ANALYSIS OF THREE DIFFERENT DIELECTRIC SUBSTRATES ON SQUARE
RING SLOT MICROSTRIP PATCH ANTENNA FOR WIRELESS APPLICATION

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ABSTRACT

The sizes and weights of various wireless electronic systems (e.g. mobile handsets) have rapidly reduced due to development of modern integrated circuit technology. However, microstrip antenna suffers from low bandwidth. The objective of this project was to improve the bandwidth by proposing square ring technique and investigation for the enhancement strategy of bandwidth performance and analysis of different commercially available dielectric materials. The performance of different dielectric material for design of a square ring microstrip patch antenna is analyzed in terms of bandwidth. A square ring microstrip patch antenna was designed not only to improve the antenna bandwidth but also to reduce the size of the conventional microstrip patch antenna. Analysis of the design of microstrip patch antenna at C-band frequency range (4-8GHz) has been carried out using commercial available computer model of CST. This study will help for authors and researchers to get a fair idea of which substrate should be given preference and why for fabricating microstrip patch antenna.

 It has been shown that the use of square ring antenna produces an optimum bandwidth performance of approximately 5.9% in roger material for using fabrication. Experimental work has been performed to validate the predicted results obtained from CST analysis by using network analyzer. Both simulated and measured results have shown a good agreement.

ABSTRAK

Pembangunan teknologi litar bersepadu moden telah mengurangkan saiz dan berat bagi pelbagai sistem tanpa wayar elektronik (contohnya telefon bimbit mudah alih). Walau bagaimanapun, antena mikrostrip mempunyai lebar jalur yang rendah. Objektif projek ini adalah untuk meningkatkan lebar jalur dengan menggunakan teknik antena cincin bersegi dan kajian ini dianalisis dengan menggunakan bahan dielektrik yang berbeza. Prestasi bahan dielektrik yang berbeza untuk rekabentuk antenna dianalisis dari segi lebar jalur. Antenna ini bukan sahaja direka untuk meningkatkan lebar jalur malah ia juga direka untuk mengurangkan saiz antena. Analisis rekabentuk antena pada julat frekuensi C-band (4-8GHz) telah dijalankan dengan menggunakan perisian CST. Ia telah menunjukkan bahawa rekabentuk antena cincin bersegi menghasilkan prestasi jalur lebar optimum kira-kira 5.9% dengan menggunakan bahan Roger untuk proses fabrikasi. Eksperimen telah dijalankan untuk mengesahkan keputusan yang diperolehi daripada analisis perisian CST dengan menggunakan Penganalisis Rangkaian. Keseluruhan keputusan bagi kajian ini telah menunjukkan bahawa hasil rekabentuk fabrikasi dan simulasi telah memenuhi keputusan jangkaan sebenar.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

Γ	-	Reflection coefficient
Zo	-	Characteristic impedance
Hz	-	Hertz
K	-	Kilo
h	-	Height
L	-	Length
W	-	Width
dB	-	Decibels
λo	-	Free space wavelength
εr	-	Dielectric constant of the substrate
t	-	Patch thickness
c	-	Speed of light speed of light 3x 10-8 m/s
PCB	-	Printed circuit board
CST	-	Computer software technology
MWS	-	Microwave studio
EM	-	Electromagnetic
S11	-	Return loss
dB	-	Decibels
BW	-	Bandwidth
VSWR	-	Voltage standing wave ratio
SMA	-	Sub Miniature A
FR4	-	Fire retardant 4
UTHM	-	University Tun Hussien Onn Malaysia
MIC	-	Microwave integrated circuits
RL	-	Return loss
GSM	-	Global system for mobile

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1   Introduction

In the early 20th century mobile technology had been predominated by military users, before World War II, most developed mobile communication were dedicated to military requirements and standards. In fact, the first wireless communication system were heavy and large that their equipment would occupy the truck of the carrying the device. The trend of the mobile phone technology has been dramatically degreased the weight and size. Antenna with high gain performance are the required some of the applications in communication [1].The rapid progress in wireless communications requires the development of lightweight, low profile, flush mounted and single feed antennas . If the concept is applied to the design of microstrip patch antennas, then this can cause improvement in the performance of microstrip patch antenna in terms of gain and bandwidth [2].

Antenna designs fabricated on substrate material with thickness are presently receiving a lot of attention in the antenna industry [3]. Microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones pagers, radar systems, and satellite communication systems [4].

Type of antennas that fulfills most of the wireless system requirements are the microstrip antenna [29]. Also it is highly desirable to integrate several RF modules for different frequencies into one piece of equipment. Microstrip antennas that can be used simultaneously in different standards have been in the focus points of many research projects.

Microstrip antennas are very attractive because of their low profile, low weight, conformal to the surface of objects and easy production. A large number of microstrip patches to be used in wireless application have been developed. Various shapes of microstrip patches have been introduced such as square, rectangle, ring, disc, triangle, elliptic, etc. The dimension of the microstrip patch is determined from mathematic equation and using CST Microwave studio [5] [6].

This project, will introduce a microstrip ring antenna, in addition to having improved bandwidth and high gain. The effect of various dielectric constants on rectangular microstrip patch antenna performance will be investigated.

1.2   Problem Statement

The study of microstrip patch antenna has made great progress in recent years. Compared with conventional antennas, Microstrip patch antennas have more advantages and better prospects. Different researchers have used different dielectric substrates to fabricate microstrip patch antenna. So question arises that which dielectric substrate among the common substrates available gives better performance and what are the properties of the dielectric substrate which affects antenna performance. So a comparative study will be performed to know the dielectric properties of three different substrates affect antenna performance. The main aim of this project is to design and fabricate a microstrip ring square antenna is chosen and it is proposed to design a square ring antenna which highly improved the antenna's bandwidth. By utilizing this technique; a microstrip with large bandwidth is achieved at end of this project and also the study will help for authors and

researchers to get a fair idea of which substrate should be given preference and why for fabricating microstrip patch antenna. The effect of various dielectric constants on square ring antenna is investigated is carried out using CST software.

