHz to 6 GHz. The antenna substrate in the study is selected for FR-4 type and Rogers R03400C type of DRA. The thickness of FR-4 substrate is selected to be 1.568mm and the Rogers R03400C is selected to be thickness of 3mm. The optimum design parameters of the design is fabricated and tested with Wireless Local Area Network (WLAN) application.

Chapter 2: Literature Review and Background Study

An antenna is an electrical device to transmit or receive radio waves or, more specific any electromagnetic waves. Antennas are commonly used in systems such as media broadcasting, radar, and space exploration. An antenna not only works in air or outer space but also can operate under water or through soil and rock at particular frequencies. As for an antenna it is an arrangement of conductors that generate radiation with an applied voltage and current. An antenna transmits a stronger signal if resonant on the frequency used. Commonly antennas have certain important parameters that should be taken note such as gain, radiation pattern, bandwidth and polarization.

An ideal antenna will radiate all the power delivered to the antenna from to the transmitter in a desired directions but the ideal performance of an antenna is still haven't achieved may be closely approached. There are various type of antenna is available and each type of the antenna have different forms according to the desired radiation characteristics for the particular applications. For this project micro-strip antenna is being used for the Industrial, Scientific and Medical (ISM) band application. Micro-strip antenna became very popular in the 1970s primarily for the application of communication in space. The micro-strip antenna has a metallic patch on a grounded substrate and the metallic patch able to accept many several configurations. They are also considered as low profile antennas, conformable to planar and non-planar surfaces, and simple and not too expensive to be fabricated using the modern printed-circuit technology. The antenna is also considered as mechanically robust when attached on rigid surfaces and very versatile in terms of resonant frequency, polarization, pattern and impedance.

There are certain parameters that can influence an antenna's performance and this parameter can be adjusted by changing the design to obtain the desired result. Following are the parameters which are the radiation pattern, radiation power density, radiation intensity, directivity, antenna efficiency, gain, beam efficiency, bandwidth, polarization, input impedance and antenna radiation efficiency.

Richtinger in 1939 had theoretically tested microwave resonators in the way that non-metal dielectric sphere and toroids[1]. It is followed by Okaya and Barash in the early of 1960s with analysis of their modes [2]. The development of low- loss ceramic materials in the end of 1960s introduce to dielectric resonator as High Q (low loss) elements for circuit applications, such as filters and oscillators, producing more compact way to waveguide cavity resonator and more efficient technology for printed circuit integration [3-5]. Dielectric resonator is usually made in cylindrical shape to have high dielectric constants and at the same time to preserve its compactness. To avoid radiation and to preserve its quality which needed for filter and oscillator designs, the dielectric resonators are covered with metal cavities.

Several dielectric resonators are capable of become efficient radiators when the shielding is taken out with appropriate steps to launch the particular mode. Besides that, radiation can be preserved over the approximate broadband frequencies by decreasing the dielectric constant. In the beginning of 1980s, research on the dielectric resonators as antenna elements have been done whereby test of the distinctive of cylindrical, rectangular, and hemispherical shapes by Long, McAllister, and Shen [6-8]. The research on their radiation patterns, resonant modes, and procedure of activity have shown new interesting alternative of old low gain radiators. In this period, there also a research work had been done for the first linear array of DRAs by Birand and Gelstrophe [8] and the first planar array by Haneishi and Takazawa [9].

In the recent year of 1990s, priority is given on finding many ways of feeding instrument to work up the DRAs by preceding several analytical or numerical researches to determine the input impedance and Q-factor. It is more targeted on single elements. A certain value of particular type was researched by two research team; first team is led by Kisk, Glisson, and Junker and the other team by Luk and Leung [11]. In the middle of 1990s, more priority given to linear and planar DRA arrays, feeding from simple two-element arrays, up to complex phase arrays of over 300 elements with beam-steering capacity.

More researchers have posted to this field at the late of 1990s and the yearly publications have increased. Importance has been given to the compact designs to provide the needs in portable wireless applications and increase the bandwidth performance of new DRA shapes. The hybrid antennas are introduced to meet the need for the broadband and ultra wide-band system [24].

2.2 Types of DRA

In the literature there are various shapes of dielectric resonant [6-8]. In this part, a study is made to compare between the most basic shapes used for dielectric resonant which are hemisphere, rectangular and cylinder.

2.2.1 Hemispherical Dielectric Resonant Antenna

An investigation has been done in free space for electromagnetic resonant modes of dielectric spheres [12]. An ideal electric conductor with high power is used on hemispherical DRA, whereby to get the radius of the hemispherical radius using picture theory and the isolated dielectric sphere obtains the same radius. There are total of two modes for dielectric sphere which are the transverse electric and transverse magnetic. For certain years, cylindrical shapes are used in circuits. For the ideal use in the filters and oscillators with their increased Q-factor and small size peculiarly in micro-strip technology it is not practical due to it waveguide cavity. As show in the figure 2.1 the three characters that describes the mode refer to the field variation in the radial (r), azimuth (ϕ), and elevation *()* directions, in the spherical coordinate system [12].

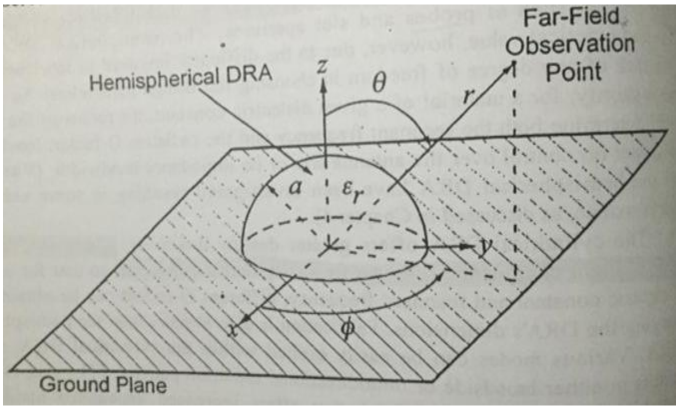

Figure 2.1: Hemispherical dielectric resonator antenna [12]

2.2.2 Cylindrical Dielectric Resonator Antenna

For cylindrical DRA in circuit utilization these are the following parts that need to be particular which is the field configuration, resonant frequency and coupling behaviour [13]. The compact size and greater value of Q-factor causes it to be used in filters and oscillators in micro-strip technology. Furthermore, the radiation properties for cylindrical dielectric resonator have been oppressed by firstly researched on properties of a probe–fed cylindrical DRA [6].

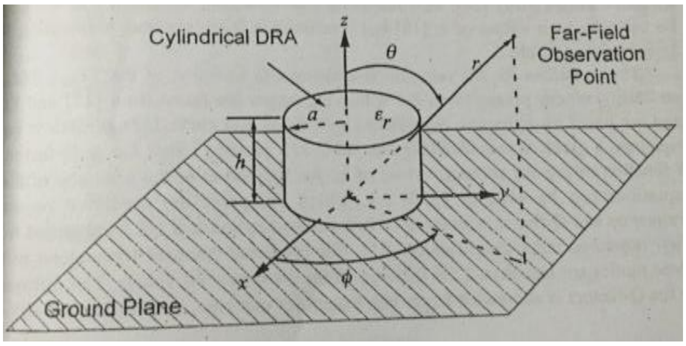

Figure 2.2 The geometry of cylindrical DRA [6]

2.2.3 Rectangular Dielectric Resonator Antenna

The rectangular shape DRAs has second degree of freedom. This is due to rectangular size DRA covers more than one cylindrical shape DRA and more than two size of hemisphere DRA. Rectangular shape DRA has a higher value in resilience due to capability of fulfilling the profile and bandwidth properties at particular resonant frequency and dielectric constant whereby the ratios such as and   can be chosen as shown in Figure 2.3.W represent the width of the DRA, h is represent the height of the DRA and for the depth of the DRA is presented as d.

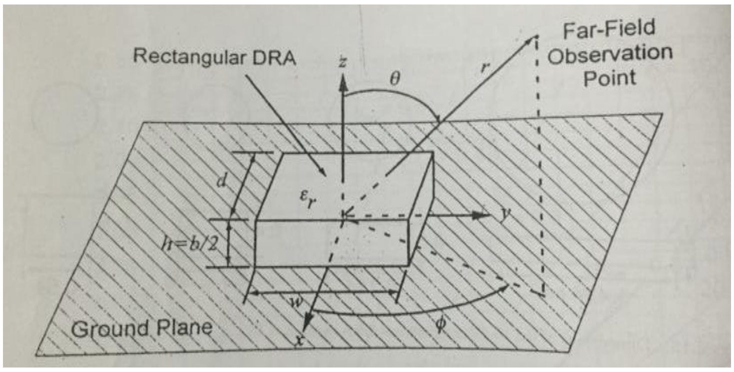

Figure 2.3 Geometry of the rectangular DRA [6]

2.3 Type of Hybrid Dielectric Resonator Antenna

Hybrid Antenna is the combination of DRA with another antenna whereby the purpose of combination is to increase the bandwidth or for dual-band operation. In the following section, detail studies and proposal are explained on the hybrid antennas, structure and characteristics.

2.3.1 Micro strip Ring – Cylindrical DRA

A proposal has been done by combining ring microstrap patch and cylindrical DRA to gain dual frequency operation [14]. On a foam spacer, the patch is placed and the inner radius is short-circuited to ground to avoid or decrease interference during the conduction period of the DRA which will be in the middle of the ring. A proposal have been done whereby a design for 4-Ghz and 6-Ghz properties for the use of satellite communication applications which results in the simulation of the impedance bandwidth of about 6% for each band. It is expected to result in broadside radiation with separate aperture-coupled feeds for both DRA and ring patch.

