INVESTIGATION OF THE MICROSTRIP LINE FEEDER EFFECT TO RESONANT FREQUENCY

BY

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15199

FINAL YEAR PROJECT

Submitted to the Department of Electrical & Electronic Engineering
In Partial Fulfillment of the Requirements
For the Degree
BACHELOR OF ENGINEERING (HONS)
(ELECTRICAL & ELECTRONIC ENGINEERING)

MAY 2013

Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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Approved by,

____

(En Mohd Azman Zakariya)
Project Supervisor

Universiti Teknologi PETRONAS

Tronoh, Perak

May 2014

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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Syaza Hannah Mohd Yusof

ACKNOWLEDGEMENT

First and foremost, I would like to thank Allah for giving me the strength and ability for me to complete my final year project according to the time given. Without His guidance and blessings, I will not be able to complete these semesters project with a success. Eventhough there were so many things happened in between this project period, He still gives me this opportunity for me to complete my task.

Second of all, I would like to express my deepest and heartfelt gratitude to both of supervisor and co-supervisor, En. Mohd Azman Zakariya and A.P Dr. Zuhairi Hj Baharuddin, for giving me guidance and continuous advice to make sure that I am able to finish my work by not just completed it but also to understand what the project is all about. Thank you so much for all guidance, knowledge and patience as to make sure that I will not be in the wrong step and keep me in track with the progress from time to time.

Furthermore, I would like to acknowledge with much appreciation the crucial role of the Technologist, Mr Adz Jamroz and also to all post-graduate students who gave me their helping hands to use all required equipments and the necessary material for me to complete my task. Thank you for all the assistance and guidance that they have given to me throughout this final year project period.

Special thank you goes to my beloved family for giving me continuous support and prayers. Not to forget, I would also to thank my teammates, Khairiah Hj. Ramli and Farahatul Khalida, who help me and gave suggestions for me to improve and support me whenever I’m at my weakest point and tend to give up. Thank you again to each and everyone who gave me support and helps during my final year project period.

ABSTRACT

This paper presents a study on the investigation on the microstip line feeder effect to its resonant frequency. The application of the cylindrical DRA (CDRA) and microstrip line is used to observe the relationship between these two variables. The microstip line will be varied according to the width and the length of the microstrip. All designs are simulated by using the Computer Simulation Technology (CST) software in order to get the desired resonant frequency and the bandwidth of the microstrip line design. Tuning of the resonant frequency is made if the designs are not achieving the desired outcome. The optimum parameter of the CDRA and microstrip line design is analyzed to obtain the operating frequency between ranges of 4 GHz to 5 GHz application. The simulation and measuring the project prototype is made to analyze the results and observe the comparisons between theoretical and experimental values. From this, the design optimum performance of the antenna can be improved and obtained at the end of the project period.

LIST OF FIGURE

LIST OF TABLE

LIST OF ABBREVIATIONS

DRA	Dielectric Resonator Antenna
CDRA	Cylindrical Dielectric Resonator Antenna
CST	Computer Simulation Technology
FYP	Final Year Project
CCTO ($CaCu_3Ti_4O_{12}$)	Calcium Copper Titanium Oxide
FR4	Flame Retardant
PCB	Printed Circuit Board
UHF	Ultra-High Frequency

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Antenna is a typically and importance device for mobile radio communications systems for aircrafts and space vehicles as the function is to transmit or receives radio frequency signals [1]. Precisely, antenna is extremely important wherever wireless communication required. Various designs have been implemented related to the antenna in order to make sure that the required resonant frequency will be achieved and improvised from time to time.

Antenna has been implemented in order to improve the gain, resonant frequency and its bandwidth and it is also a type of an electrical device that converts electric power to radio waves. There are a few types of antenna which has received much attention and gained popularity and become a major research topic in both theoretical and applied electromagnetic and in the arena of modern communications. Microstrip or patch antennas and dielectric resonator antenna (DRA) have been widely used among the users and improved its design as to make sure that the application will be much broader.

Generally, physical characteristics of DRA are light in weight, and have thin profile, that can be made conformal to the host vehicle or equipment and in making it suitable for aerospace and mobile applications [2]. In other words, DRA is relatively inexpensive to manufacture and design because of the physical geometry. These antennas usually employed at ultra high frequencies (UHF) and higher frequencies because of the antenna are directly tied to the wavelength at the resonant frequency. Common DRA shapes are hemispherical, rectangular and cylindrical shapes. Various studies according to these DRA have been conducted to observe the effect on its resonant frequency. As shown in Figure 1.1 is the example of DRA.

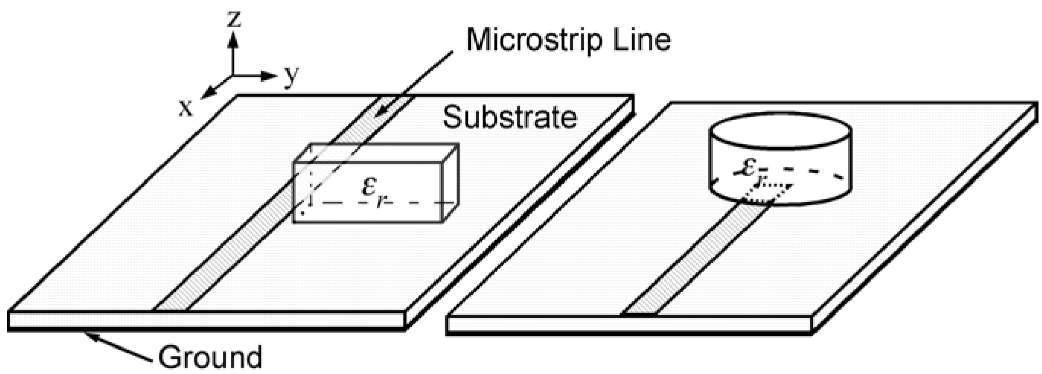

FIGURE 1.1: Dielectric Resonator Antenna

Dielectric resonator antenna (DRA) is the development of low-loss ceramic materials as high-Q (low-loss) elements for circuit applications, such as filters and oscillators which offer more compact alternative to the waveguide cavity resonator and a more amenable technology for printed circuit integration. To prevent radiation and thus maintain a high quality-factor, DRA is usually shielded (enclosed in metal cavities) that is required for filter and oscillator designs. The advantage of DRA is its high degree of flexibility and versatility, allowing for the designs to suit a wide range of physical or electrical requirements of varied communications applications. The performance of the basic DRA elements was summarized and studied to predict the resonant frequency and Q-factors for several DRA shapes [14].

The coupling of DRA can have a significant impact on the resonant frequency and Q-factor. An examination of the internal field configuration within rectangular and cylindrical DRA is essential for understanding how the various feeds can excite different modes within the DRA. Power must be coupled into or out of the DRA throughout one or more ports and this will determine which mode will be excited and how much power will be coupled between the port and the antenna. The mode or modes generated, the amount of coupling, and the frequency response of the impedance are all important in determining the performance of the DRA [14].

The purpose of this project is to investigate and analyze the effect of microstrip line feeder for DRA. The works involve design approaches by varying the parameter of the microstrip line feeder of the DRA. The analysis of the resonant frequency due to microstrip line feeder will be analyzed. The performance of the optimum design for the DRA will be fabricated and measured.

1.2 Problem Statement

DRA has been used widely in communications because of its features which are light weight, low profile and ease of fabrication and great compatibility with planar integrated circuits and even non planar surface [12]. By maintaining the features and parameters of the microstrip antenna and DRA application, this project will emphasize the effect changes of resonant frequency by varying the micro strip length and width of the antenna. Due to the hardness of fabricating the DRA and it involves complicated process, this modification by varying the microstrip line will be made in order to achieve the required range of resonant frequency.

1.3 Objectives

The aims of this project are:

- To study the relationship of micro strip line feeder effect to the resonant frequency and DRA application.
- To design and analyze the optimum parameter of the cylindrical DRA (CDRA) design with the operating frequency between ranges of 4 GHz to 5 Ghz application.

1.4 Scope of Study

This project studies the topic of the direct microstrip line coupling technique for design of the CDRA operates at resonant frequency in range of 4 Ghz to 5Ghz. The design of the antenna is simulate using Computer Simulation Technology (CST) software in order to achieve the resonant frequency. The comparison between the theoretical and experimental values will be analyzed in order to improvise the designs optimum performance of the antenna.

CHAPTER 2

LITERATURE REVIEW

In recent years, communications have advances and become a way of life of societies all over the world. The increases number of users will lead to the complexity of the antenna system required to be increased. The study of various designs of antennas has been conducted over the years based on its theoretical and applied electromagnetic and also in the area of modern communication system [3]. In addition, the designs of the antennas which can operate over multiple bands will have a huge demand due to their vital role in wireless communication system [7].

Based on literature [2], the concept of DRA has been proposed in 1960. Throughout these years, DRA has been received so much attention and popular due to the advantages they have over the conventional microwave antenna. The DRA is used in broad range applications from communication systems to biomedical systems. The major reason for that is due to their features such as their simplicity, conformability, low manufacturing cost, light weight, low profile, reproducibility, reliability and ease in fabrication [8]. From this paper, it stated the accurate determination of the resonant frequency in every design of DRA. From this literature, it determines that the resonant frequency is also related to the antenna's bandwidth.

A dielectric object that has free-space boundaries can resonate in various modes and it has been known for many years [11]. For fundamental mode, the basic parameters of a single resonator for the analysis of coupling coefficient between dielectric resonators are resonant frequency, field distribution, stored energy and magnetic pole-dipole moment [11]. From [14], since there are three basic shapes for this DRA which are hemispherical, cylindrical and rectangular, this will eventually affect the resonant frequency and the Q-factors.

2.1 Hemispherical DRA and Cylindrical DRA

This antenna consists of a material with a dielectric constant of ε_R and radius of a. Hemispherical DRA is assumed to have infinite conductivity and be infinite in extent because it is mounted on a ground plane. The resonant frequency and radiation Q-factor will be examined accordingly to these modes which are TE_{11}, lowest mode and TM_{101}, radiates like a short electric monopole antenna and typically excited using a probe located at the centre of DRA.