1.3 Objective

The objectives of this project are:

I. To design a square ring microstrip patch antenna operating at the resonanc e frequency 5.5 GHz for the wireless application.

II. To study the effect of the ration ring size of the microstrip square patch antenna in order to improve the bandwidth of the antenna.

III. To analyses the effect of dielectric constant on various materials.

1.4 Project Scope

The project scopes focusing on three major components which represent as follows:

I. The frequency operation of this antenna is from 4GHz to 8GHz, which is the C-band frequency range for wireless application. The resonant frequency of the antenna is selected as 5.5GHz.

II. The antenna will be simulated by using CST microwave studio. This software is chosen because it is a specialist tool for the 3D EM simulation of high frequency components.

III. The square ring microstrip patch antenna will be tested by using Network Analyzer.

1.5   Thesis outline

For the thesis outline, it covers on the whole thesis. This report is divided into certain part. Each part will cover on a topic required.

As for Chapter 1, it covers on introduction of the project. A little bit of the explanation will be done due to the project. It also includes the objectives, motivation of work, scope and thesis outline.

Chapter 2 is a chapter which covers on literature review of the project. In this chapter is focusing into certain sub topic. The literature review begins with the introduction, followed by antennas formulations, transmission lines and antenna applications.

Chapter 3 will be cover on project methodology where it is focusing on the method that used to completing the project accordingly. The methodology will be presenting in the flowchart. In addition, it is representing in details in the form of sentences.

The expected result and analysis will be covered on chapter 4. This chapter will be elaborate on the expected result for the whole project as well as frequency response that will be obtained at the end of the simulation process. Besides, is also gives a detail on the analysis of the result due to fabrication and the flowed by testing. The discussion is on the calculation and simulation, fabrication and testing.

The last chapter is the chapter 5, where it is on overall conclusion for the project. It is also includes the future works of the projects. The conclusion is related to the project. It is important in order to assure that our objective is achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Microstrip antenna was a simple antenna that consists of radiated patch component, dielectric substrate and ground plane. The radiated patch and ground plane is a thin layer of copper or gold which is good conductor. Each dielectric substrate has own dielectric permittivity value. This permittivity will influence the size of the antenna. Microstrip antenna is a low profile antenna, conformable to planar and non-planar surface, simple and inexpensive to manufacture using modern printed-circuit technology. They have several advantages light weight, small dimension, cheap, conformability and easily to integrate with other circuit make it is chosen in many applications [7].

2.2 Basic Microstrip Antenna

The idea of microstrip antenna was first proposed by Deschamps in 1953 and a patent in 1955. However, the first antenna was developed and fabricated during the 1970's when good substrates became available [7, 9]. Microstrip antenna is also referred as a patch antenna. Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side as shown in Figure 2.1.
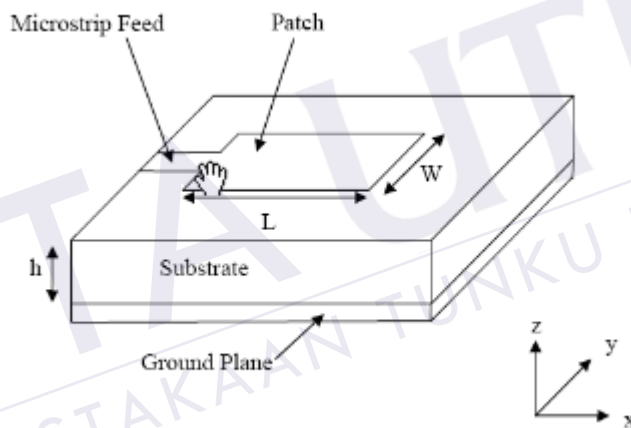
Figure 2.1: Basic microstrip patch antenna [22]

There are several shapes that can be used as the radiating patch. The radiating patch may be square, rectangular, thin strip (dipole), circular, triangular, Circular ring, elliptical, combination of these shapes or any other configuration [6]. These are illustrated in Figure 2.2. Every shape has its own characteristics but square, rectangular, and circular are the most common configurations because of their easier analysis and fabrication.
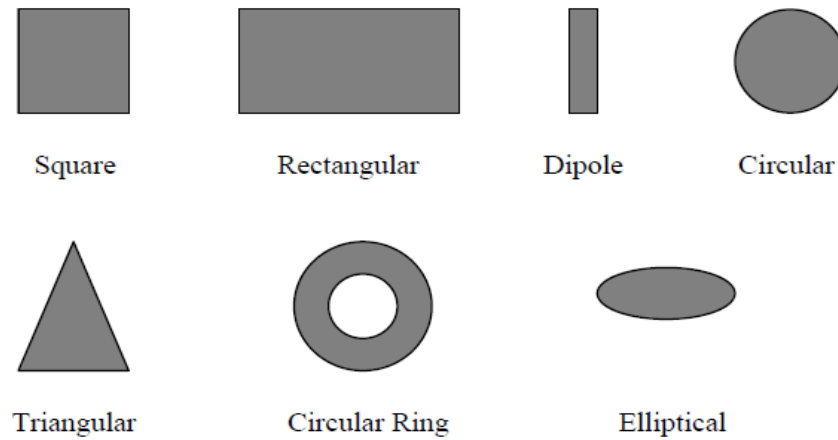
Figure 2.2: Representative shapes of microstrip patch antenna [27]

There are numerous substrates that can be used for the design of the microstrip antennas, and their dielectric constants (ε_r are usually in the range of 2.2≤ ε_r ≥ 12). The ones that most desirable for antenna performance are thick substrate whose dielectric constant is in the lower end of the range because they provide better efficiency, lager bandwidth, loosely bound fields for radiation into the space, but at the expense of larger element size [12].