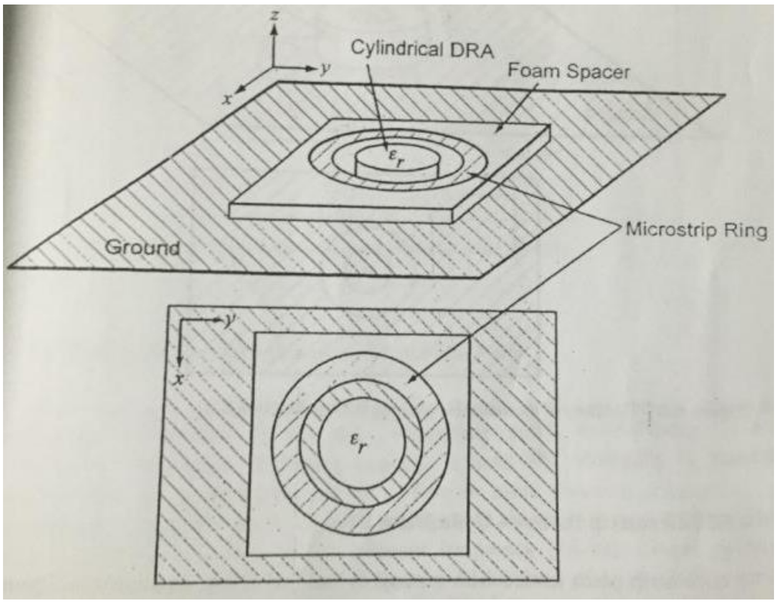

Figure 2.4: Geometry of hybrid micro-strip ring and cylindrical DRA [14]

2.3.2 DRA-Loaded Monopole

Another Hybrid Antenna has been developed whereby it is the combination of monopole and ring DRA [15]. By selecting the particular resonant frequencies of the monopole and ring DRA, the combination of the antenna could produce radiation in omni-directional pattern with a 3:1 bandwidth at the same path it maintains the return loss of 10dB or lesser. This compact antenna designs are suitable for ultra-wideband communication that requires omni-directional coverage. The monopole antenna is being excited by a coaxial probe and acts as a single feed, consequently serves to excite the DRA.

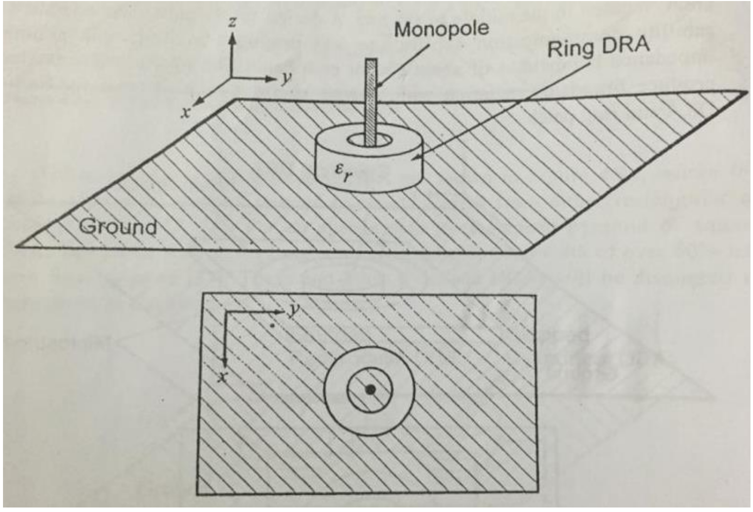

Figure 2.5 Geometry of the monopole and ring DRA [16]

2.3.3 Micro-strip Patch – Cylindrical DRA

Another proposal has been done to enhance the impedance of bandwidth by combining a micro-strip patch loaded with a small cylindrical DRA [16]. A research has been done and the impedance bandwidth in unloaded case is approximately 2% and it could increase until 10% by placing the DRA properly. It is also founded that the gain of the DRA loaded patch is 1-dB which would be higher than an unloaded micro-strip patch.

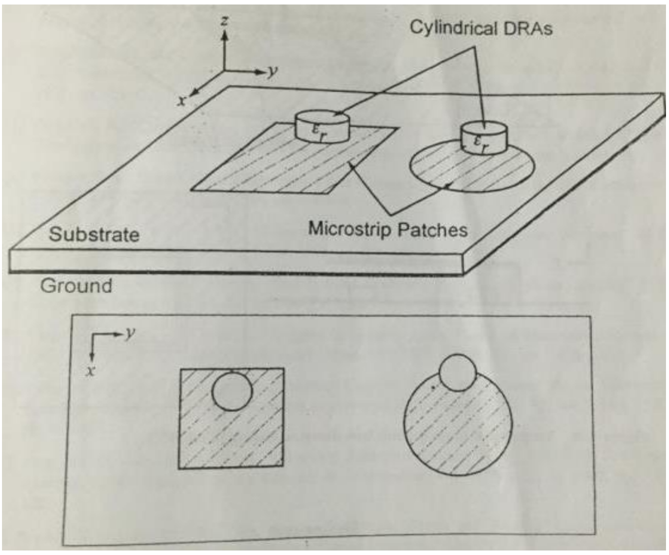

Figure 2.6 Examples of DRA-loaded micro-strip patches [16]

2.3.4 Dielectric-Loaded Micro-strip Suspended Patch

The hybrid antenna structure can also been developed with elements of microstrip patch and dielectric resonator. As shown in Figure 1.7, to obtain a broadband impedance response, the micro-strip patch is suspended in air. Underneath the patches at the edges, two or more dielectrics are inserted and as a result the resonant frequency could be reduced in particular value [17]. For the linear polarized design, it has been reported that the frequency has been decreased up to 30 % compared to a non-loaded patch meanwhile for the impedance bandwidth is remained at 8 % [18].

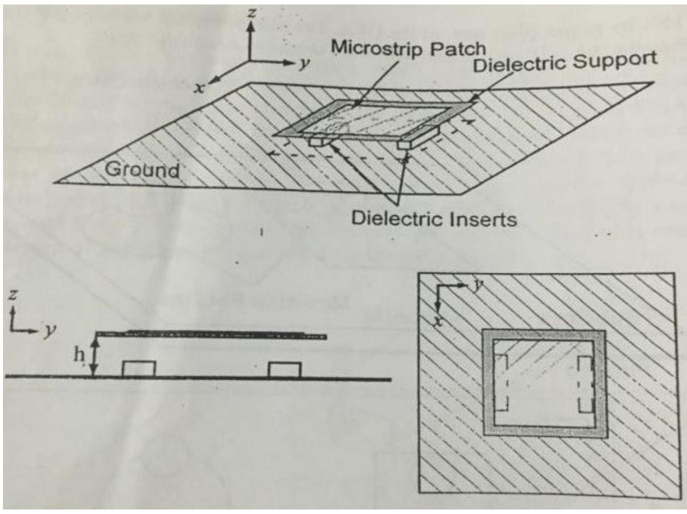

Figure 2.7 Suspended micro-strip patch with dielectric loading [18]

Chapter 3: Methodology

The design methodology is explained in this section. It consists of designing and identifying the parameters of the dual band hybrid Dielectric Resonant Antenna. The methodology begins with interpreting details about Dielectric Resonant Antenna technology. The hybrid Dielectric Antenna is designed and is simulated using CST and the result obtained from the simulation is recorded. The dual band hybrid Dielectric Resonant Antenna is fabricated and it is tested and measured. The data is collected and analysis is performed by comparing with the simulation result and discussion is discussed according to the result obtained.

3.1 Flow Chart of Design Methodology

It is important to design a flowchart for a project to ensure the project can be managed and the continuous o improvement can be done in developing the dual band hybrid Dielectric Resonant Antenna. The project is being divided in to two parts which it is the hardware implementation and simulation of design. To design the antenna, CST software is used and simulation is performed and consequently the simulated data are analyzed. It is followed by the hardware implementation which consists of fabrication of the DRA antenna and also the testing and measuring of the DRA antenna performance. Overall procedure for the methodology of the project is shown in Figure 3.1.

3.1.1 Designing and Simulation of the Dual Band Hybrid Dielectric Resonant Antenna.

The concept of hybrid Dielectric Resonant Antenna is understood and methods of achieving the higher bandwidth are researched. Simulation using CST software is used to design the hybrid Dielectric Resonant Antenna and the simulation result is obtained. CST provided friendly user software for 3D electromagnetic simulation for high frequency components. It also enables fast and accurate analysis of high frequency devices such as antenna, filters, coupler, planar and multilayer structures. The software has time domain solver and frequency domain solver that are used for simulation purpose. Once the design and simulation is succeeded, the antenna design is sent for fabrication.

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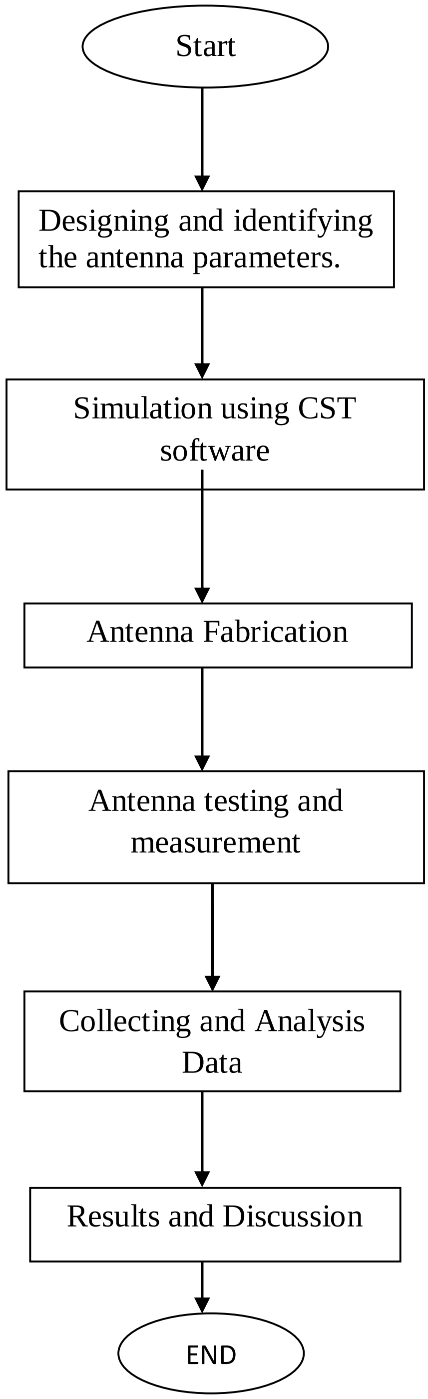

Figure 3.1 Flow chart of the project

3.1.2 Antenna Fabrication

The Dual Band Hybrid Dielectric Resonant Antenna is fabricated in RF and MW Lab facilities at block 22 and block 21 of Electrical and Electronics Engineering department consequently the design is tested using MW-2000 Microwave Communication Trainer. The experiment module is used to evaluate the performance of hybrid Dielectric Resonant Antenna by using the microwaves devices and interfaces that were software provided in the kit. The performance of transmission rate, reacting gain and signal strength will be discussed and analyzed.