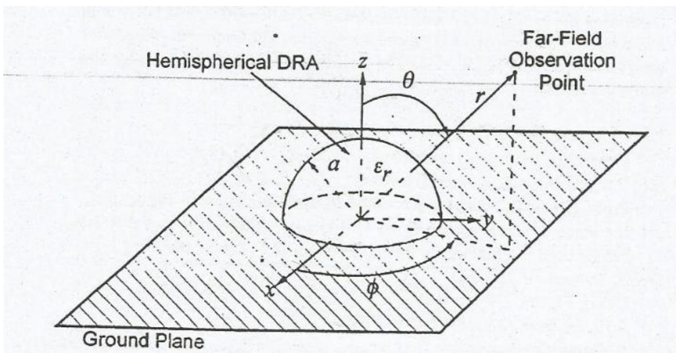

FIGURE 2.1: Hemispherical Dielectric Resonator Antenna

For many recent years, cylindrical DRA has been widely used in circuit applications. This is due to its high Q-factor and compact size which make them ideal for use in filters and oscillators especially in microstrip technology. Most literatures discuss to the field configuration, resonant frequency and coupling behavior of the cylindrical dielectric resonator in the context of circuit applications. As shown in Figure 2.2, this antenna is characterized by a height h, a radius a, and a dielectric ε_R. Compared to hemispherical shape, cylindrical shape offers one degree freedom more and the Q-factors for these two resonators will be different. This is due to the aspect ratio a/h. From this, the designer can choose the suitable aspect ratio to best realize the desired frequency and bandwidth with this cylindrical DRA. The resonant frequency and radiation Q-factor of the three lowest modes cylindrical DRA can be divided into three type which are TE, TM (both modes are axially symmetric and have no azimuthal dependence) and hybrid modes (have dependence on azimuth).

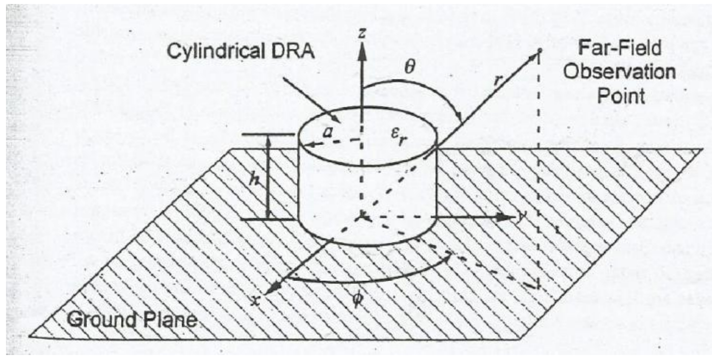

FIGURE 2.2: Cylindrical Dielectric Resonator Antenna

2.2 Rectangular DRA

As shown in Figure 2.3, rectangular DRA is characterized by a height h, a width w, a depth d, and dielectric constant ε_R. In different with cylindrical DRA, rectangular DRA offers a second degree freedom in making it more versatile based on its shapes. The design of this antenna can be very flexible in order to achieve the desired profile and bandwidth characteristics for a given resonant frequency and dielectric constant because the ratios w/h and w/d can be chosen independently. Modes of an isolated rectangular dielectric can be classified as TE and TM but when the DRA mounted on the ground plane, the excitation will be at TM modes.

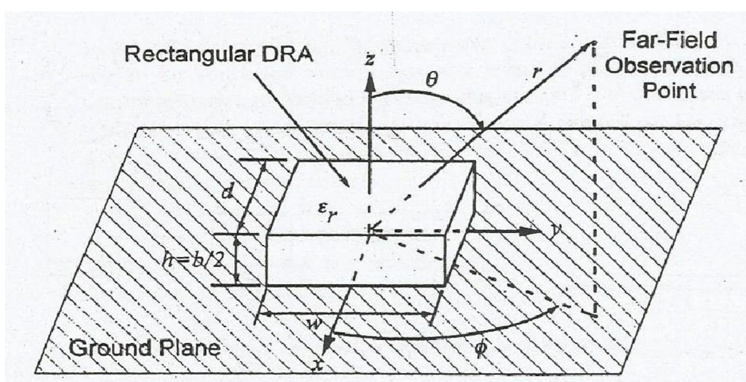

FIGURE 2.3: Rectangular Dielectric Resonator Antenna

2.3 Direct Coupling

Many techniques have been used to excite the DR such as direct coupling or microstrip line coupling but this method is the common method to DR in microwave circuits [7]. In this technique, the transmission line and DRA are placed on the back side of the ground plane. The amount of coupling depends on the permittivity of the DR, distance between the microstrip line and DR. However, the main disadvantage for this technique is that it produces cross polarization which generated the magnetic field inside the resonator parallel to the transmission line.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The research methodology has been outlined as shown in Figure 3.1 below for final year project 1 &2.

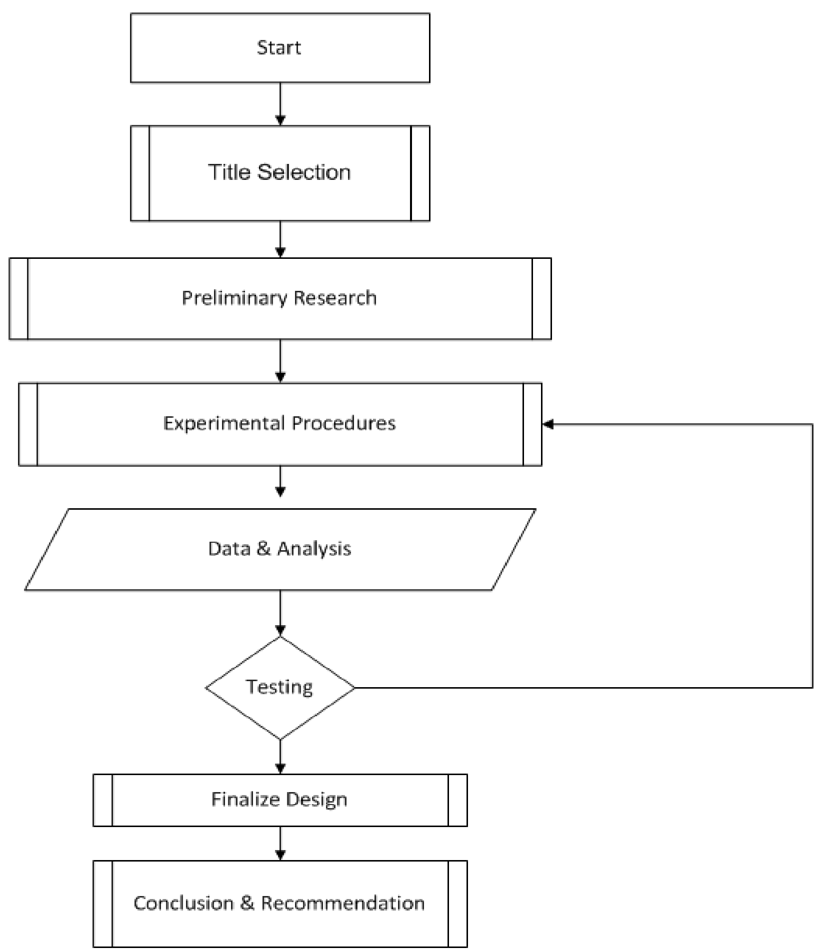

FIGURE 3.1: Research Methodology

3.2 Project Activities

Preliminary Research

The background study on previous work of DRA designs are studied and reviewed. Research papers that emphasize about the antenna designs parameter, direct coupling technique, testing and measurement are been focused and highlighted.

Experimental Procedure

The design and simulation of CDRA in the CST software simulation has been conducted and preliminary designs have been made. The modification of the designs is to maximize the antenna performance by adjusting the configuration. Important parameters in the design are the microstrip line and CDRA as to obtain the desired range resonant frequency and to radiate the electromagnetic wave. The length and width of the microstrip line are adjusted for each design in order to achieve the desired range of resonant frequency.

Data and Analysis

Collection of results from the simulation of CST will be obtained. The simulation result is analyses on resonant frequency, return loss, impedance bandwidth, radiation pattern and gain. The effect of the adjustment of microstrip line feeder and the resonant requested are investigated and analyzed.

Testing and Finalized Design

Before the measurement of all design, the best design will be fabricated at PCB lab. All designs are tested using Fieldfox handheld spectrum analyzer and the final design will be chose according to the best optimum performance. Results from the simulation and measurement will be compared.

Conclusion and Recommendation

The overall design parameters and result for both simulation and measured will be described and highlighted according to the resonant frequency tuning that has been made. Few recommendations are made in order to improve for the future work.

3.3 Project Flow/Gantt Chart

TABLE 3.1: Project Flow/Gantt Chart

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Title Proposal																												
2	Preliminary research work and preparing proposal																												
3	Submission of extended proposal							X																					
4	Propose designs																												
5	Fabrication and simulation																												
6	Gathering material and data collection																												
7	Submission of interim draft report																												
8	Submission of final interim report														X														
9	Progress Report															X													
10	Finalise Fabrication																												
11	Design Testing																												
12	Compilation and analysis of data																												
13	Submission of draft report																												
14	Submission of dissertation report																												X

3.4 Tools and Equipments

3.4.1 Hardware

List of hardware used for measuring the equipment:

- Fieldfox handheld spectrum analyzer

Figure below show the set up of experiment before measuring the designs.

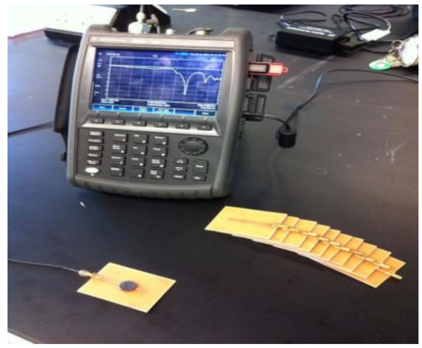

FIGURE 3.3: Set up of Experiment

The procedures followed to measure the return loss, S11 and resonant frequencies are presented below:

1. Calibrate the FieldFox handheld spectrum analyzer for required frequency band (4 GHz-6 GHz).
2. Connect the device (designed antenna prototype) using one of the two ports through RF cable.
3. Place the CDRA at the required position on the PCB board and record the measurements.

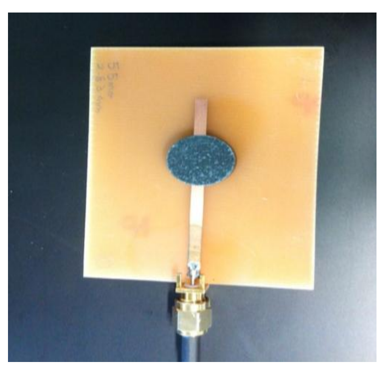

Figure 3.4: CDRA placement

3.4.2 Software

- CST Microwave Studio

  The designs of this project will be simulated by using this software. By adjusting the length and the width of the microstrip, the output of the project will be obtained and best optimum performances will be finalized to proceed to the next stage of this project which is the measurement of the designs.