The effective dielectric constant (ε_{reff}), of microstrip line is given approximately.

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+12[\frac{h}{w}]}}\right] \tag{2.1}$$

The effective dielectric constant can be interpreted as dielectric constant of the homogeneous medium that replaces the air and dielectric regions of the microstrip given the dimensions of the microstrip line. The characteristic impedance (Zo) can be calculated as [13].

$$Zo = \frac{60}{\sqrt{\varepsilon_{reff}}}\ln[\frac{8h}{w} + \frac{w}{4h}] \quad \text{For w/h} <1 \tag{2.2.0}$$

$$Zo = \frac{120\pi}{[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)]\sqrt{\varepsilon_{reff}}} \text{For w/h} >1 \qquad (2.2.1)$$

2.3   Feeding Techniques

Feeding techniques are important in designing the antenna to make sure antenna structure can operate at full power of transmission. Designing the feeding techniques for the high frequency, need more difficult process. It is because of input loss on feeding increase depending on frequency, and finally given huge effect on overall design. There are a few techniques that can be used. The technique is used in this project is microstrip feed. It is easy to fabricate, simple to match and model. However as the substrate thickness increase surface wave and spurious feed radiation increase, which for practical designs limit the bandwidth [14]. A microstrip ring antenna is significantly smaller than a regular patch antenna. Its smallness is dependent on the width of the ring, so is its input impedance. Since it is a reduced size antenna, its bandwidth is narrower compared to a regular patch antenna [10, 11].

2.3.1   Square patch

The square patch is one of the most widely used configurations. Because it is easy to analyze using both the transmission-line and cavity models, which are most accurate for thin substrate.

2.3.1.1 Transmissions-Line model

a) Fringing Effects

The dimensions of the patch are finite along the length and width so, the fields at the edges of the patch undergo fringing. Fringing process is making the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and the some in the air, an effective dielectric constant is introduced to the account for fringing and the wave propagation in the line.

For low frequencies the effective dielectric constant is essential constant. The initial values (at low frequencies) of the effective constant (ε_{reff}) are referred to as static values, as give in the equation 2.1 [15].

b) Effective Length, Resonant Frequency, and Effective width

For the principle E-plane, this is demonstrated in the figure 2.3.
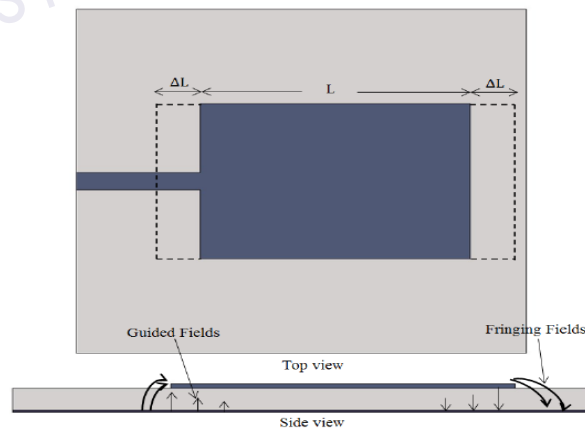
Figure 2.3: physical and effective length of the square microstrip patch

Normalized extension of the length is

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)\left(W/h+0.264\right)}{(\varepsilon_{reff}-0.258)\left(W/h+0.8\right)} \tag{2.3}$$

For practical length of the square patch antenna is

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{2.4}$$

A practical width that leads to good radiation efficiencies

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}}. \tag{2.5}$$

2.3.1.2 Quarter wave transformer feed

The type of the feeding technique that will be used is the quarter wave transformer technique. It is a simple and useful method for matching real load impedance to different source impedance and is frequently used in antenna [30]. Calculation of the microstrip feed line width is shown by equation (2.6).

$$\frac{W1}{h} = \frac{8e^A}{e^{2A}-2} \quad \frac{W1}{h} < 2 \tag{2.6}$$

Where, A is $\frac{Z_o}{60}\sqrt{\frac{\varepsilon r+1}{2}} + \frac{\varepsilon r-1}{\varepsilon r+1}(0.23 + \frac{0.11}{\varepsilon r})$

$$\frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\varepsilon r - 1}{2\varepsilon r}\left\{\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon r}\right\}\right] \quad for \frac{W}{h} > 2 \qquad (2.6.1)$$

Where, B is $\frac{377\pi}{2Z_0\sqrt{\varepsilon r}}$

The single section quarter-wave transformer has a length equal to the quarter wave in microstrip and its characteristic impedance should be given.

$$L_f = \frac{\lambda_g}{4} \qquad\qquad\qquad (2.7)$$

Where, $\lambda_g = \frac{c}{f_r\sqrt{\varepsilon_{reff}}}$

$$Z_c = \sqrt{Z_o Z_{in}} \qquad\qquad\qquad (2.8)$$

Where, $Z_{in} = 90\left(\frac{\varepsilon r^2}{\varepsilon r - 1}\right)\left(\frac{L}{W}\right)^2$

Where Z_o the characteristic impedance of the 50ohm is line and Z_{in} is the input impedance of the square ring patch. The width W_2 of the quarter-wave transformer can be finding out by equation (2.6) for calculating value of Z_c from equation (2.8).