3.1.3 Testing and Measurement and Collecting and Analysis Data

The fabricated antenna will be measured to ensure that the fabricated antenna having the same measurement as in the simulation. The antenna is then will be soldered with a SMA connector on the micro-strip line. The antenna is tested and the result is obtained and it is compared with simulation result. Analysis of data is evaluated on the result from the simulation and the testing of the hardware.

3.2 Gantt Chart and Milestone Planning

For FYP I, it started by project title selection whereby the student needs to find a project with a supervisor that could monitor the student and assist the student for the final year project. This includes with the supervisor need to provide certain information about the project. Once the student get a clear view about the project, the student have to continue with more detailed information about the project by searching for journal, research paper, conference paper or any data regarding the project through the Internet. In preliminary research and literature review part, the student has started working on the literature review part for their extended proposal. It is important the literature have to be done so that, the student get to knows the previous project that have been done and can explore more during their project. During week five the student have to come up with an extended proposal and have to be submitted through Turnitin software that is used to check the plagiarism of the proposal done by the student. It is a must for the student to come up with an extended proposal that is less than 15% to ensure the originality of the paper.

Table 3.1 Gantt chart

Activities	Week														
FYP 1 Progress and Milestone (September 2015)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Title Selection	■	■													
Preliminary Research & Literature Review		■	■	■	■										
Familiarize with CST software and HFSS software				■	■	■	■	■							
Components Identification				■	■	■	■	■							
Prototype Preparation								■	■	■	■	■	■	■	
Prototype Designing								■	■	■	■	■	■	■	
FYP 1 Assesment															
Extended Proposal					■	■									
Proposal Defense							■	■	■						
FYP 1 Report (Draft Interim)										■	■	■	■		
FYP 1 Report (Final Interim)														■	
FYP 2 Progress and Milestone (January 2016)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fabrication of Antenna	■	■													
Soldering the port on the antenna			■												
Testing the antenna				■	■	■	■	■							
Examine the findings							■	■	■	■					
FYP 2 Assesment															
Submission of progress report								■							
Electrex / Pre-Sedex presentation											■				
Submission of Draft Report													■		
Submission of Final Report														■	
Final Viva															■

The student then continues the project progress with familiarizing with CST software. The student is being assisted by the post graduate students in Block 21 to learn about the CST software. It is important for the student to get familiarized with the CST software the designing and simulation part of the antenna is done in the software. From the software the student can get a theoretical result and can compare with the other design that has been made so that the best antenna design is sent for fabrication. The student is being given a basic tutorial on the software and getting to know about basic matter of designing an antenna using the CST software. By week 7 the student should be able to work by their own on the CST software and start to designing their own antenna. At this period, the student has to present their own proposal defense whereby the presentation is being evaluated by exam panels and supervisor.

The project progress then continues with components identification for the projects. The every part of the antenna plays its own role and it is important to knowing every each part of the design of the antenna. The student needs to come up with a parameter value of the design using the method of calculation used before in designing the antenna. The material used to build the antenna must be choosing correctly according to the antenna needs since material will affect the output results.

Once the antenna parameters are defined and the materials are decided, the project is then moved on to the antenna designing. Using the parameters that have been calculated and the material that is suitable for the antenna, the simulation of the antenna is done result is obtained from the CST software. To improvise the value of the result to obtain the desired value, the parameters of the antenna is being varied. By week 13, the student needs to come up with the finalized result of the antenna design done in the CST software that will be sent for fabrication during the FYP 2. Besides that, in the interim report the student needs to show the result obtained from the simulation done and the submission of the final interim report will be on the week 14.

For FYP 2 the progress starts with sending the antenna design that is done in the CST simulation for fabrication. The fabrication lab is in block 22 whereby the student needs to send the design in GBR file which is converted using the CST software. Once submitting the design, the student will be called for fabrication consultation to ensure that the design of the antenna that will be fabricated is according to the student's desired design. The process of consultation takes about 2 weeks. Once the fabricated antenna is received, the student needs to cut the substrate of the antenna according to the parameters used in the simulation. Then the port for the antenna is soldered. Week 4 onward the antenna is tested for the return lost S-parameter and Far Field Radiation pattern using the Field Fox RF Network analyzer and the result is saved and graph is plotted using Microsoft excel according to the data retrieved from the Field Fox RF analyzer.

On week 8 the student need to submit the progress report for FYP 2 which includes the data from the testing. The data is compared with the data retrieved from the simulation. Next, the assessment followed by Pre-Sedex presentation falls on the week 11 whereby the student needs to present their project. Besides that, by week 13 the student needs to complete with final report and need to submit it by week 14 in the Turnitin software for plagiarism. On week 15 the student needs to submit the hard bounded final report and the Final Viva will be done.

3.3 Tools

3.3.1 Software

- Computer Simulation Technology Software (CST)
  The software is used for the purpose of the simulation of the design. By adjusting the design parameters of the micro-strip and CDRA the result of the design will be obtained and from the simulation done, the best optimum performance will be finalized that achieve the desired bandwidth. Once getting the finalized design, the design is send for fabrication. Figure 3.2 shows the overview 3D structure for the proposed design in this project.

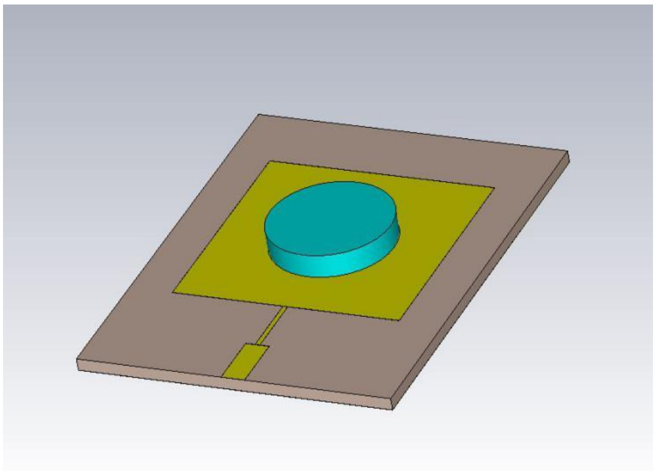

Figure 3.2: Hybrid antenna result using CST software

3.3.2. Hardware

3.3.2.1 MW-2000 Microwave Communication Trainer

Figure 3.3 Microwave Communication Trainer kit

Figure 3.3 shows the MW 2000 communication trainer that the trainer consists of has the components that needs for an experimental to design. The RF components involves the passive and active devices that commonly used in the microwave band by using the micro-strip line theory and microwave design principle. The device is connected to a PC and it is used into the receiver and transmitter. It also enables the personnel to send text and files through the system used in the software program that is provided in the communication trainer. The MW 2000 communication trainer is also provides the knowledge on modulation, demodulation and microwave devices and communication system.

3.3.2.2 Field fox handheld RF analyser.

Figure 3.4 Field Fox Handheld RF Analyzer

A RF analyzer is an instrument that used to display the signal amplitude which is the strength as it varies by signal frequency. The unit that is used to show on the horizontal axis, and for the amplitude it shows in the vertical axis. To be more exact, a spectrum analyzer looks and functions like an oscilloscope but it differs from oscilloscope since this instrument is used commonly used for frequency-amplitude analysis, signal isolation, new signal detection, and measuring total signal power or energy. A spectrum analyzer is used to check whether a wireless transmitter working accordingly to the desired output. By analyzing the characteristic of the signal on the spectrum analyzer, it is possible to determine the performance of the antenna and troubleshoot the antenna. To measure using the spectrum analyzer a passive receiver is needed so that the spectrum analyzer displays in a way that it easy to analyze the signal that is obtained this is due to Spectrum analyzer displays raw display, unprocessed signal information such as wave shape, side bands, frequency, voltage, power and period.

A Network Analyzer with the domain option, Field Fox computes the inverse Fourier transform of the frequency-domain data to display reflection or transmission coefficients versus time. Time domain gating can be used to remove unwanted responses such as connector mismatch or cable discontinues, and the results that is displayed in either time or frequency domain. Field Fox's time domain function supports both low pass mode and band pass mode, enabling users to measure both broadband and frequency selective devices. S11, S11 phase, antenna gain, Smith chart and polar display is available with Network analysis capability. It also haves 3 types of times stimulus modes which are Low pass stop, Low- pass impulse, Band-pass impulse. It also has a windowing function that can be used to filter the frequency – domain data and thereby reduce overshoot and ringing in the time-domain response.