- SigmaPlot

  Data obtained as in graphs will be plotted by using this software. This software is much easier compared to other software.

- Microsoft Excel

  Values obtained will be recorded using this software.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will present the results and discussion of cylindrical dielectric resonator antenna (CDRA) and the microstrip line feeder designs. All designs have been varied accordingly to its length and width and direct coupling technique has been used for the design.

The direct coupling technique or microstrip line coupling is important in order to excite the CDRA. The microstrip line and CDRA are place on the back of ground plane as shown in the Figure 4.1. Direct coupling is depending on the amount of the permittivity of the dielectric resonator, distance between the microstrip line and dielectric resonators. [2]

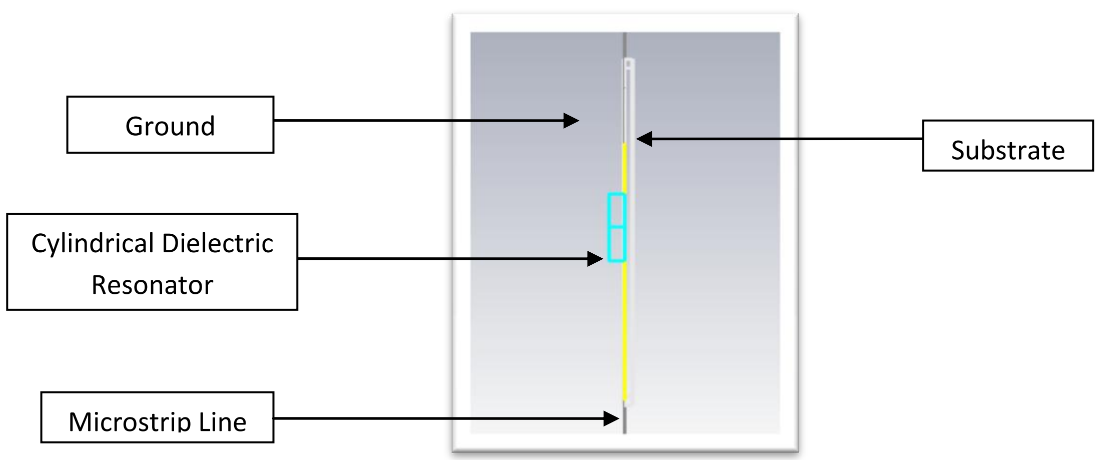

FIGURE 4.1: The Microstrip Line Coupling

The results of all designs by varying the length and width of the microstrip line will be obtained by doing the simulation using the CST software. The results in terms of bandwidth, radiation pattern and resonant frequency will be shown through the simulation graph.

4.2 Preliminary Design

The direct coupling of CDRA fed by microstrip transmission line is designed and simulated using the CST software before it is being fabricated and Figure 4.2 and Figure 4.3 are the example of the preliminary design with parameters that needs to be followed.

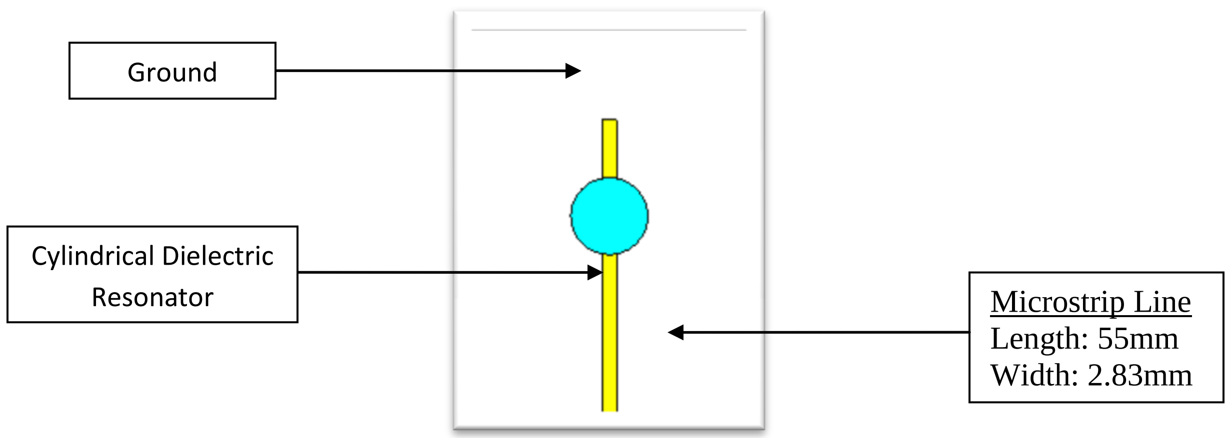

FIGURE 4.2: Front view of the design

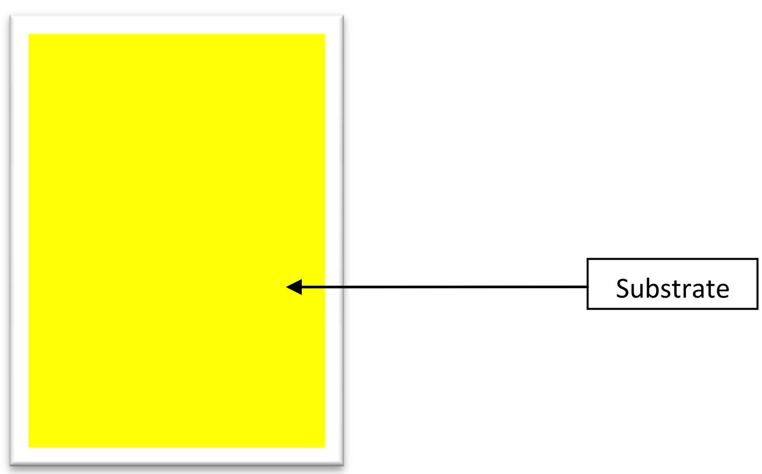

FIGURE 4.3: Back view of the design

The preliminary antenna design is fabricated after achieving satisfactory simulation results by using CST. Figure 4.1 and 4.2 show the front and back view of the antenna design. The design includes ground plane, cylindrical dielectric resonator antenna (CDRA), microstrip line and substrate. The CCTO ($CaCu3Ti_4O_{12}$) dielectric material with permittivity of 55 is used to fabricate CDRA. The amount of coupling will depend on the permittivity of the dielectric material and distance between the microstrip line and the DRA. For the substrate, the FR-4 board with permittivity ε_s=4.9 and thickness h_s=1.6 mm is being implemented. The length and width of the microstrip line is varied in each fabricated design and the material used for this microstrip line is copper. This is because copper has the ability to minimize power dissipation, improve reliability, good conductor and affordable to manufacture. The final antenna circuit design is fabricated by utilizing the PCB fabrication Lab and Wireless Communication Lab facilities, which is carried out by providing the layout of the design to a fabrication lab in the form of gerber file.

TABLE 4.1: Parameters in the design

CDRA	
Material	CCTO
Epsilon	55
Mue	1
Outer Radius	7.2 mm
Height	3 mm
Microstrip Line	
Material	Copper
Mue	1
Electric Conductivity	5.8e+007
Thickness	0.034 mm
Ground	
Material	Copper
Mue	1

Electric Conductivity	5.8e+007
Thickness	0.034 mm
Substrate	
Material	FR-4
Epsilon	4.9
Mue	1
Thickness	1.6 mm
Width	52 mm
Lentgh	72 mm

Parametric study has been conducted in order to observe and analyze the relationship between all parameters as shown in Table 4.4, such as the length and width of microstrip line with the CDRA. The effects of changing the tuning parameters on the resonant frequency, bandwidth, radiation pattern and the return loss of the antenna design are being observed and discussed.

4.3 Results and discussion

4.3.1 Simulation Result

4.3.1.1 Return Loss Level

In practice, the most commonly quoted parameter to antenna is return loss S_{11}. Antenna return loss S_{11} represents how much loss of power in the signal is reflected or returned by discontinuity in a transmission line. The return loss S_{11} is obtained after the simulation of the design using the CST software. The return loss S_{11} from the simulation are taken below -10dB that indicates the power loss reflected is about 10% over the entire frequency band. As shown in Figure 4.5 is the return loss s_{11} graph versus the resonant frequency from the first preliminary design with length of 55 mm and width of 2.83 mm.

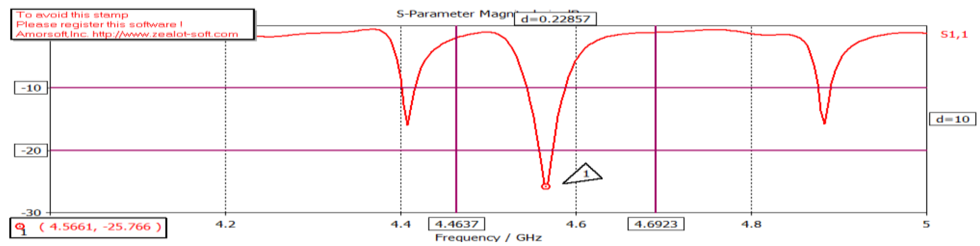

FIGURE 4.5: Graph of Return Loss s_{11} versus Resonant Frequency

From the Figure 4.5 above, the highest value of resonant frequency over the entire frequency below -10dB was taken in order to compare the results from the other designs. From the resonant frequency, the return loss will be observed and different designs may contain different value of resonant frequency and return losses. From figure 4.5 and 4.6, the simulated resonant frequency value is 4.5561 GHz, return loss value, S_{11} is -25.766 dB and impedance bandwidth value is 0.046154 GHz. Overall results for every design are shown in Table 4.2 below. Apart from the value of the return loss, S_{11}, value of bandwidth and the resonant frequency, the radiation pattern of the design also can be obtained after the simulation.