2.4 Antenna Characteristic and Parameters

Although there are many important parameters in order to design microstrip patch antenna. The most important parameters that characterize need to be considered in this design is bandwidth performance and retune loss [28].

2.4.1 Bandwidth

The bandwidth of the antenna is the range of the frequencies in which the antenna operates satisfactorily [23]. In other words, it is the range over which the power gain is maintained to be within 3dB of its maximum value or the range over which the VSWR is no greater than 2. The bandwidth of the antenna is defined as:

$$Bandwidth, BW = \frac{f_h - f_l}{f_c}$$ (2.9)

Where,

f_h = highest frequency,

f_l = lowest frequency

f_c = center frequency.

For microstrip patch antenaa a VSWR ≤ 2 with RL $\geq$ -10dB ensures good performance.

2.4.2 Bandwidth enhancement

One of the principal disadvantages of the microstrip antenna technology is the narrow bandwidth of the basic element [24]. The bandwidth of the basic patch element is usually 1% - 3%. Significant research has been devoted to the bandwidth problem in recent years and many techniques have been suggested to achieve wider bandwidth. There is different bandwidth improvement strategies employed in microstrip antennas

such as, multilayer configuration [16]. This technique can enhance the bandwidth performance but, is difficult to fabricate.

However, in this project square ring technique is proposed due to improve the bandwidth performance; reduce some of the material volume of the patch antenna and it easy to fabricate.

2.4.3 Return loss (RL)

The Return Loss is a parameter that shows the amount of power that is lost to the load and does not return as a reflection. When the transmitter and antenna impedance do not match, waves are reflected and this creates standing waves [25]. Hence RL is a parameter similar to the VSWR.

$$Return\ loss(RL), S_{11} = -10log|S_{11}|^2\ or -20\log|\Gamma|\ (dB) \qquad (2.10)$$

Where, $|\Gamma| = \dfrac{V_0^-}{V_0^+} = \dfrac{Z_L - Z_0}{Z_L + Z_0}$ \hspace{2cm} (2.11)

$|\Gamma|$ = Reflection coefficient

V_0^- = the reflected voltage

V_0^+ = the incident voltage

Z_L = Load impedance

Z_0 = Characteristic impedance

For perfect matching between the transmitter and the antenna, $\Gamma = 0$ and $RL = \infty$ which means no power would be reflected back, whereas a $\Gamma = 1$ has a $RL = 0$ dB, which

implies that all incident power is reflected. For practical applications, a VSWR of 2 is acceptable, since this corresponds to a return loss of -9.54 dB [17].

2.5   Previous Papers

2.5.1   Investigation on probe –fed open-ring microstrip antenna for

Miniaturization

Previous study showed that there are many projects based on Square-ring microstrip patch antennas. According to S. I. Latif and L. Shafai [18], there are several important parameters of the square ring antenna which affects its resonance frequency. They are substrate thickness h, probe position, and width of the ring w. The geometry of the microstrip square-ring antenna is shown in figure 2.4.
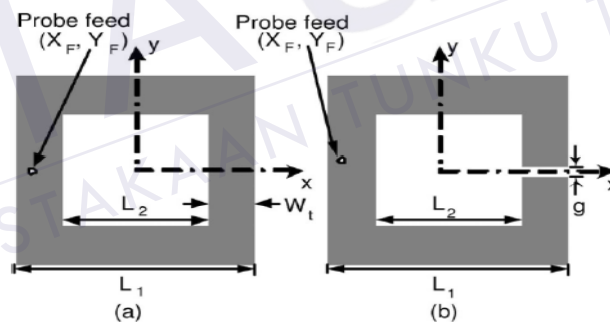
Figure 2.4: Geometry of the (a) square-ring (b) open square-ring antenna
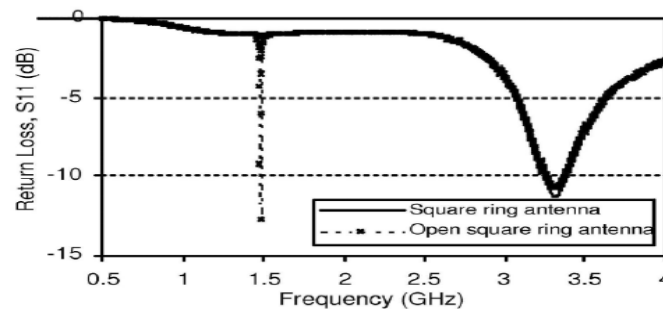
Figure 2.5: comparison between square-ring and open square-ring

A miniaturization is achieved but the bandwidth is not encouraging and also there is poor return loss performance shown in figure 2.5. In addition, the radiation efficiency and bore sight is high due to the cross-polarization caused by the loading gap.