Chapter 4: Results and Discussion

4.1 Antenna Design

The Dual Band Hybrid antenna with the combination of micro-strip patch and Cylindrical Dielectric Resonator Antenna is designed and simulated using the CST software before it is being fabricated. The antenna is designed to operate from 2.4 GHz to 2.6 GHz and 5 GHz to 6 GHz. The design as shown in the figure 4.1 and 4.2, are the design that is being tested.

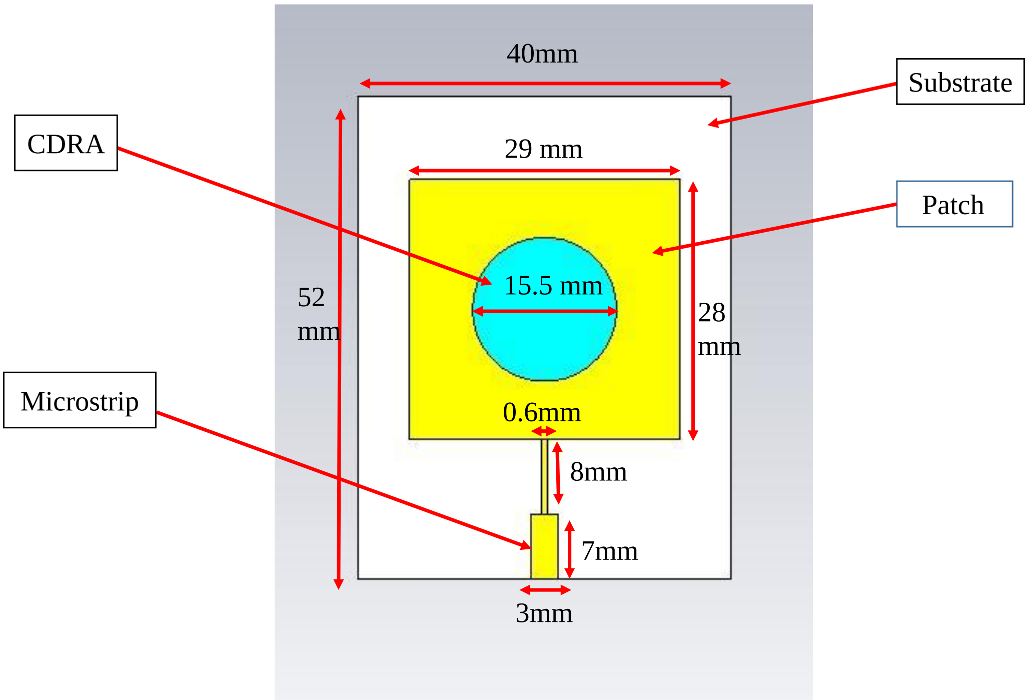

Figure 4.1.The geometry of Hybrid Antenna (Top view)

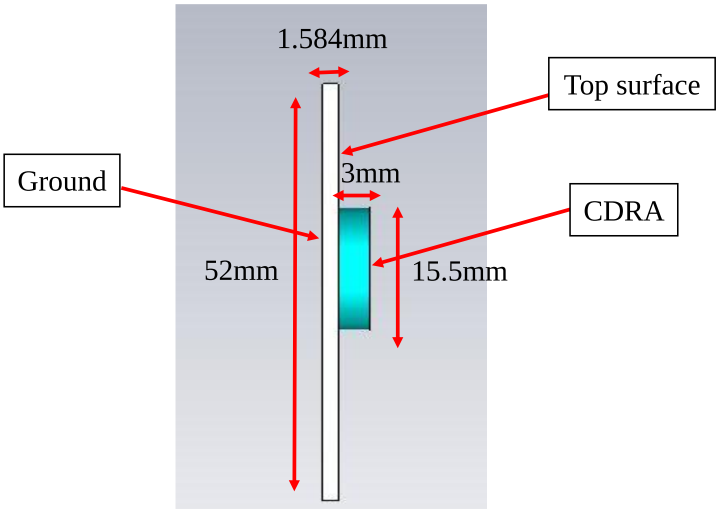

Figure 4.2.The geometry of Hybrid Antenna (Side view)

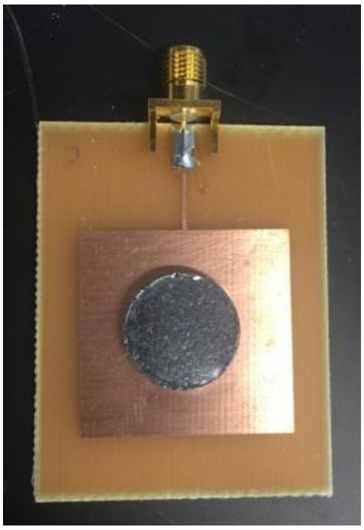

Figure 4.3 The fabricated antenna design

The antenna design is done by using CST software and the parameters are varied to achieve the result needed and the antenna is sent for fabrication. The design of an antenna includes the ground plane, the patch, micro-strip line, substrate, cylindrical dielectric resonator antenna (CDRA) and their parameters value are important to achieve the bandwidth needed. As for the Substrate, the FR-4 material is used with the permittivity of εs = 4.3 with the thickness of 1.568mm are used for the antenna. Copper material is used with thickness of 0.016mm for the patch, micro-strip line, and the ground plane. Rogers R03400Cdielectric material used as the cylindrical dielectric resonant antenna with the permittivity of 55. For the patch parameters of width and length are being calculated using the formula;

$$\boldsymbol{W} = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}};\ \varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{\left[1+12\frac{W}{h}\right]}};\ L_{eff} = \frac{c}{2f_{o\sqrt{\varepsilon_{eff}}}} \quad (1)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\ (\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)\ (\frac{W}{h}+0.8)};\boldsymbol{L} = L_{eff} - 2\Delta L \quad (2)$$

f_o = Resonance Frequency

W is the width of the patch

L is the length of the patch

h is the thickness of the substrate and patch εr is the relative permittivity of the dielectric substrate

c is the speed of light: $3x10^8$

Table 4.1 The parameters of the antenna design

Parameters Design	Material	Height	Length	Width	Epsilon
CDRA	Rogers R03400 C	3 mm	15.5(diameter)	-	55
Substrate	FR-4	1.568 mm	52 mm	40 mm	4.3
Ground	Copper	0.016 mm	52 mm	40 mm	-
Patch	Copper	0.016 mm	29 mm	28 mm	-
Micro-strip (big)	Copper	0.016 mm	7 mm	3 mm	-
Micro-strip (small)	Copper	0.016 mm	8 mm	0.3 mm	-

A study has been done on the parameters of the antenna design to analyze and observe the relationship of the parameters in the table shown above. When the width and length of the patch or micro-strip are changed, the output result will also vary. For this project, the expected resonant is frequency are 5.5 GHz with bandwidth output increased till 24%. Besides that, the radiation pattern and the return loss of the antenna design are also observed.

4.2 Simulation Result

S-Parameters or also knows as scattering parameters explains the electrical behaviour of linear electric networks when undergoing various steady state stimuli by electric signals. For this project, S11 parameter graph are considered as important since the graph determines and analyze the gain value and the range of bandwidth from the antenna. Besides that, the radiation pattern graph is also considered as important since the range of radiation can be observed from the graph.

4.2.1 Return Loss Result

The hybrid antenna that is designed using CST software is being simulated to obtain the S11 parameters result. Figure 4.2 shows the graph obtained from the simulation using the

CST software. According to the simulation result, the bandwidth that achieved by the design are 0.08 GHz (2.38 GHz – 2.46 GHz) and 0.11 GHz (5.44 GHz - 5.55 GHz). Besides that, the resonant frequency that achieved from the simulation is 2.4 GHz and 5.5 GHz with the gain of –12.6 dB and –17.94 dB respectively.

After the fabrication, the antenna is tested including with CDRA using the Field Fox Network Analyzer and S11 parameter graph is obtained as shown in the Figure 4.3. The bandwidth that is obtained from the testing is 0.07 GHz (2.52 GHz - 2.595 GHz) and 0.05 GHz (5.585 GHz – 5.635 GHz). For the resonant frequency, the tested measurement is 2.55 GHz and 5.61 GHz with the gain of –17.32 dB and –11.82 dB respectively.

From both the result, it is shown that for the both the case there is some variance in the value of the bandwidth. In the simulation, the result of bandwidth are different by 0.01 GHz and 0.06 GHz which are higher compared to the measured result. The gain obtained from the measured result are higher compared to the simulation result.

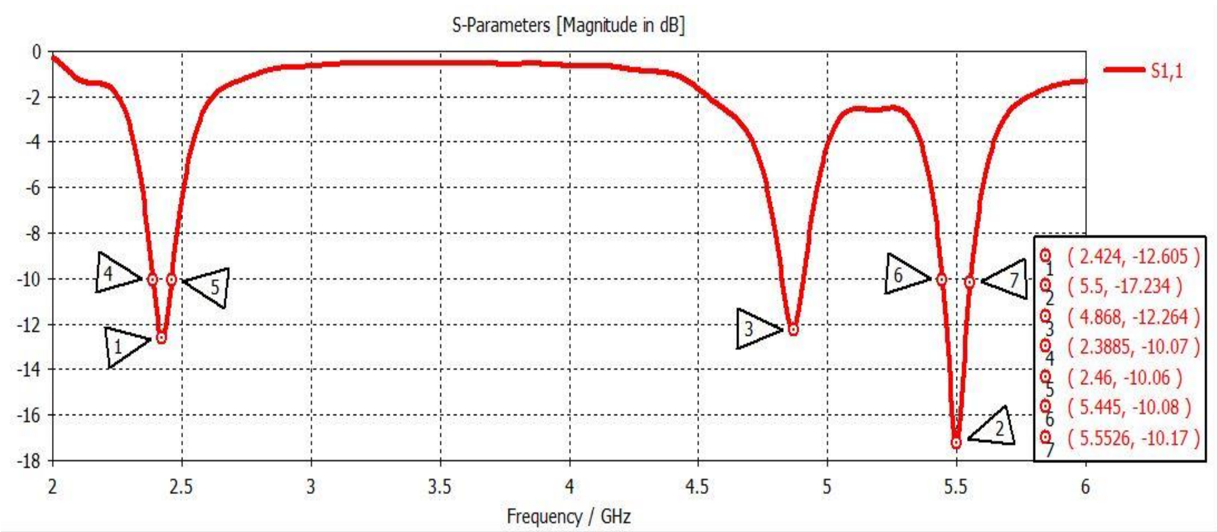

Figure 4.4 S11 Parameter graph (simulation)