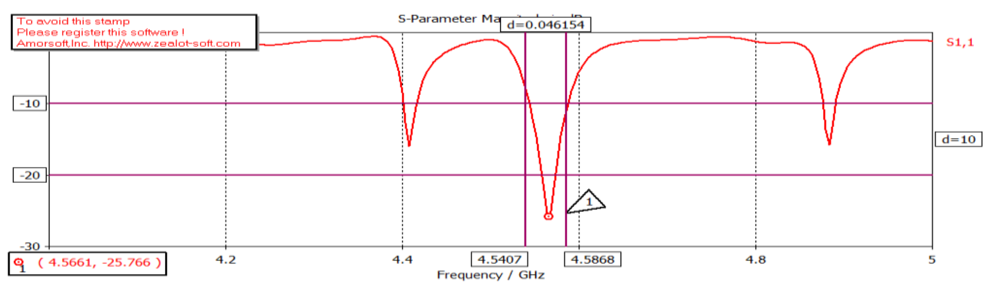

FIGURE 4.6: Graph of Bandwidth

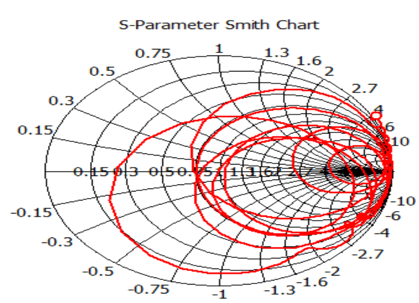

FIGURE 4.7: Radiation Pattern of the Design

4.3.1.2 Effects of Microstrip Length

By adjusting the length and width of the microstrip line, different values of resonant frequencies, radiation pattern and bandwidth are obtained. Table 4.2 shows the simulated result of the variation of microstrip length to the resonant frequency and impedance bandwidth.

TABLE 4.2: Table of Simulation Result

No	Length (mm)	Width (mm)	Resonant Frequency (GHz)	Bandwidth (GHz)
1	55	2.83	4.576	0.04615
2	55	3.00	4.575	0.03205
3	55	3.25	4.570	0.03427
4	55	3.50	4.566	0.03782
5	55	3.75	4.565	0.03875
6	55	4.00	4.660	0.03901
7	57.5	2.83	4.550	0.01942
8	60	2.83	4.535	0.01114
9	62.5	2.83	4.525	0.00848
10	65	2.83	4.520	0.01219
11	67.5	2.83	4.505	0.00594
12	70	2.83	4.445	0.01099

The effects of varying the length and width of the microstrip line are to improve the performance the direct coupling to the CDRA, to get the desired resonant frequency and to find the optimum bandwidth. From Table 4.2 above, the values of resonant frequencies obtained were in the desired range of the resonant frequencies which are between 4 GHz to 5 GHz. By varying the width of the microstrip line, the smaller the width of the microstrip line will obtain the optimum value of bandwidth. Optimum bandwidth was also obtained at shorter length of microstrip line from the simulation. Besides bandwidth, by varying the length and width of microstrip line, the resonant frequency obtained also changed from 4 GHz to 5 GHz. Despite that, the resonant frequencies are still in the desired range of resonant frequencies for this project.

4.3.2 Comparison between Simulation and Measured Result

The fabricated antenna designs will be measured using the FieldFox handheld spectrum analyzer in order to measure the return loss (S11) and resonant frequencies. The validity of the fabricated prototype is verified by comparing measured results against CST simulation results

The graph from the simulated and measured value are plotted using the SigmaPlot software in order to see the differences between these two results.

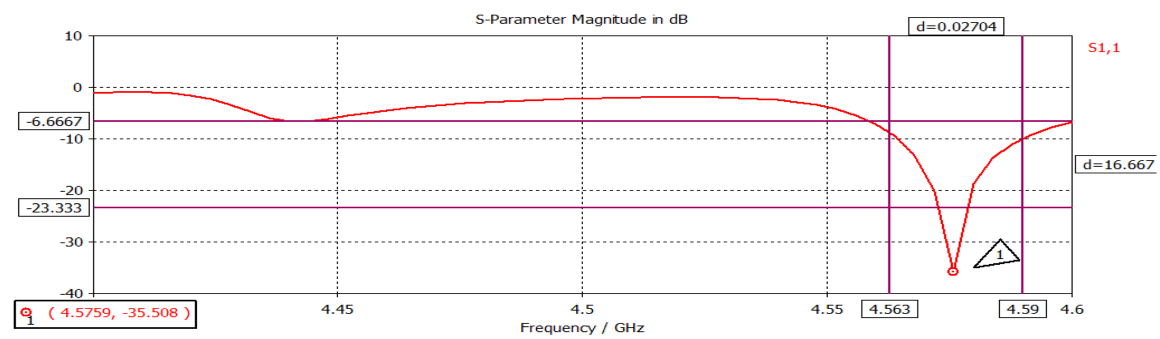

FIGURE 4.9: Simulation Graph of Design 1

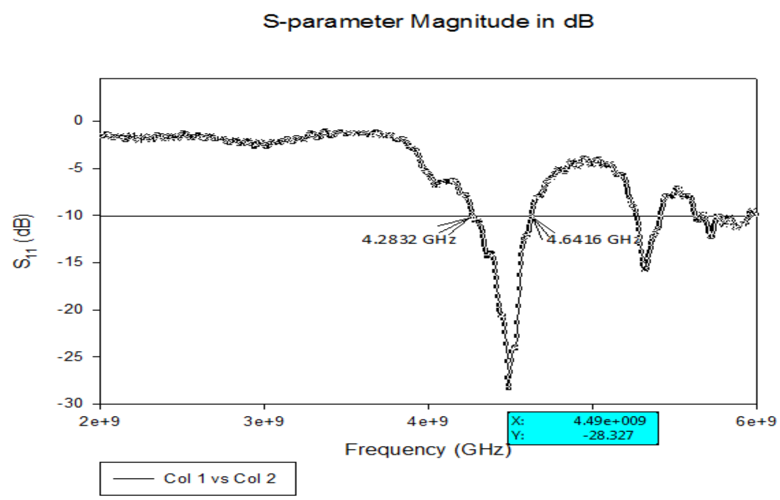

FIGURE 4.10: Measured Graph of Design 1

From figure 4.9 and 4.10, it shows that there are differences in the resonant frequency values which are, from the simulation, the resonant frequency is 4.576 GHz and for measured, the resonant frequency is 4.490 GHz. For S_{11} values, from simulation graph is -35.508 dB and from measured graph is -28.327 dB. There might be some errors occurred during the measurement of the designs or during the fabrication of the designs. The perimeters and design sizing will not be accurately the same with the simulation designs. Therefore, the values of the result obtained will not be the same like in the simulation results.

TABLE 4.3: Table of Simulation and Tested Result

No	Length (mm)	Width (mm)	Simulation Result		Measured Result	
			Resonant Frequency (GHz)	S_{11}(dB)	Resonant Frequency (GHz)	S_{11}(dB)
1	55	2.83	4.576	-35.508	4.490	-28.327
2	55	3.00	4.575	-15.830	4.510	-60.840
3	55	3.25	4.570	-15.073	4.535	-24.471
4	55	3.50	4.566	-14.283	4.555	-19.117
5	55	3.75	4.565	-15.088	4.390	-28.485
6	55	4.00	4.660	-18.001	4.380	-28.938
7	57.5	2.83	4.550	-20.289	4.460	-42.391
8	60	2.83	4.535	-13.264	4.495	-29.273
9	62.5	2.83	4.521	-12.841	4.525	-12.344
10	65	2.83	4.520	-15.162	4.340	-19.105
11	67.5	2.83	4.505	-10.874	4.370	-19.625
12	70	2.83	4.445	-11.610	4.645	-13.276

From the overall results obtained are shown in Table 4.3, the values between those two results are not exactly the same. The results obtained during the simulation showing that there is a decrement of resonant frequencies value but for measured, the results are not showing the same pattern like in simulation. Similar to the S_{11} values, it shows a slightly differences between these two values. This is because there is errors that might possibly happened during the measuring and during the fabrication of the designs.

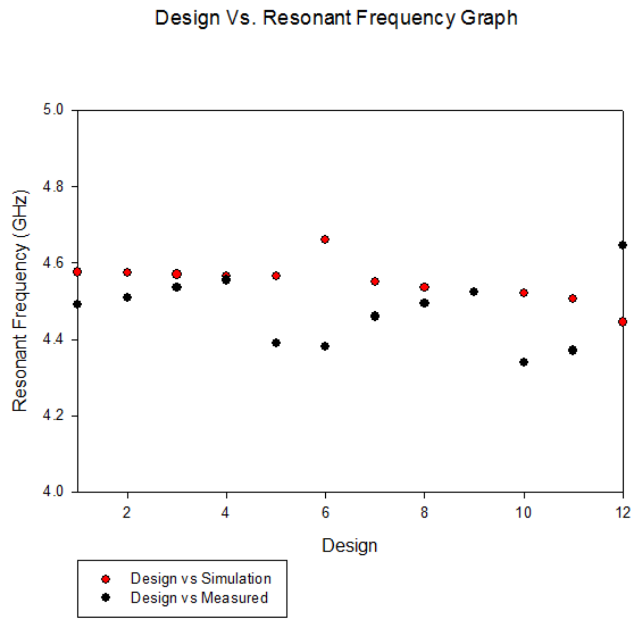

FIGURE 4.11: Design vs. Resonant Frequency Graph

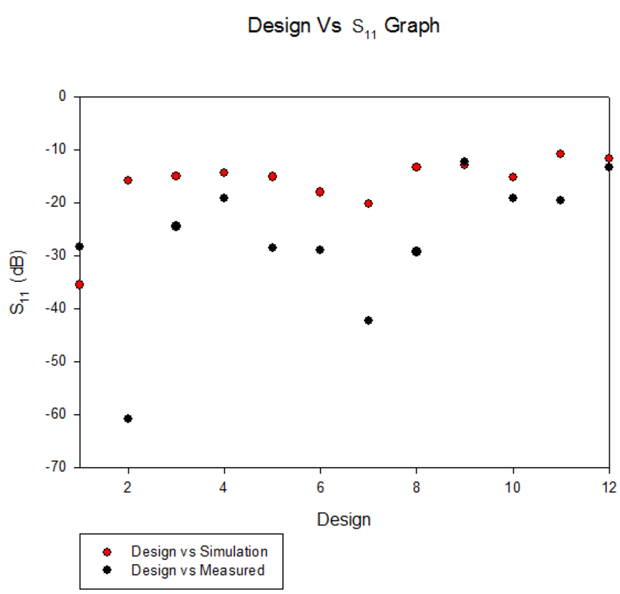

FIGURE 4.12: Design vs. S_{11}

Figure 4.11 and 4.12 shows the comparison between simulation and measured value. From both figure, it is depicted that the result shows a closed agreement between simulation and measured value. From figure 4.11, the best fit for both results is at design no 4 and 9 while for figure 4.12; the best fit at design no 9. It shows that design no 9 is considered as the optimum design for this investigation with the reference at the resonant frequency and S_{11} values that are obtained from both simulated and measurement results.