2.5.2 Design of square-ring microstrip antenna for circular polarisation

The experiment done by J S. Row [19] was aimed to compact the antenna size and overcome the high impedance problem which mainly responsible the discrepancy that can be seen in the comparison of the simulated and measured results in term of the resonance of frequency. Figures 2.6 shown the measured return loss against frequency, it is clearly seen that there was discrepancy between simulated and measured slight shift results could be mainly due to the error in substrate permittivity. That kind of feed is responsible for the distortion of that can be observed in radiation pattern results as illustrated in figure 2.7. One way to be solved is by using a quarter wavelength impedance transformer in order to match the impedance of the system.
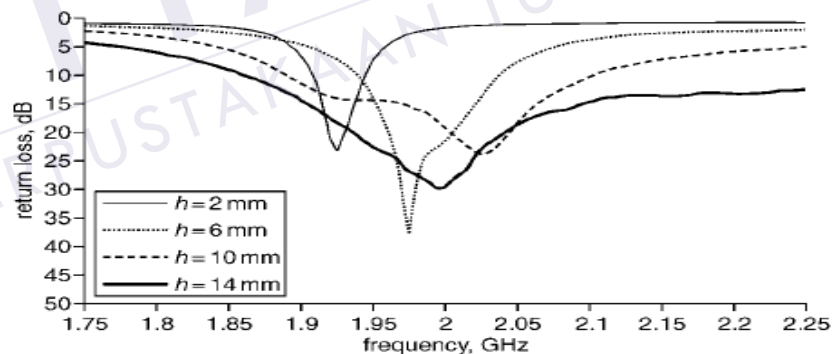
Figure 2.6: Measured return loss Vs frequency with various substrate thickness
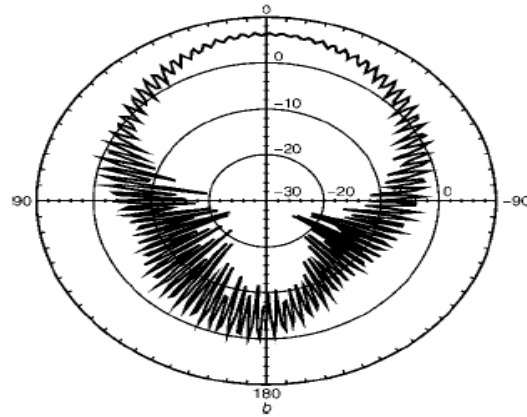
Figure 2.7: radiation pattern of the system designed

2.5.3 Microstrip Square Ring Antenna for Dual Band Operation

S. Behera and K. J. Vinoy [20]. In this paper, an electromagnetic coupled square ring antenna with stub loading is proposed for dual-band operation. The technique used in journal causes the resonance frequency shift to the higher frequency and the behavior of the radiation pattern in the second band is not useful since in they have a null in the bore sight direction shown in the figure 2.8. Simulation, the first band has lower bandwidth compared to the bandwidth of the second band in the Table 2.1.
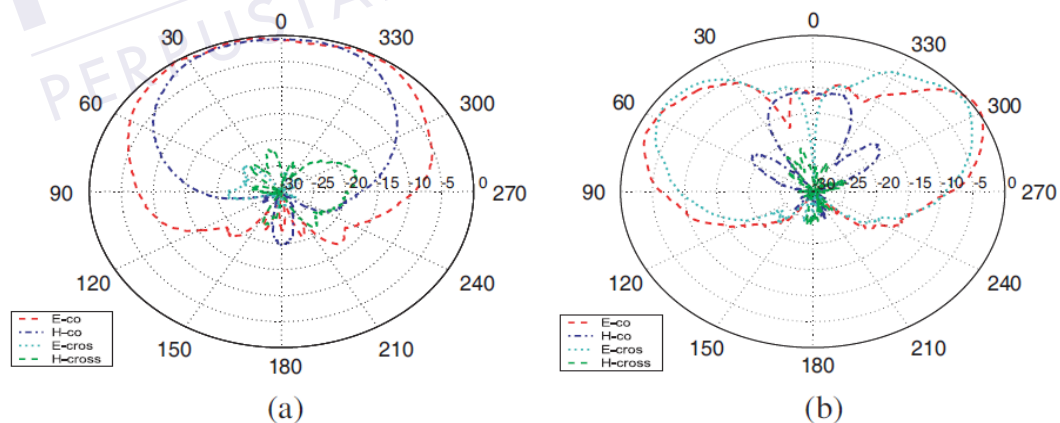
Figure 2.8: measured radiation pattern of the uniform width antenna at (a) 2.4GHz and
    (b) 5.2GHz

Table2.1: Comparison of simulated performance of the ring antenna with three different configurations

		Uniform Width Antenna		Non-uniform width Antenna		Dual frequency Antenna	
		Simulated	Measured	Simulated	Measured	Simulated	Measured
First resonance	Frequency [GHz]	2.431	2.431	3.152	3.15	2.992	2.99
	Bandwidth [MHz]	36.4	36	75.2	75.5	50.2	52
	Gain [dBi]	6.15	4.8	6.23	5.4	6.2	5.53
Second resonance	Frequency [GHz]	5.228	5.23	5.478	5.48	4.787	4.78
	Bandwidth [MHz]	144	144	77.2	76	73	71.5
	Gain [dBi]	−8.1	−12	−6.14	−11.0	3	2.42

2.5.4 Analysis of design optimization of bandwidth and loss performance of reflectarray antenna based on material properties

Previous study showed that there are many projects based on different material properties. Generally the reflection loss of the reflectarray antennas is primarily limited to dielectric absorption in the dielectric layer and conductor loss [1]. The reflection loss of reflectarry antenna depends on the material properties of the dielectric material which includes the substrate thickness and the conducting material used for the patch element and the ground plane.

The material listed in table 2.2 are used to design infinite reflectarrays resonating at 10 GHz. In this paper is shown that infinite rectangular microstrp reflectarray antenna with different dielectric materials are analyzed in terms of bandwidth and reflection loss performance. Different factors of the reflection loss are shown separately which permits the optimization of loss performance of the reflectarrays. Finally the paper recommends further investigation is required to utilize the material properties in order to enhance the performance of the reflectarray antennas.

The table 2.2 and figure 2.9 are shown combined, the dielectric and conductor loss for different materials.