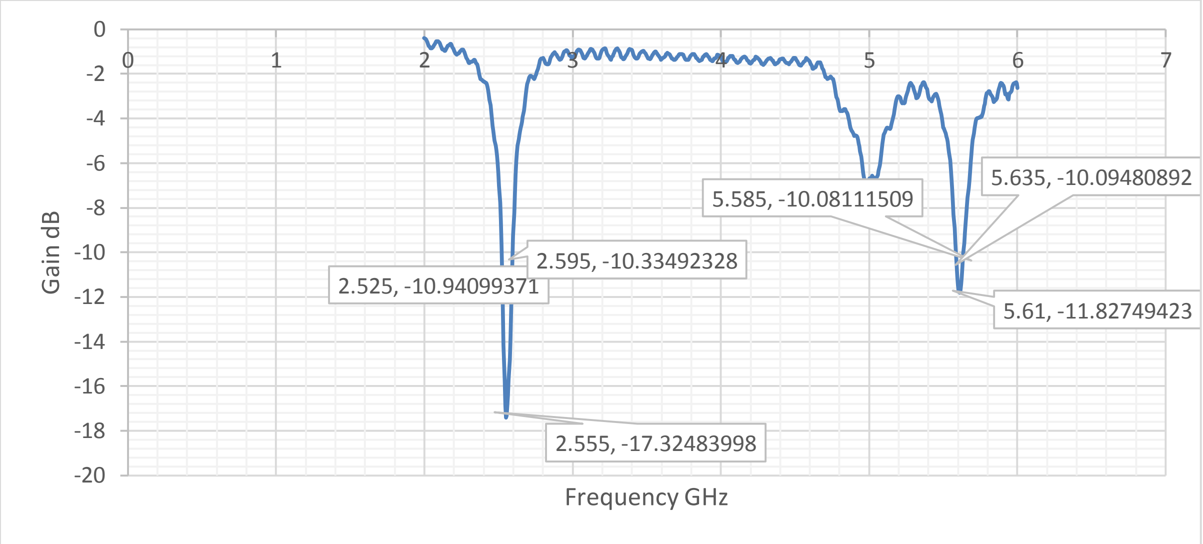

Figure 4.5 S11 Parameter graph (Measured)

4.2.2 Far Field Radiation Pattern Result

The combination of the electric and magnetic field strength of an electromagnetic wave vary inversely as the distance from the antenna and other contributions of the field strength are radiation patterns. To determine the antenna radiation pattern, the far field regions are important as antennas are used to communicate wirelessly from a long distance it is also important to knowing the region of operation. Basically, for the CDRA antenna, radiation will be in omni-directional and this type of radiation is suitable to be used as in an application of Wireless Local Area Network Communication (WLAN). As for Wireless Local Area Network (WLAN) will be placed at the higher position, more directional of the radiation from the antenna should be obtained.

Based on the simulation done on the antenna designed in the CST, the figure below shows the far-field radiation pattern with of the cylindrical dielectric antenna with micro-strip patch. In figure 4.3, it shows the radiation pattern of with an operating range of 2.4 GHz with a gain of 5.51 dBi and has an omni-directional pattern. For the testing of the fabricated antenna, horn antenna is being used to test the antenna far field radiation pattern. The testing of the antenna's radiation pattern procedure is stated in appendix A. In figure 4.7, it shows the measured radiation pattern of the antenna for 2.4 GHz operating range. It has almost the same pattern as in the simulation which is an omni-directional but a vary in the value of the gain which is 5.6 dBi. In figure 4.8 shows the simulation radiation pattern with operating range of 5.5 GHz with a gain of 4.14 dBi. For the measured radiation pattern it is shown in figure 4.10 whereby the radiation pattern is almost the similar which is also an omni-directional pattern whereby the gain is more on the left side at the front part of the antenna. The gain that obtained by the measurement is considered higher compared to the simulation which is 4.41.

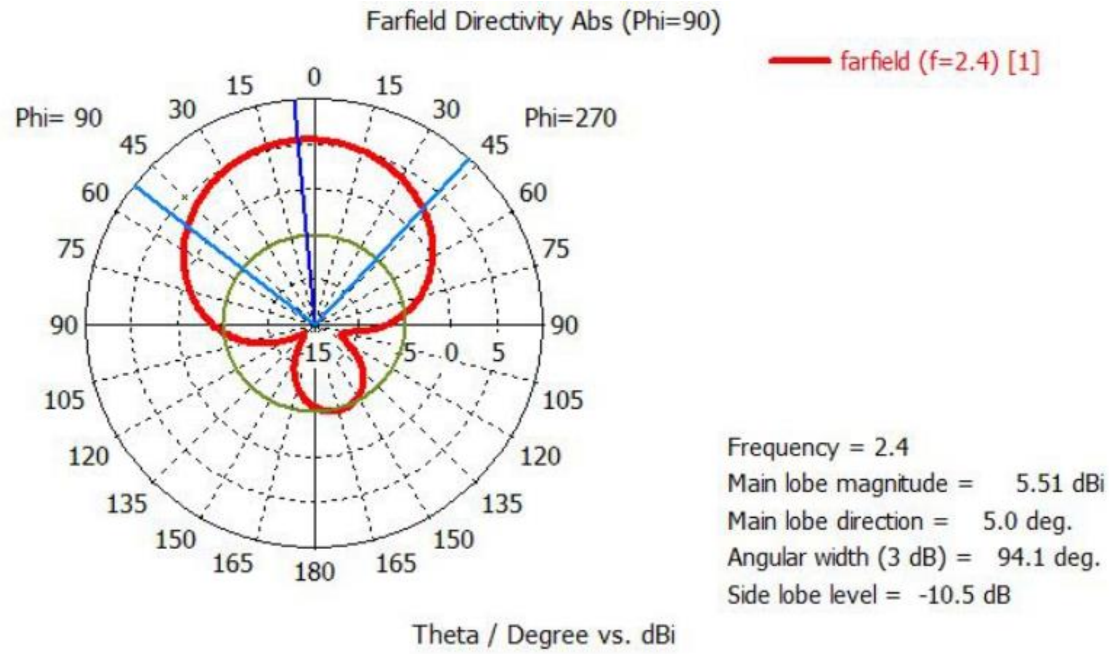

Figure 4.7 Far Field Radiation Pattern for 2.4 GHz (Simulation)

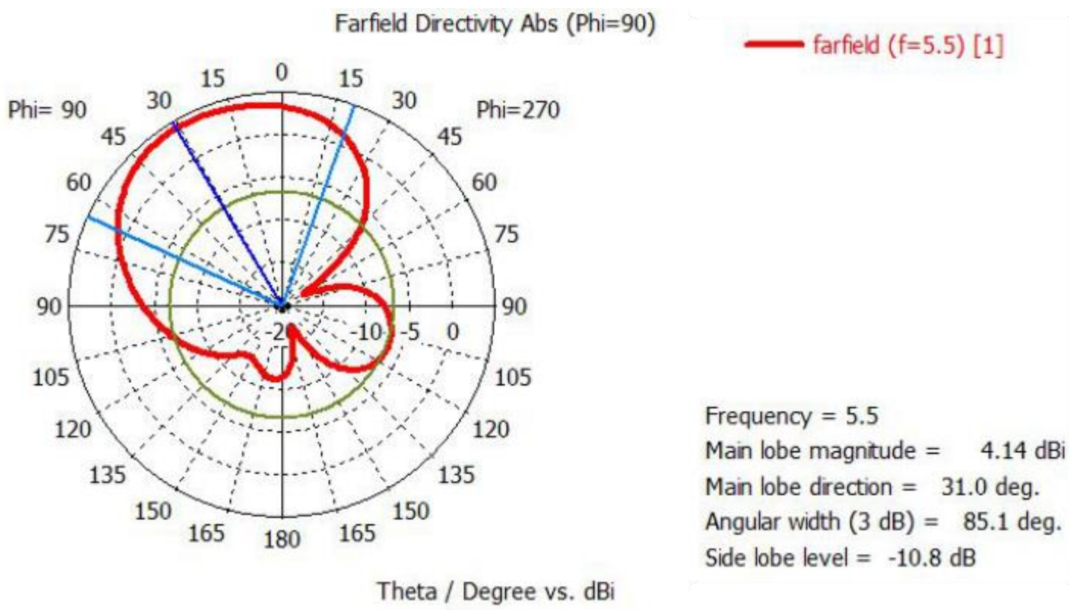

Figure 4.8 Far Field Radiation Pattern for 5.5 GHz (Simulation)