4.3.3 Error calculation and discussion

In order to analyze the relationship between the simulation and measured results, the error from both results is calculated in order to justify the comparisons between design simulation and design measurement. From this calculation, the lowest value of error is determined the optimum design for this project. The following equation below is used to calculate the value of error.

$$\text{Error} = \frac{|Calculated - simulated|}{simulated} x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4.1)}$$

TABLE 4.4: Comparison Value of Error between Simulation and Measured Results

No	Resonant Frequency (GHz)		Error (%)	S_{11} (dB)		Error (%)
	Simulation	Measured		Simulation	Measured	
1	4.576	4.490	1.877	-35.508	-28.327	20.223
2	4.575	4.510	1.414	-15.830	-60.840	284.335
3	4.570	4.535	0.766	-15.073	-24.471	62.349
4	4.566	4.555	0.241	-14.283	-19.117	33.844
5	4.565	4.390	3.834	-15.088	-28.485	88.792
6	4.660	4.380	6.009	-18.001	-28.938	60.758
7	4.550	4.460	1.978	-20.289	-42.391	108.936
8	4.535	4.495	0.882	-13.264	-29.273	114.863
9	4.525	4.521	0.088	-12.841	-12.344	3.870
10	4.520	4.340	3.982	-15.162	-19.105	1.666
11	4.505	4.370	2.997	-10.874	-19.625	80.476
12	4.445	4.645	4.499	-11.610	-13.276	14.349

From the Table 4.4, the smallest error for resonant frequency calculated from simulation and measured results is when the length=62.5 mm and width=2.83 mm and for

S_{11} is when the length=67.5 mm and width=2.83 mm. From overall results, by changing the length for 2.5 mm and width for 2.5 mm, the resonant frequency from the simulated designs are increased. However, for the measured results, the resonant frequencies obtained are not constantly changed. For S11 values for both simulated and measured results, the values are not constantly changed. This is due to the amount of radiation that radiates at the antenna are not the same in every antenna designs. Smallest error will justify the high accuracy of design between the simulation and measured results.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The main purpose of this project is to ensure that all objectives are achieved towards the end of the experiment. By doing the research related to the project and by following the guidelines and activities throughout the period of the project, the procedures will be followed accordingly to the project time frame and within the time given. Designation of the microstrip antenna and DRA application is conducted as well as the simulation of the design in order to get the required range of the design's resonant frequency.

Simulation and testing have been conducted in order to analyze and observed the comparisons between the theoretical and measurements result. There are slight changes when the parameters of the microstip is been adjusted according to the value of its width and length. The main data that is observed from this project will be the value of the resonant frequency, bandwidth and the radiation pattern.

From that result, the purposed of conducted this project is to make sure that there will be a change when the tuning of parameters is been applicable to the microstrip and achieve the desired range of frequency for this project. The error from the simulation and measured result is determined in order to justify the objectives of this project. Therefore, the optimum design for the antenna design with the DRA application is clarified after the designs have been simulated and measured.

5.2 Recommendations

After conducting this project, there are a lot of improvements can be done or made for the future of this project.

1. Using different coupling techniques such as:
   - Aperture
   - Probe
   - Coplanar

2. The parameters design for this design can be varied in order to improve and varied the value of the resonant frequencies.
3. The coupling involves with the different shape of DRA:
   - Rectangular
   - Hemispherical