Table 2.2: Combined the dielectric and conductor loss for different materials

Dielectric Material	Dielectric Constant	Loss tangent	Conductivity of conductor (Copper)	Combined Loss R_l	Dielectric Loss α_d	Conductor Loss α_c
	(ε_r)	$(Tan\delta)$	σ (Ms/m)	(dB)	(dB)	(dB)
Alumina (95%)	9.75	0.0003	59.6 Ms/m	0.519 dB	0.148 dB	0.370 dB
Beryllia	6.5	0.0004	59.6 Ms/m	0.395 dB	0.138 dB	0.257 dB
CEM	4.5	0.025	59.6 Ms/m	6.875 dB	6.656 dB	0.187 dB
Gallium Arsenide	13	0.006	59.6 Ms/m	4.326 dB	3.831 dB	0.455 dB
Roger 5870	2.33	0.0012	59.6 Ms/m	0.313 dB	0.189 dB	0.122 dB
Roger 5880	2.2	0.0004	59.6 Ms/m	0.178 dB	0.060 dB	0.118 dB
Silicon	11.9	0.004	59.6 Ms/m	2.857 dB	2.406 dB	0.444 dB
Teflon	2.08	0.0004	59.6 Ms/m	0.183 dB	0.063 dB	0.119 dB
Vaseline	2.16	0.001	59.6 Ms/m	0.261 dB	0.146 dB	0.114 dB
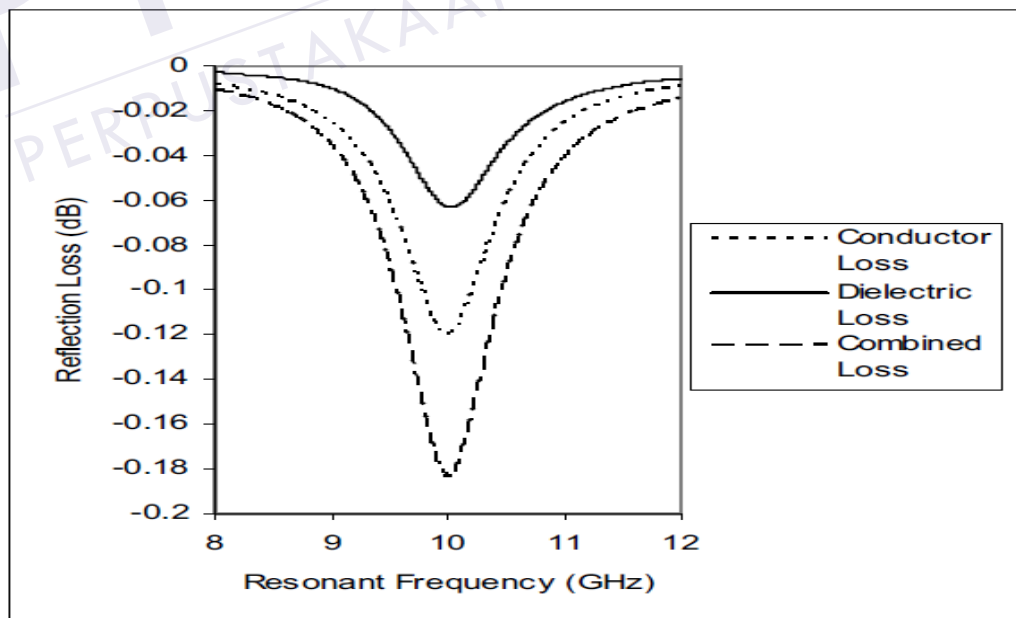
Figure 2.9: Individual and Combined loss for Teflon

2.6 Applications

Microstrip patch antennas are well known for their performance and their robust design, fabrication and their extent usage. The usages of the microstrip antennas are spreading widely in all the fields and areas and now they are booming in the commercial aspects due to their low cost of the substrate material and the fabrication. It is also that due to the increasing usage of the patch in the wide range this could take over the usage of the conventional antennas for maximum applications. Microstrip patch antenna has several applications. In this project we use wireless communication because is require small, Low-cost, low profile antennas. Microstrip patch antenna meets all requirements and various type of microstrip antennas have been designed for use in mobile communication systems [21].

Figure 2.9: Patch antennas inside a NOKIA cellular phone

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the methods used in order to obtain the optimum result of the project, starting from the designing process until the testing process. The design and simulation processes are done by using CST Microwave Studio. The simulation result is optimized to achieve the best performance of antenna.
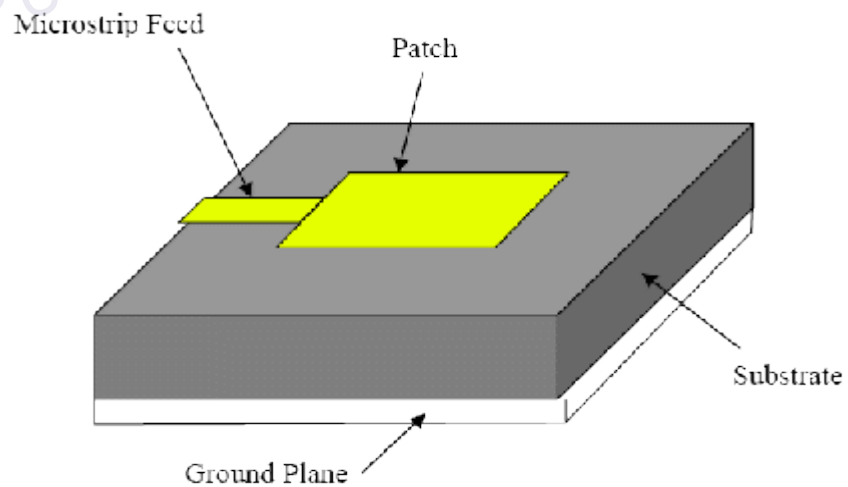
Figure 3.1: Square Patch Antenna