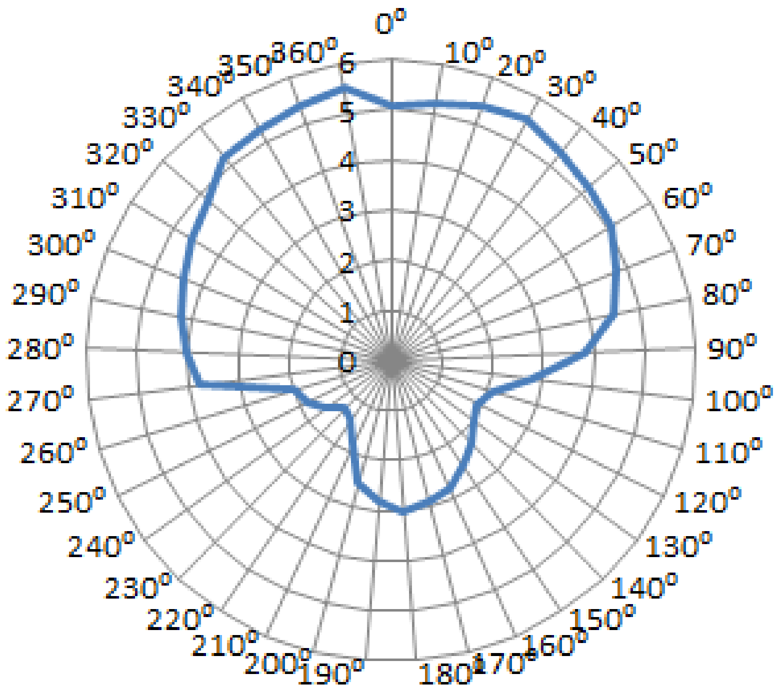

Figure 4.9 Far Field Radiation Pattern for 2.4 GHz (Measured)

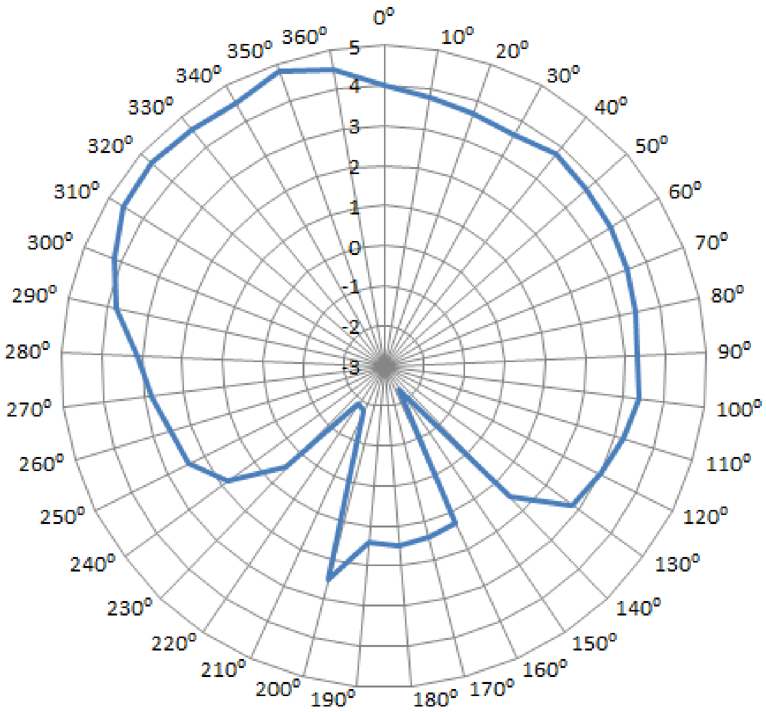

Figure 4.10 Far Field Radiation Pattern for 5.5 GHz (Measured)

4.3 Effect of Tuning the parameter of the antenna

A parametric study is done on the microstrip patch, microstrip feeding and microstrip on the antenna to obtain the optimum results for the antenna which are in the range of 2.4 GHz – 2.6 GHz and 5 GHz – 6 GHz. The effect of the varying the parameters of the patch, microstrip feeding and microstrip on the resonance frequency of the antenna are studied.

4.3.1 Effect of tuning microstrip patch width

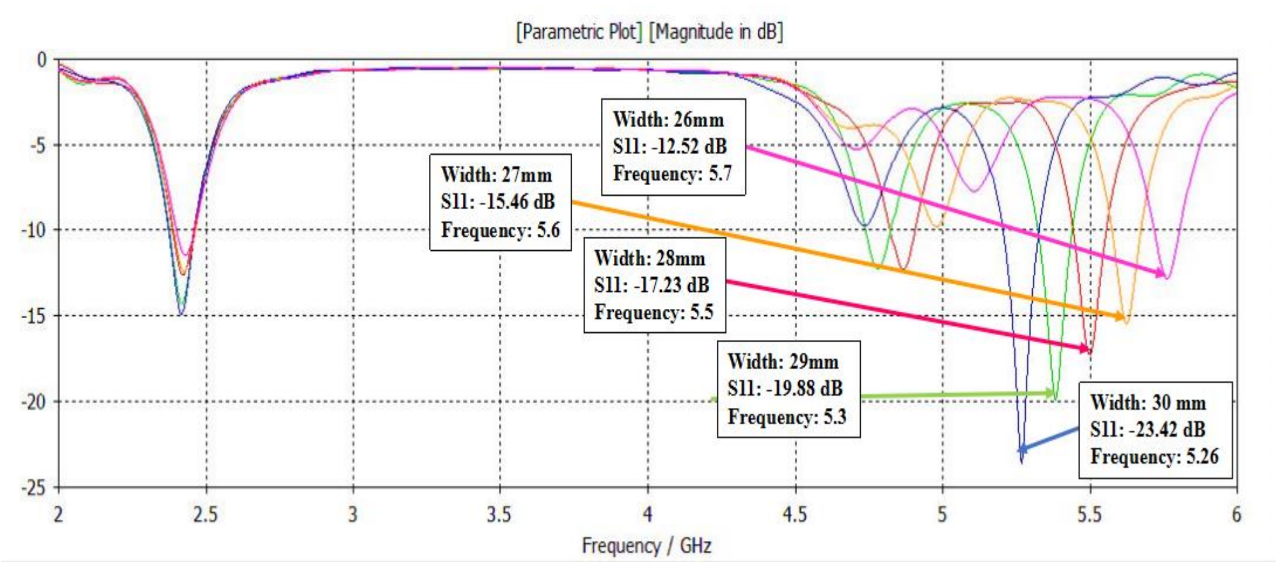

Figure 4.11 S11 Parameter Graph for effect of tuning Microstrip Patch width.

Figure 4.11 shows the effect of variation of micro-strip patch as the width of patch is varied from 26 mm to 30 mm. It shows that at resonance frequency at range 2.4 GHz varies in minimum values. All the resonant remains at 2.4 GHz to 2.45 GHz. The resonant is produced by dielectric resonator pallet. It is also shown that the resonance frequency varies from 5.7 GHz, 5.6 GHz, 5.5 GHz, 5.3 GHz, 5.26 GHz at the width of 26 mm, 27 mm, 28 mm, 29 mm, 30mm respectively. It is found that the return loss value increases at -12.52 dB, -15.46 dB, -17.23 dB, -19.88 dB, and -23.42 dB respectively. Somehow the impedance value at -10dB remains constant. It is also found that the resonant frequency decreases when the width of the patch increases. The resonant frequency can be observable in the range of 400 MHz with tuning range of 5 mm. Therefore, each 1 mm of variation of the patch width is able to increase the resonant frequency up to 100 MHz.

4.3.2 Effect of Microstrip Patch Length

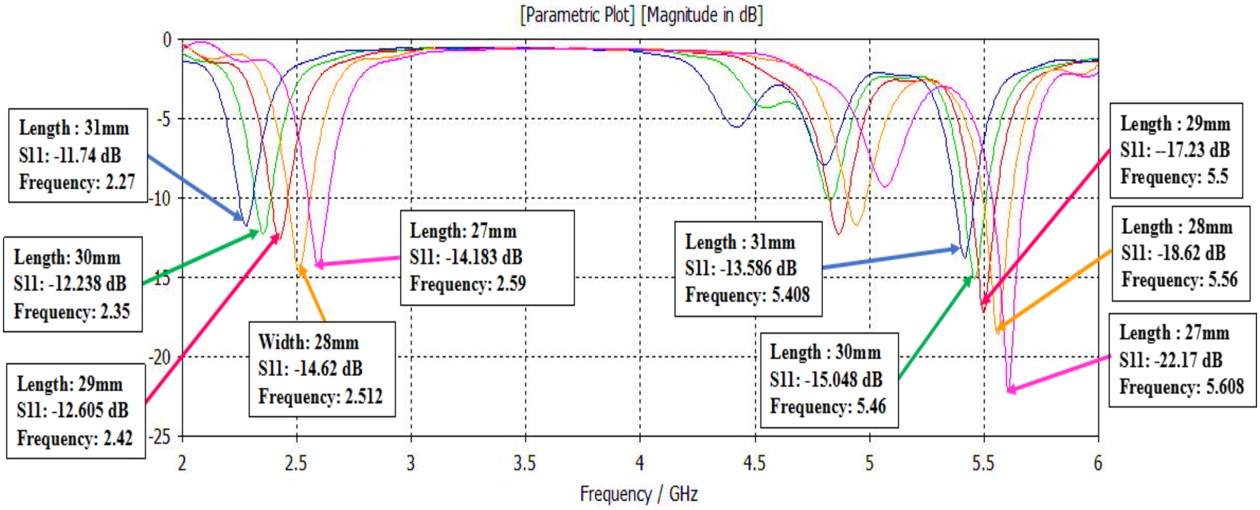

Figure 4.12 S11 Parameter graph for effect of tuning Microstrip Patch Length

Figure 4.12 shows the effect of variation of microstrip patch as the length of the patch is being varied from 27 mm till 31mm. It shows that the there is large variation for the resonant frequency at range of 2.4 GHz -2.6 GHz band and 5 GHz - 6 GHz band.

It is shown that the resonant frequency for 2.4Ghz -2.6 GHz band varies from 2.27 GHz, 2.35 GHz, 2.42 GHz, 2.512 GHz, 2.59 GHz at the length of 31 mm, 30 mm , 29 mm, 28 mm, 27 mm respectively. It is also found that the return loss value increases at -11.74 dB, 12.238 dB, -12.605 dB, -14.62 dB, -14.183 dB respectively. As for the impedance value at -10 dB, it has a constant value throughout the variation of the patch length. It is found that the resonant frequency increases when the length of the microstrip patch decreases. The resonant frequency can be formed in range of 320 MHz with tuning range of 5 mm. Each of 1 mm variation is able to increase the resonant frequency up to 80 MHz.