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APPENDICES

APPENDIX A

Simulation and Measured Graph for Other Designs

Design 2

Length=55mm

Width=3.00mm

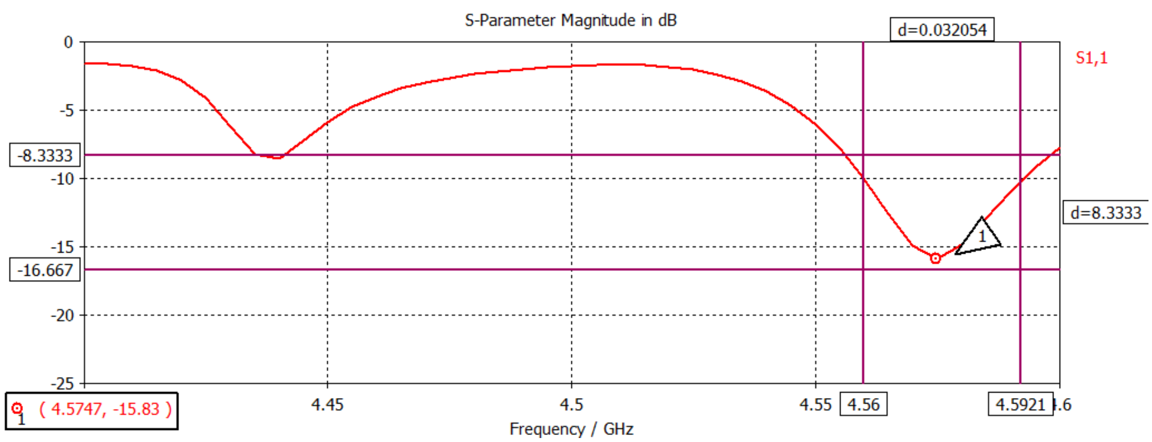

Figure A1: Simulation Graph for Design 2

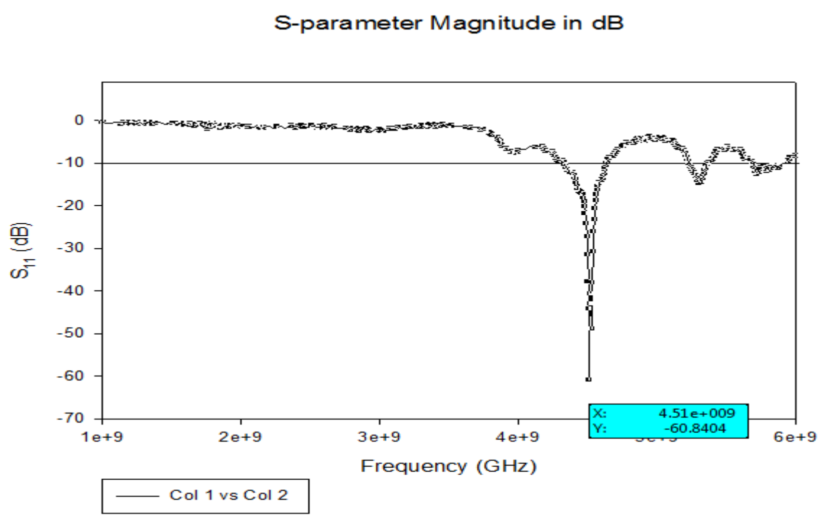

Figure A2: Measured Graph for Design 2

Design 3

Length=55mm

Width=3.25mm

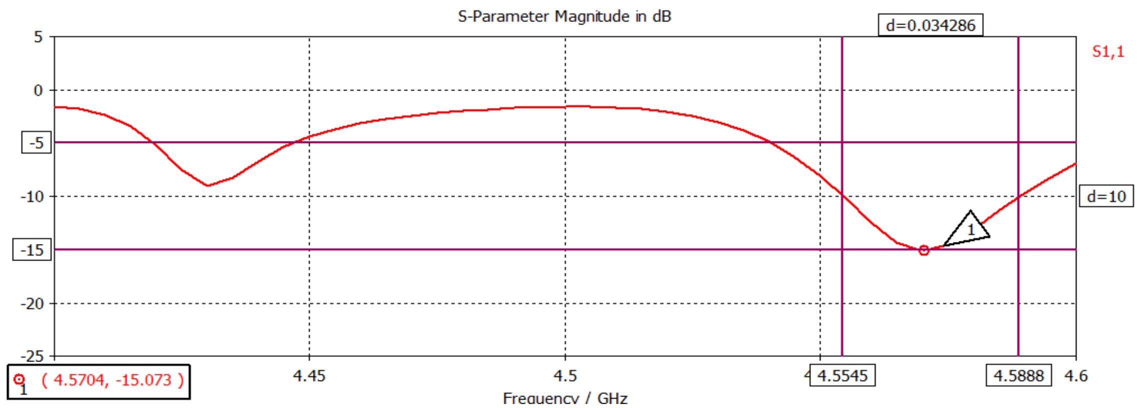

Figure A3: Simulation Graph for Design 3

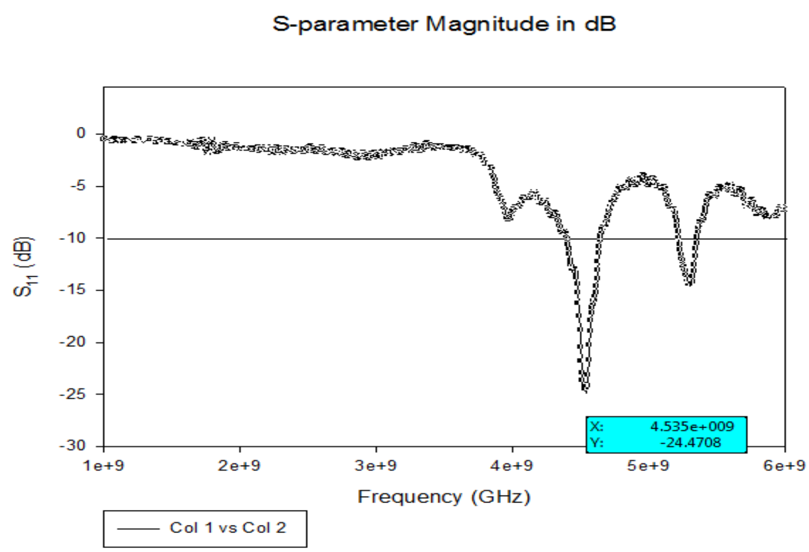

Figure A4: Measured Graph for Design 3

Design 4

Length=55mm

Width=3.50mm

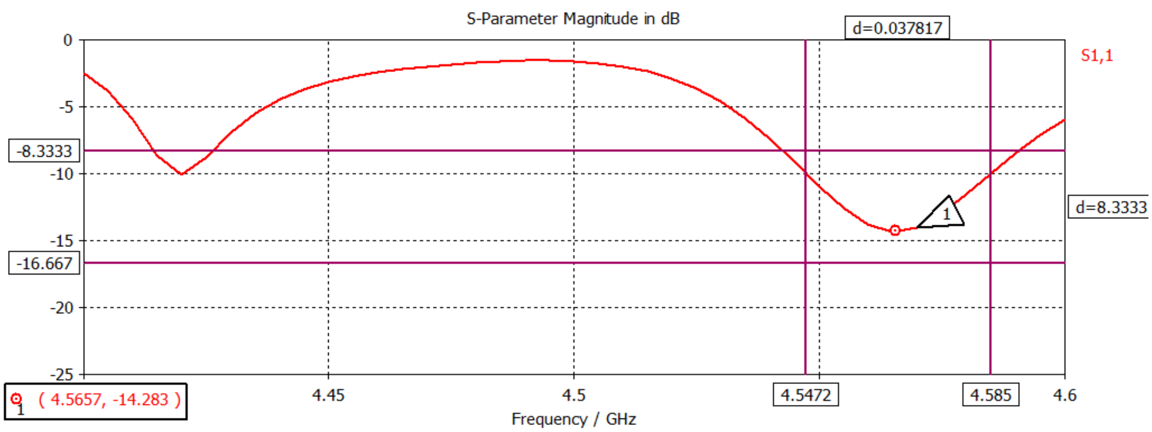

Figure A5: Simulation Graph for Design 4

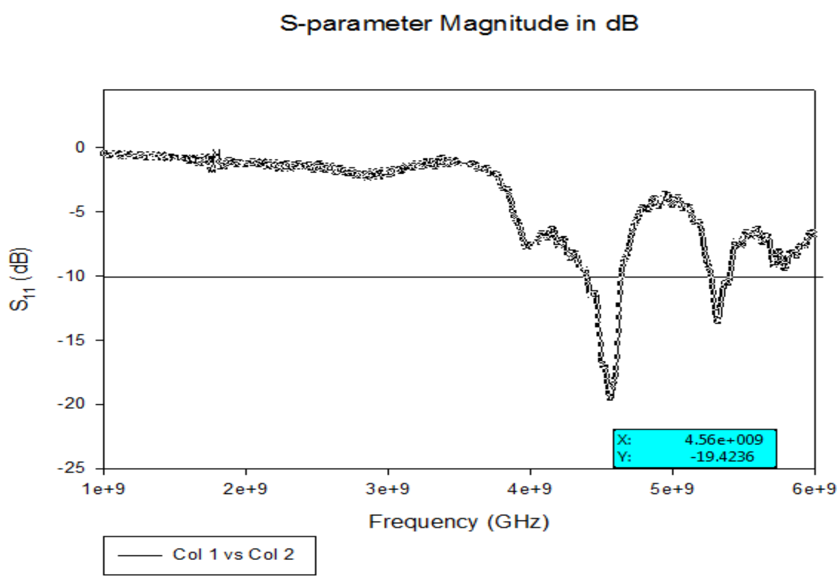

Figure A6: Simulation Graph for Design 4

Design 5

Length=55mm

Width=3.75mm

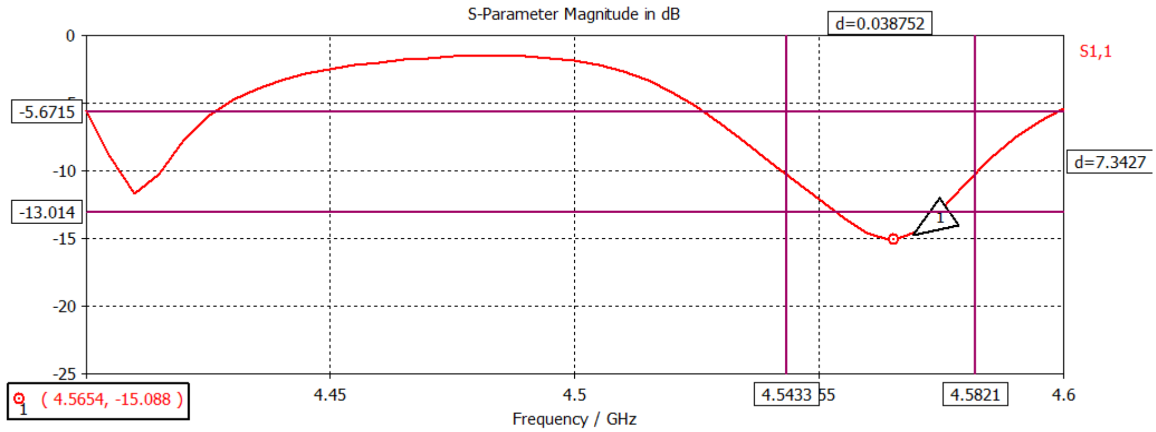