3.2 Flow chart

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                        ┌─────────────┐
                        │    START    │
                        └──────┬──────┘
                               │
                        ┌──────▼──────────┐
                        │ Literature Study │
                        └──────┬──────────┘
                               │
                        ┌──────▼──────────┐
                        │  Antenna Design │
                        └──────┬──────────┘
                               │
                        ┌──────▼──────────┐
                        │ Simulate Square │
                        │ Patch Antenna in│
                        │      CST        │
                        └──────┬──────────┘
     YES                       │
                        ┌──────▼──────────────┐
                        │ Evaluate the         │
                        │ performance          │
                        └──────┬──────────────┘
                               │
          ◇ Problem ? ◇────────┘
               │
     NO        │
          ┌────▼──────────────┐           ┌──────────────┐
          │ Fabricate the     │◄──────────┤              │
          │ Antenna           │           │   Problem ?  │
          └────┬──────────────┘           ◇──────────────◇
               │                             │ YES
          ┌────▼──────────────┐              │
          │ Testing the       │──────────────┘
          │ Antenna           │        NO
          └───────────────────┘
          ┌───────────────────┐
          │ Measure the       │
          │ fabricated Antenna│
          └────┬──────────────┘
               │
          ┌────▼──────────────┐
          │ Compare the       │
          │ measured and      │
          │ simulated results │
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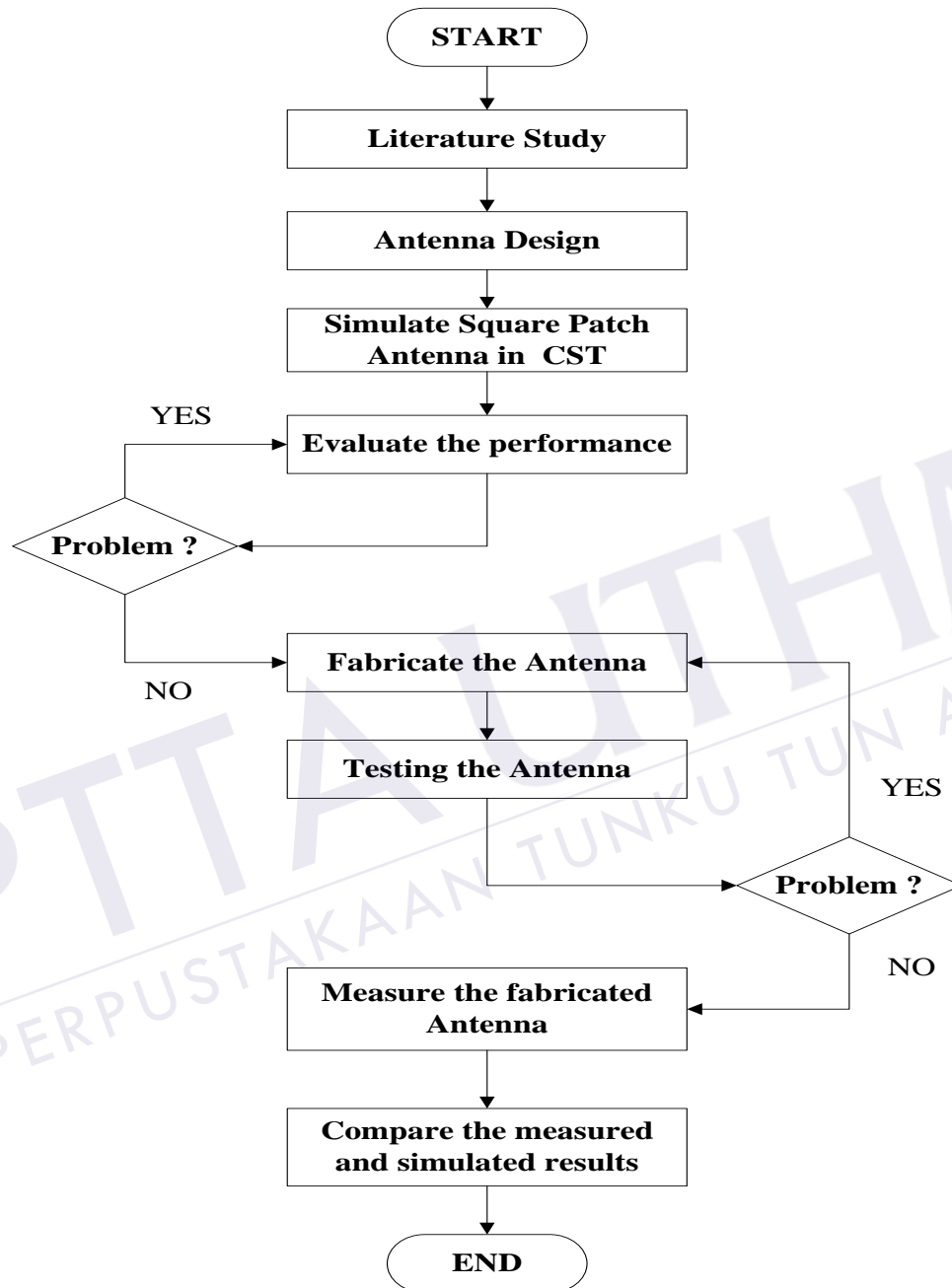
Figure 3.2: Flow chart of the project

3.3   Design procedures

This part explains about the designing and specifications of the single feed square-ring patch antenna. Generally, the design process of this antenna is two parts: Conventional square microstrip patch antenna and square-ring microstrip patch antenna designs.