Besides that, the resonant frequency for 5 GHz - 6 GHz band varies from 5.408 GHz, 5.46 GHz, 5.5 GHz, 5.56 GHz, 5.608 GHz at the length of 31 mm, 30 mm, 29 mm, 28 mm, 27 mm respectively. It is also found that the return loss value increases at -13.586 dB, -15.048 dB, -17.23 dB, -18.62 dB, -22.17 db respectively. As for the impedance value at -10 dB it remains constant for the variation of patch length. It is also found that the resonant frequency increases as the length of the microstrip patch decreases. The resonant frequency can be formed in range of 200 MHz with the tuning range of 5mm. For each of 1 mm variation of the length it is able to increase the resonant frequency of up to 60 MHz. On the other hand, it is observable that the return loss parameter can be varies up -3.55 dB.

4.3.3 Effect of Microstrip feeding Length

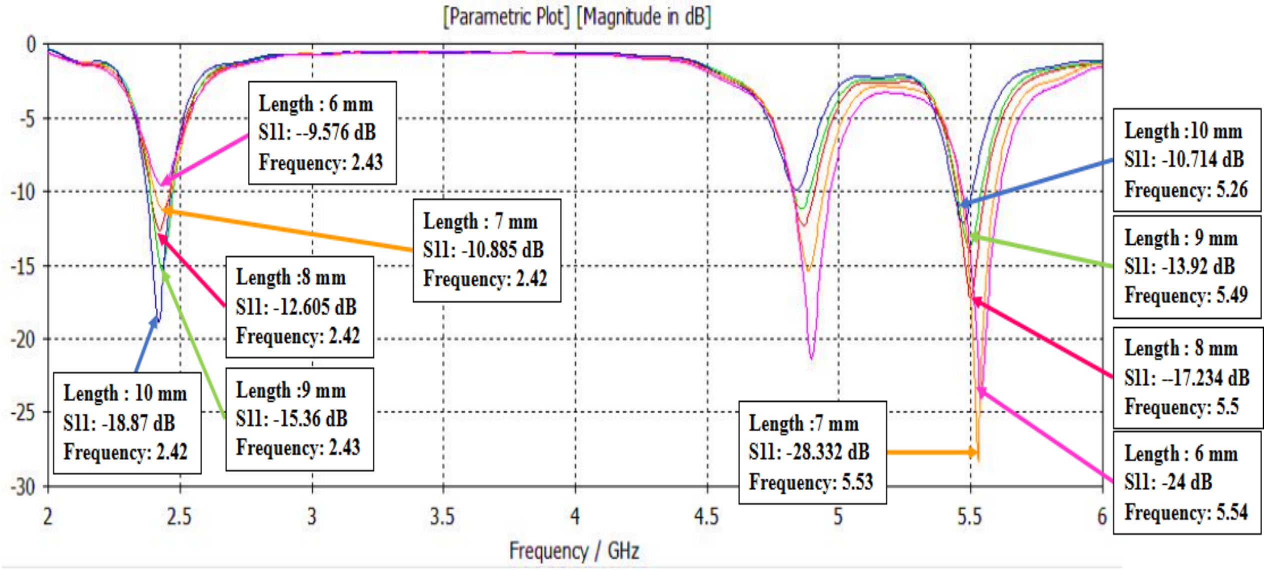

Figure 4.13: S11 Parameter graph for effect of tuning Microstrip Feeding Length.

Figure 4.13 shows the effect of variation of microstrip feeding as the length of the patch is varied from 7mm to 10 mm. It shows that the resonance frequency at range of 2.4 GHz and 5.5 GHz varies minimally. The resonant is produced by the the dielectric resonator pallets. It is shown that the return loss value for 2.4GHz band varies from -18.87 dB, -15.36 dB, -12.605 dB, -10.885 dB, -9.576 dB at the length of 10 mm, 9 mm, 8 mm, 7 mm, 6 mm respectively. Somehow the impedance value at -10 dB have a constant value throughout the varying size of microstrip feeding length. It is also found that the return loss value increases when the length of the microstrip feeding decreases. Each 1 mm of variation is able to increase the return loss value up to -3.51 dB.

As for 5.5 GHz band, the return loss value varies from -24 dB, -28.33 dB, -17.23dB, -13.92 dB, -10.74 db at the length of 6 mm, 7 mm, 8 mm, 9 mm, 10 mm respectively. For the impedance value at -10 dB have a constant value throughout the varying size of the microstrip feeding length. It is also observable that the return loss value increases from 7mm length onward. Each 1 mm of variation is capable to increase the return loss value up to -11.1 dB. The return loss value tends to increase back when the microstrip strip length is 6mm and below.

4.4 Summary

From the result obtained from the simulation and measured graph, there are certain factors that causes the result are not same. The factors are maybe due to the presence of air gaps, the fabrication of the antenna’s patch, the location of DRA in the antenna and the transmission loss factors in the cable used to test the antenna. The presences of air gaps are due to the DRA are not attached on the surface of the patch which causes air gap between the patch and DRA. Besides that, the variation in the size of the patch during fabrication will causes changes in the resonant frequency and bandwidth. The location of DRA will affect the far field radiation pattern whereby the location of the DRA is not the same as in the simulated design, therefore the result will vary. The port for the antenna soldered with excessive lead will causes the radiation of the antenna to affect therefore a proper soldering on the port must be done to avoid high variance.

Chapter 5: Conclusion

5.1 Conclusion

The project has achieved its objective which is to design a hybrid dielectric resonator antenna. The hybrid antenna is a combination of cylindrical dielectric resonator antenna and micro-strip patch to achieve dual band frequency of 2.4 GHz –2.6 GHz and 5 GHz –6 GHz in the industrial, scientific and Medicine (ISM) band for Wireless Local Area Network (WLAN) 802.11 a/b/g/n application. Simulation is done on designing the Hybrid Antenna with Computer Simulation Technology (CST) software to obtain the theoretical result from the antenna design before the design is send for fabrication.

The desired result is obtained by simulation where by the hybrid antenna has a bandwidth of 0.08 GHz (2.38 GHz – 2.46 GHz) with a gain of –12.16 dB at resonance frequency of 2.4 GH and 0.11 GHz (5.55 GHz – 5.635 GHz) with a gain of –17.94 dB at resonance frequency of 5.5 GHz. An observation is done whereby the micro-strip patch plays an important role to obtain a better bandwidth and gain for 5 GHz – 6 GHz band. The variation of the micro-strip feeding, can affect the resonance frequency for 2.4 GHz band. After the fabrication, the antenna is being measured by using a network analyzer but the reading are slightly different compared to the desired values that been done in the simulation. Although it varies, the antenna still in the range of the dual band frequency which are 2.4 GHz –2.6 GHz and 5GHz - 6 GHz.The simulation result of the far field radiation pattern is compared by with the measured radiation pattern and the radiation pattern are almost the same in way of the same type of radiation pattern which is omni-directional for both the band with the gain value which slightly different.

From the result, the hybrid antenna can be improvised in the term of bandwidth and gain so that the antenna is applicable in more usage for Wireless Local Area Network (WLAN) 802.11 a/b/g/n application. Tuning of the antenna parameters during the simulation especially the micro-strip patch and the micro-strip feed is important since it determines the desired range of frequency for this project. Therefore, the optimum design for the antenna design with the DRA application is clarified after the design have been simulated and measured.

5.2 Recommendation

In this project during the process of developing the antenna, there few problems that occurred. During the fabrication, the antenna parameters differ from the parameters that have been done in the simulation. A slight difference occurred in the fabrication causes in the variation of the measured result and the simulation result. So to ensure the antenna parameters are the same with the simulated design, it is recommended so that the fabricated antenna is measured manually before starting the testing on the fabricated antenna. Besides that, to enhance the performance of the antenna by using reflector to obtain higher directivity and at the same time could increase the antenna gain. By using a reflector, it also could increase the performance of the CDRA.

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Appendix A: Procedure to measure antenna gain using gain transfer method

Introduction

Gain is considered as one of the term in antenna datasheet and it is explained as the ratio of the intensity antenna. Antenna gain is mentioned as (dBi) in datasheets. dB refers to the ratio or gain by the antenna and "i' is the comparison to an isotropic antenna, a hypothetical antenna that radiates in every direction without any loss with equal intensity.

For the gain transfer method it requires 3 types of antenna which are 1 AUT, 1 reference and 1 unknown gain antenna. AUT is known as antenna under test and it is the antenna to find the gain (the designed antenna). The reference antenna is used as a benchmark whereby the gain (Gref) is accurate known. For the unknown gain antenna is not important to know the gain exactly but it much have enough dynamic range to transmit to the AUT.

S- Parameter is a term that is used in RF circuit design and it specifies the input-output relationship between ports in electrical system. Nowadays the modern network analyzer is able to measure S-Parameters due to the network always engaged with transmission medium with common characteristic of reference impedance, S-Parameters. They are able to relate directly to particular performance parameters known as insertion gain and return loss. The gain of AUT is obtained by applying the insertion loss S 21 value which represents the power transfer from Port to Port 2

Following are the procedure to measure the gain using Voltage Network Analyzer as shown Figure A1

1. The "unknown gain antenna" is mounted at the reference antenna (antenna with known gain) on two stands.

2. The distance between known gain antenna and reference antenna is defined as R. To calculate the distance R following are the equation,

$$R = 2D^2/\lambda$$

$$R >> D$$

Where

R is the distance between both the antennas

D is the linear maximum dimension of antenna.