Figure A7: Simulation Graph for Design 5

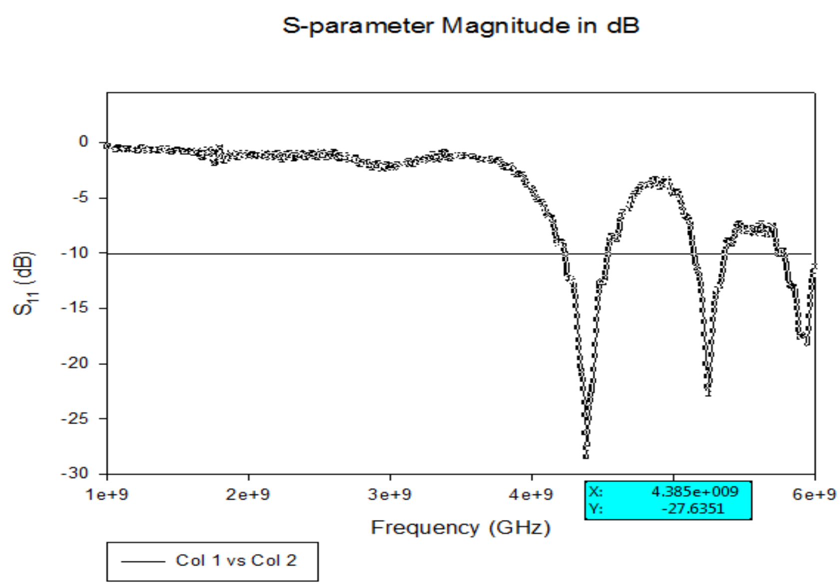

Figure A8: Measured Graph for Design 5

Design 6

Length=55mm

Width=4.00mm

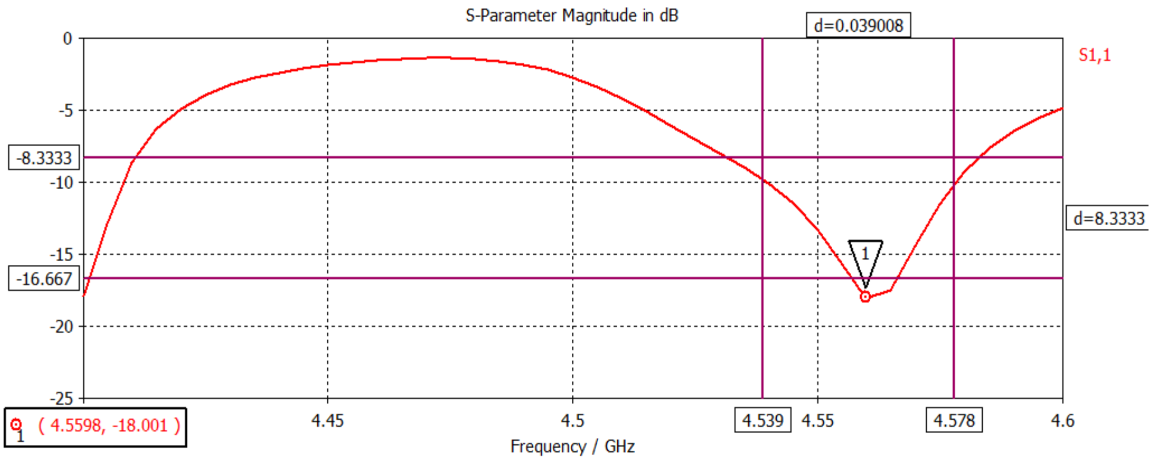

Figure A9: Simulation Graph for Design 6

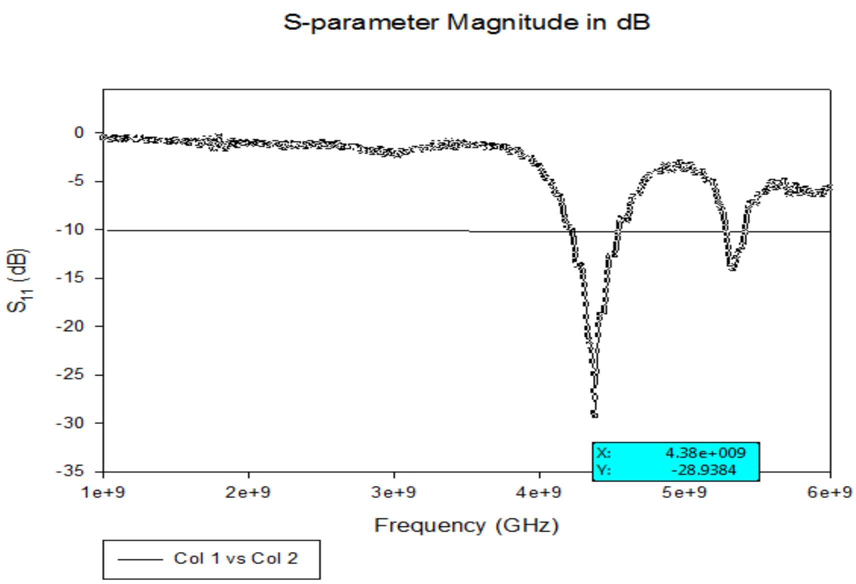

Figure A10: Measured Graph for Design 6

Design 7

Length=57.5mm

Width=2.83mm

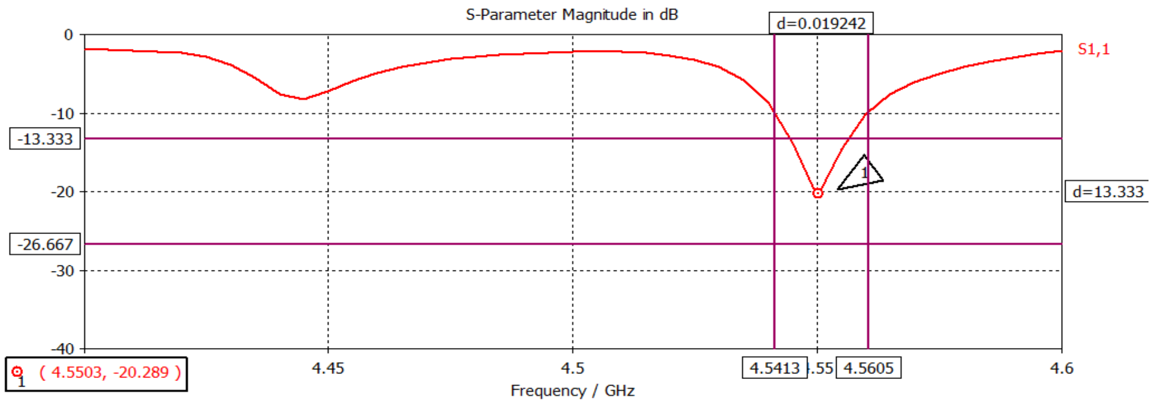

Figure A11: Simulation Graph for Design 7

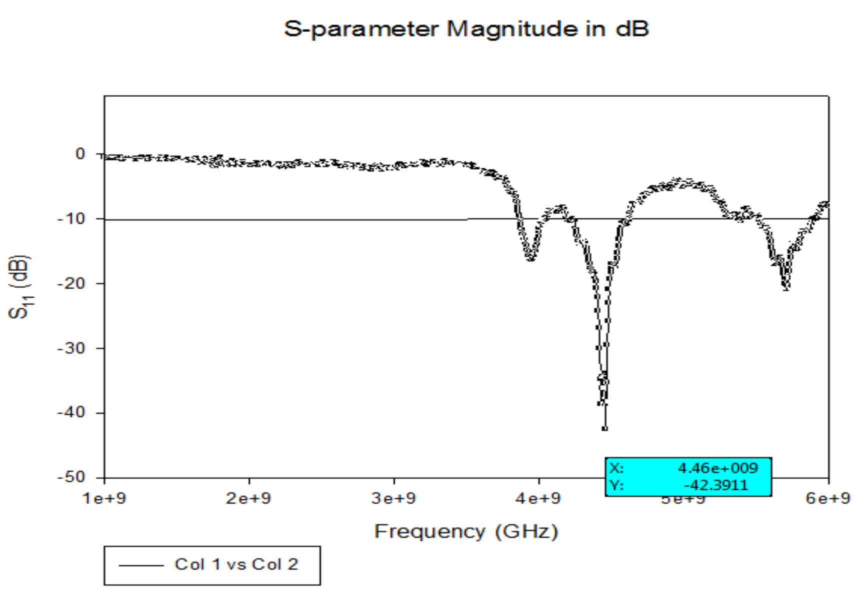

Figure A12: Measured Graph for Design 7

Design 8

Length=60mm

Width=2.83mm

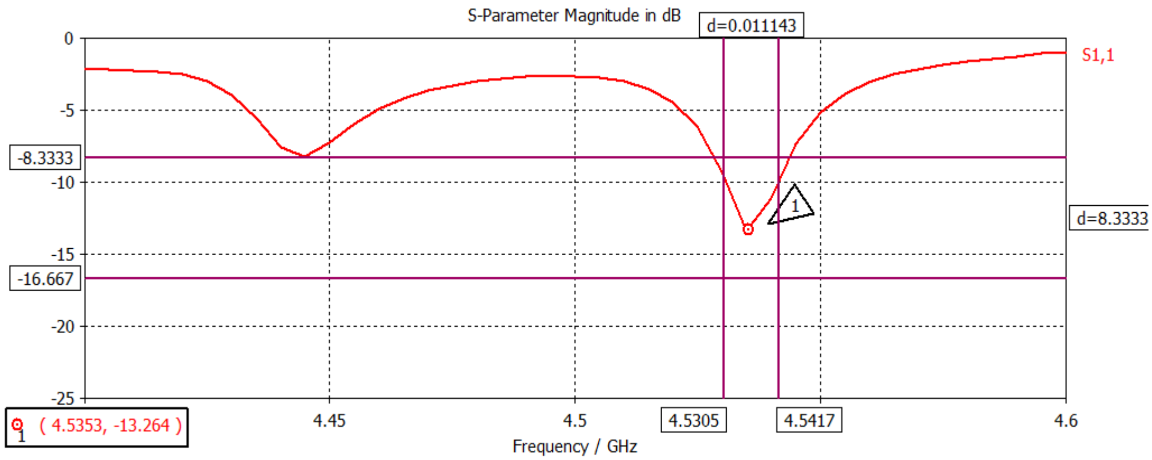

Figure A13: Simulation Graph for Design 8

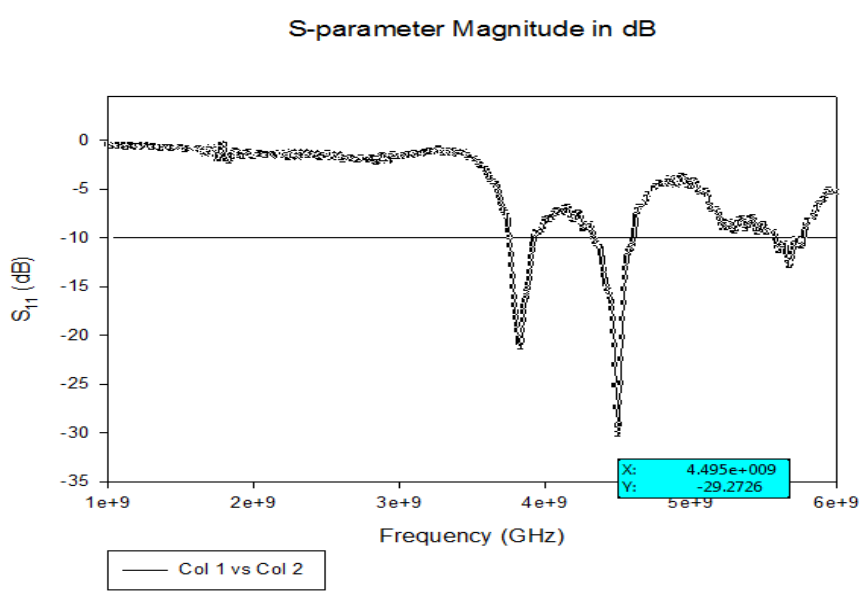

Figure A14: Measured Graph for Design 8

Design 9

Length=62.5mm

Width=2.83mm