3.3.1 Design of Square Patch Antenna

The three essential parameters for the design of a square microstrip patch antenna are:

• Frequency of operation (fr): The resonant frequency of the antenna must be selected appropriately. The Mobile Communication Systems uses the frequency range from 4-8 GHz Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 5.5 GHz

• Dielectric constant of the substrate (ε_r): The dielectric materials selected for this design are FR-4, Roger 5870 and Teflon with a dielectric constant of 4.3, 2.33 and 2.1 respectively

• Height of dielectric substrate (*h*): For the square microstrip patch antenna to be used in GSM, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

Table 3.1: The essential parameters for square patch

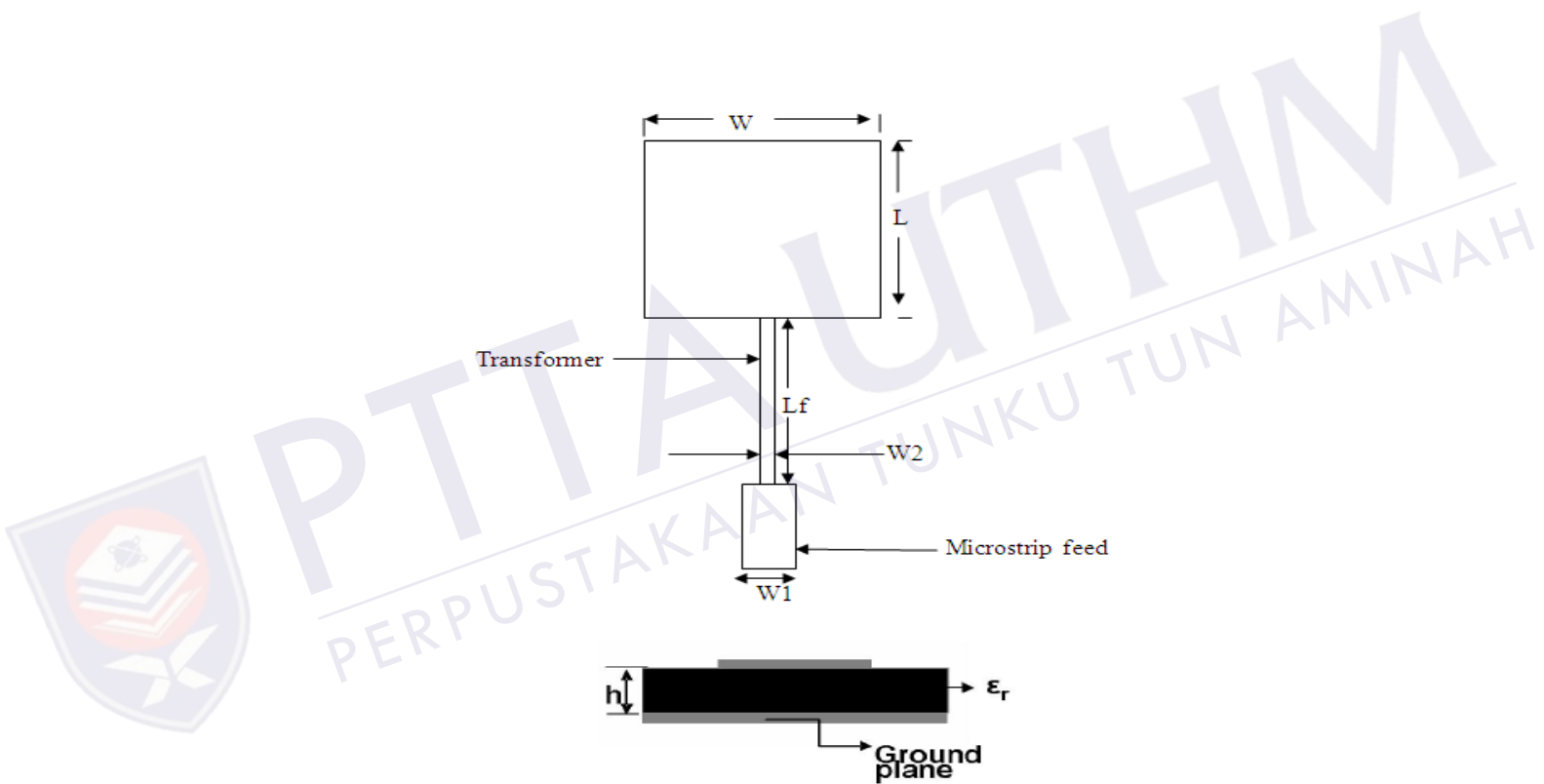| Cental frequency, fr	5.5 GHz
Dielectric constant, ε_r	4.3
Substrate thickness, h	1.6mm

Parameter Calculation Antenna

Figure 3.3: Layout of square patch antenna with micro-strip feed

Figure 3.2: shows the geometry of a microstrip square patch antenna. Let the patch length, width, feed line length and width be denoted by L, W, Lf, W1, and W2.

3.3.1.1 Design of Square Microstrip Antenna Using Theory Calculation FR4

The propagation of electromagnetic field is usually considered in free space, where it is travels at the speed of light C is $3x10^8$m/s. λ, lambda is the wavelength, expressed in meters.

Wavelength of the GSM band

In GSM band, the following expression is used

$$\lambda = \frac{c}{fr(GHz)}$$
(3.1)

Hence, the wavelength of the antenna when operating at 5.5 GHz is 0.05455 m.

The width and the length of substrate is $\lambda/2$.

$$\frac{\lambda}{2} = 27.273 \text{ mm}$$

From the above, the essential parameters for the design we can calculate that

a) Calculation of the width

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}}.$$
(3.2)

Substitution C = $3x10^8$m/s, ε_r =4.3, fr = 5.5GHz

16.75mm

b) Calculation of effective dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[\frac{1}{\sqrt{1+12[\frac{h}{w}]}}]$$
(3.3)

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