3. The “unknown gain antenna is connected to port 1 (transmitter) and in port 2 (receiver) the reference antenna is connected.

4. Alignment is done until maximum gain is obtained.

5. S21 measurement is then activated.

6. At the network analyzer the frequency range is set from 5.0 GHz to 6 GHz.

7. Optimize the dynamic range.

8. Response/normalize calibration is performed to achieve a flat S21 response at dB across to preferred range of the frequency. The gain is currently normalized to the reference antenna.

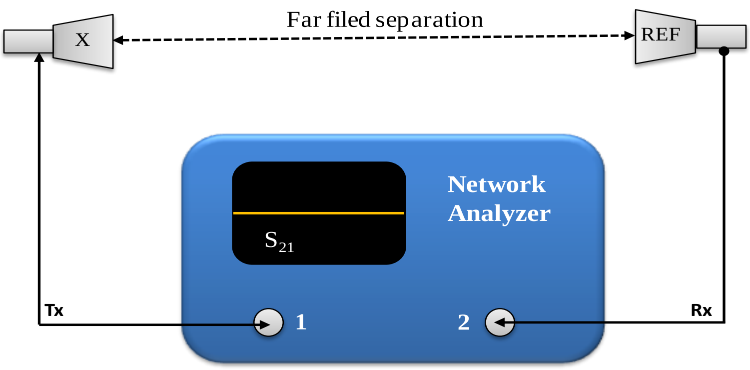

Figure A1: Setup for normalization to a reference antenna.

9. Reference antenna is replaced with the AUT (designed antenna) at the same position and alignment.

10. The new S21 values are recorded and it is the value for gain/loss $G_{relative}$ of the AUT relative to the reference antenna.

11. Following are the equation that is used to obtain the gain of AUT;

Example of Measuring the Antenna Gain Using Gain Transfer Method

By using step 1 to step 11, measuring is done for the antenna gain at 5.5 GHz and 2.4 GHz by using the gain transfer method. Total of three antennas is used to measure the antenna gain by using the gain transfer method which consists of 1 AUT (Cylindrical Dielectric Resonator Antenna), 1 reference antenna (Horn Antenna with 10 dB gain and 1 unknown gain (Horn Antenna).

Following are the procedure to measure the gain that is given;

1. The "unknown gain antenna" reference antenna is mounted as shown in figure A2.

2. The distance is calculate using the equation $R = 2D^2/\lambda$ and the value obtained from the calculation for this testing is 182.94mm whereby the dimension of antenna D, is 80mm and the λ is 55mm.

Figure A2: Setup for normalization to a reference antenna.

3. The testing is performed as by using the procedure from step 3 until step 9 stated in Appendix A.

4. The S_{21} value is recorded and the gain of reference antenna is added to determine the gain of AUT (Cylindrical Dielectric Resonator Antenna). The gain of AUT antenna is calculated by using the equation below which is 8.5 dBi.

5. The radiation of the antenna is obtained by rotating the AUT antenna 360° with the step size of 10°. The gain of the antenna at 5.5 GHz and 2.4 GHz for different angles is recorded in Table A1. The radiation pattern of the antenna is obtained by plotting values from the table A1 using sigma plot software.

Angle	Gain (diB) 2.4 GHz	Gain (diB) 5.5 GHz
0^0	5.1	4
10^0	5.2	3.8
20^0	5.4	3.7
30^0	5.5	3.6
40^0	5.3	3.8
50^0	5.2	3.7
60^0	5.1	3.6
70^0	4.8	3.5
80^0	4.5	3.4
90^0	3.8	3.3
100^0	2.8	3.4
110^0	2.1	3.2
120^0	1.9	3
130^0	2	2.82
140^0	2.3	1.5
150^0	2.5	-2.3
160^0	2.8	1.3
170^0	2.9	1.4
180^0	3	1.5
190^0	2.8	1.4
200^0	2.5	2.49
210^0	1.81	-1.8
220^0	1.4	-1.9
230^0	1.3	0.5
240^0	1.6	1.8
250^0	1.8	2.4
260^0	2	2.5
270^0	3.8	2.8
280^0	4	3.1
290^0	4.2	3.8
300^0	4.4	4.2
310^0	4.6	4.6
320^0	4.8	4.7
330^0	5.2	4.6
340^0	5.3	4.5
350^0	5.4	4.8
360^0	5.5	4.5

Table A1: Gain of the antenna in different angle.

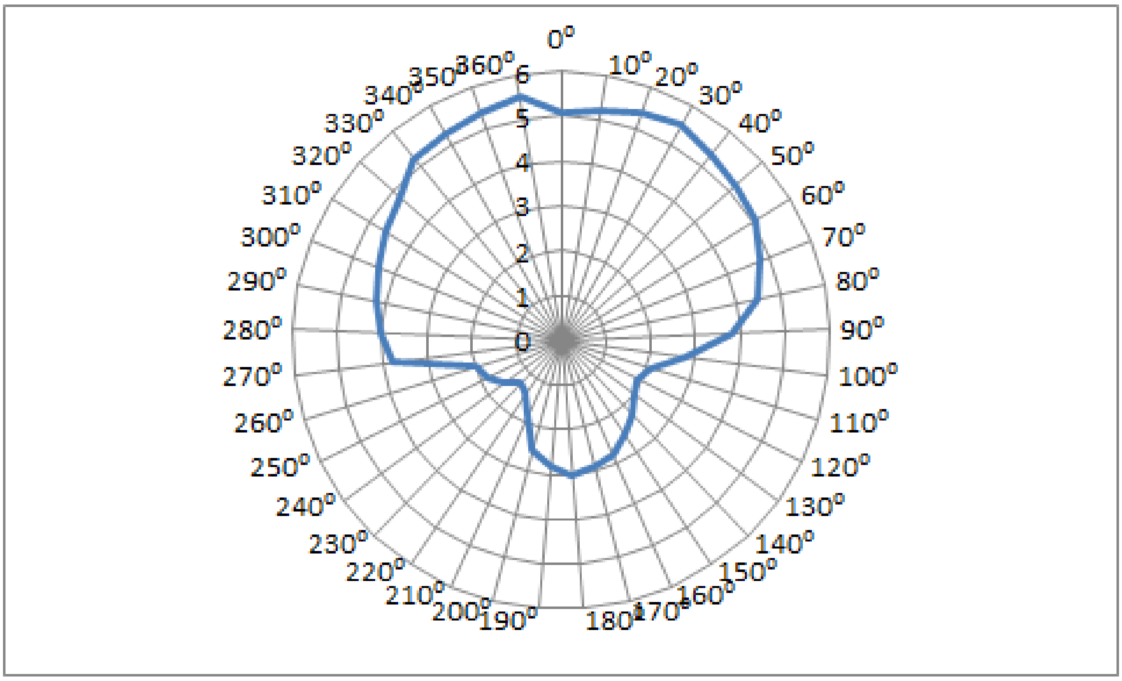

Figure A3: Example of radiation pattern for 2.4 GHz measured by using gain transfer method.

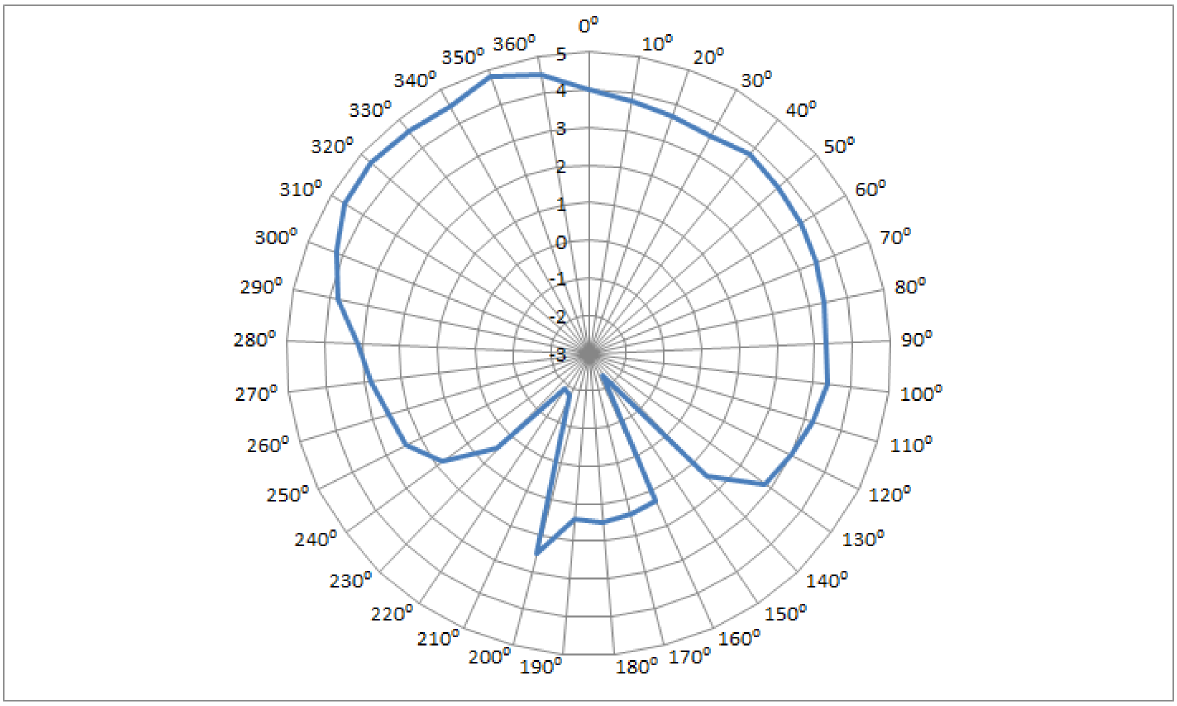

Figure A4: Example of radiation pattern for 5.5 GHz measured by using gain transfer method.