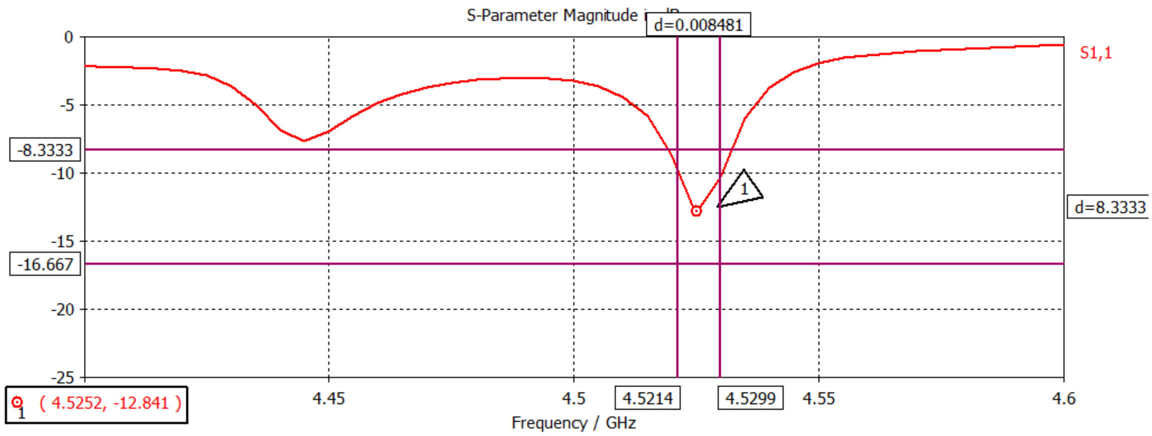

Figure A15: Simulation Graph for Design 9

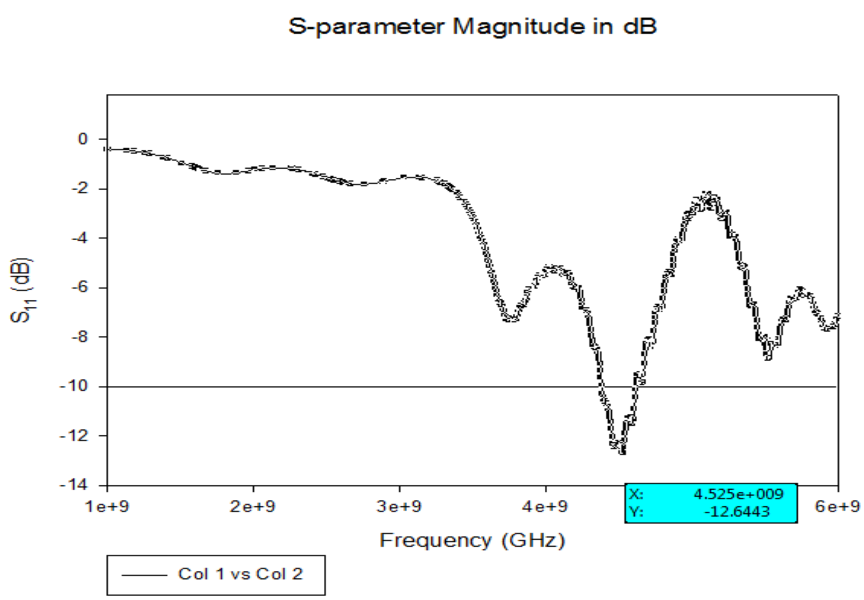

Figure A16: Measured Graph for Design 9

Design 10

Length=65mm

Width=2.83mm

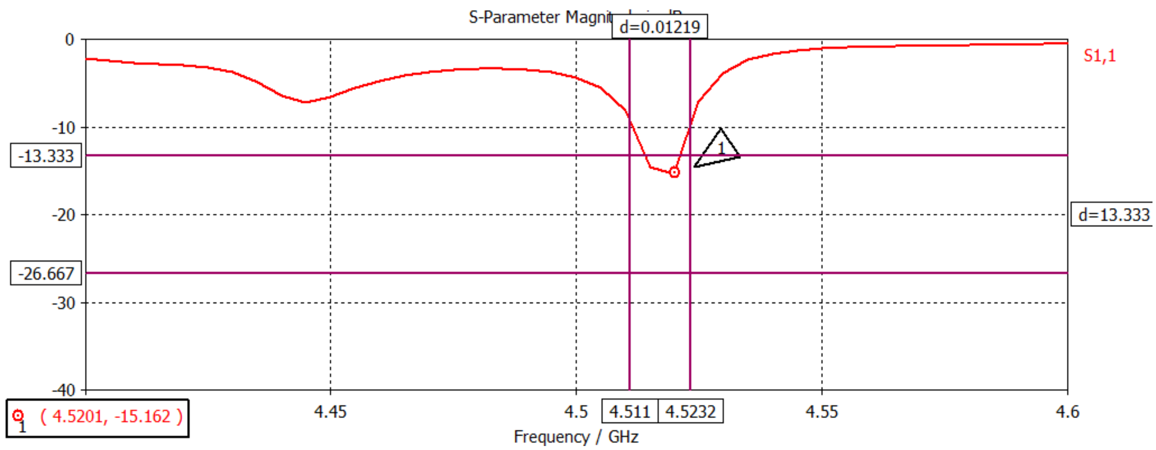

Figure A17: Simulation Graph for Design 10

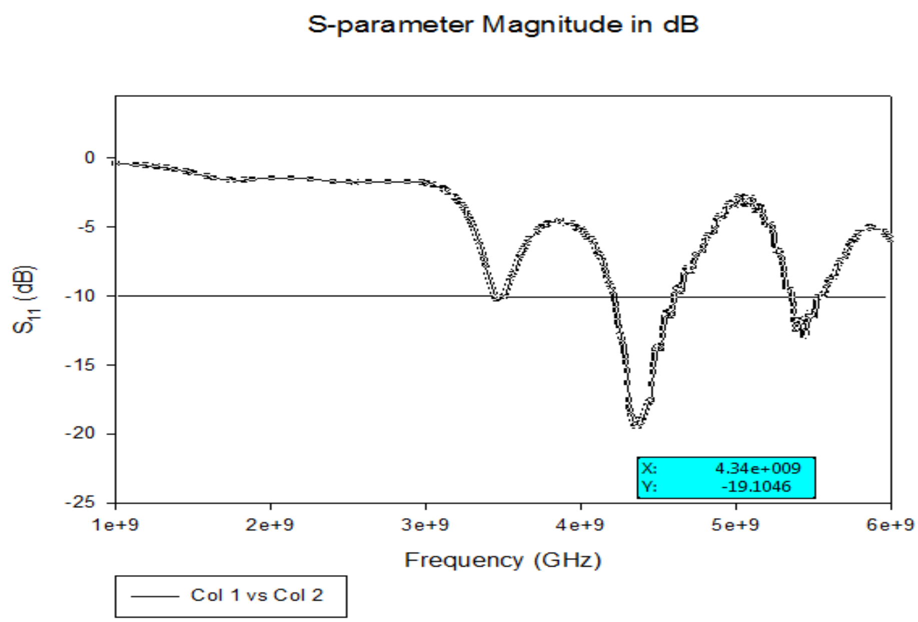

Figure A18: Measured Graph for Design 10

Design 11

Length=67.5mm

Width=2.83mm

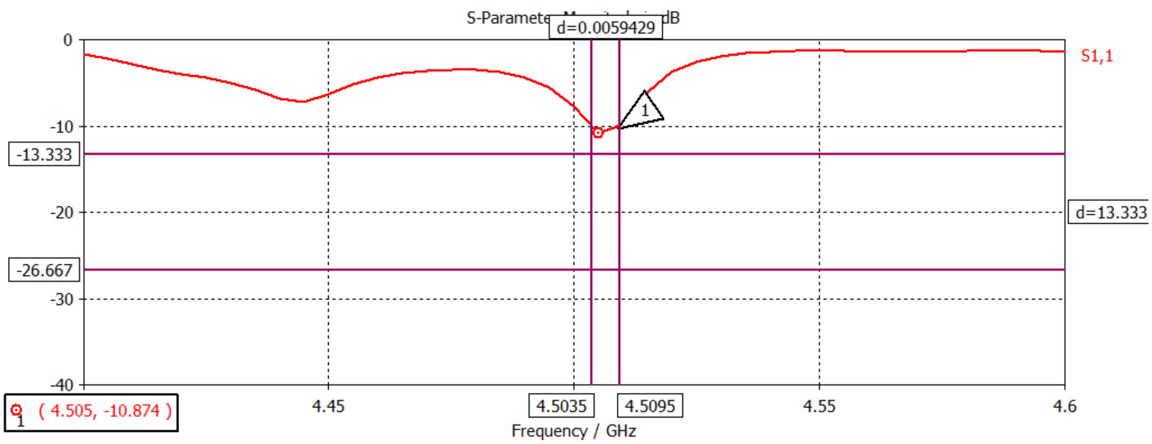

Figure A19: Simulation Graph for Design 11

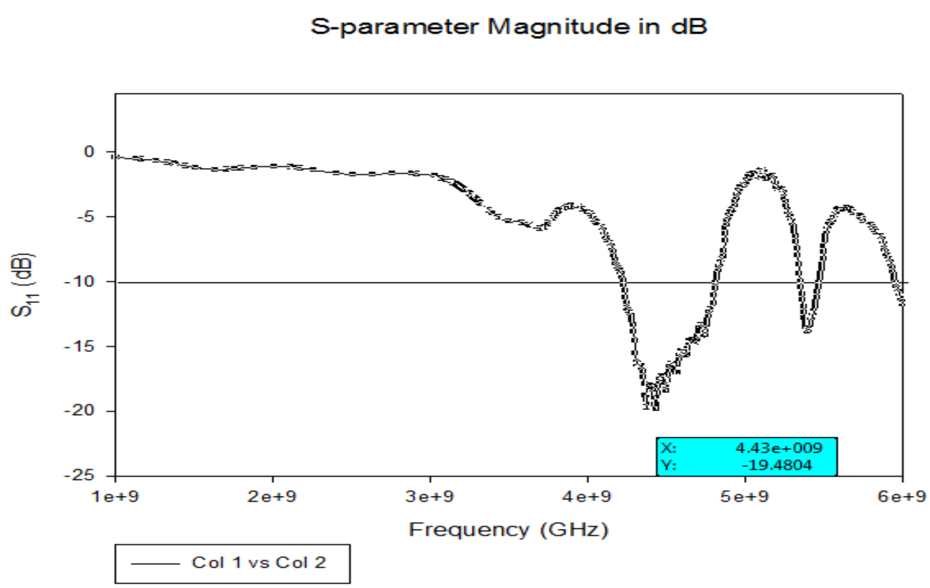

Figure A20: Simulation Graph for Design 11

Design 12

Length=70mm

Width=2.83mm

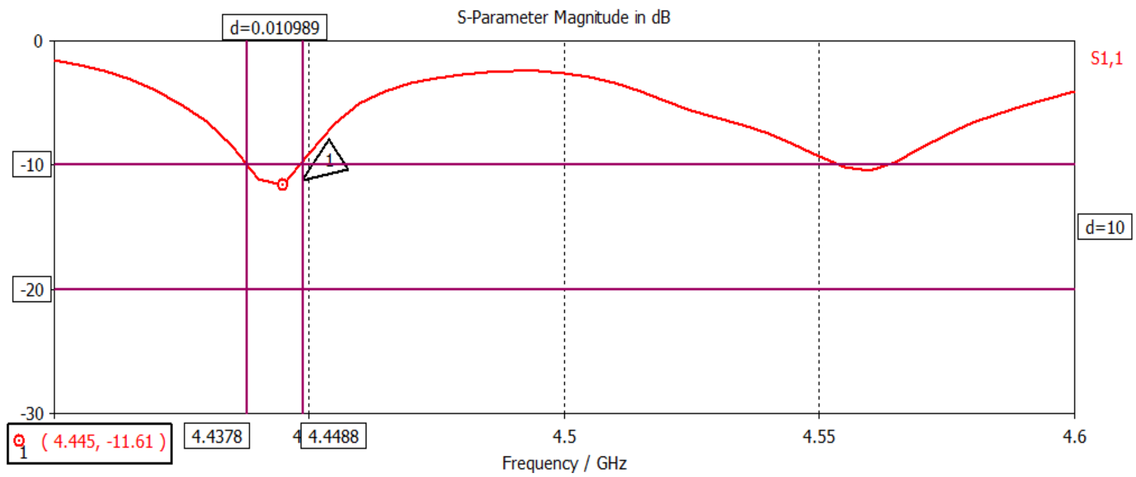

Figure A21: Simulation Graph for Design 12

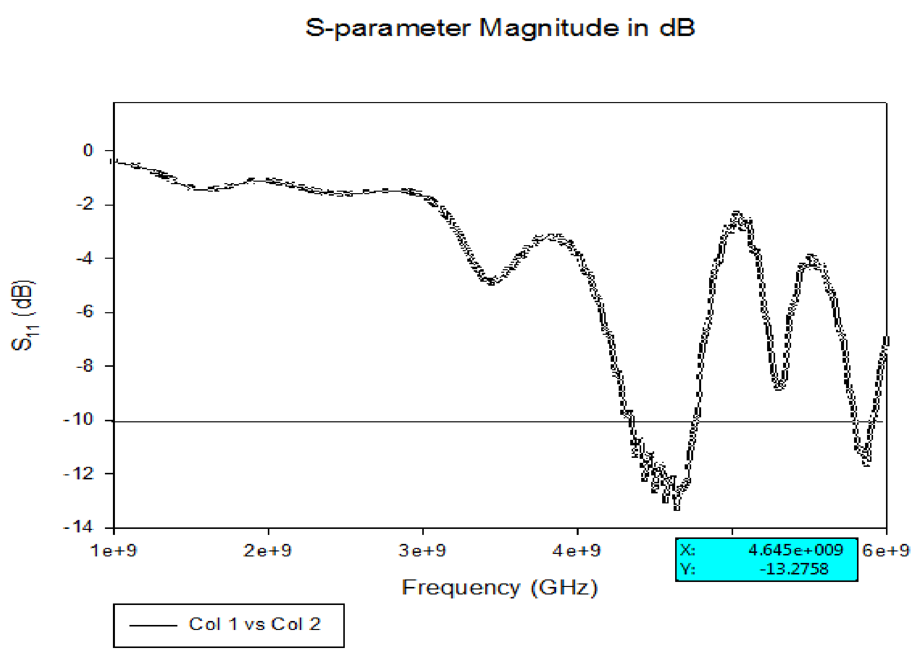

Figure A22: Measured Graph for Design 12