

**MICROSTRIP BANDPASS FILTER AT 5.8 GHz**

**SITI NOR HASIMA BINTI MAT JUSOH**

**This report is submitted in partial fulfillment of the requirements for the award of**

**Bachelor of Electronic Engineering (Telecommunication Electronics)**

**With Honours**

**Faculty of Electronic and Computer Engineering**

**Universiti Teknikal Malaysia Melaka**

**April 2009**



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**  
**FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN**  
**KOMPUTER**

**BORANG PENGESAHAN STATUS LAPORAN**

**PROJEK SARJANA MUDA II**

**Tajuk Projek : MICROSTRIP BANDPASS FILTER AT 5.8 GHz**

**Sesi Pengajian : 2008/2009**

Saya **SITI NOR HASIMA BINTI MAT JUSOH**

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (  ) :

**SULIT\***

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

**TERHAD\***

(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

**TIDAK TERHAD**

Disahkan oleh:

\_\_\_\_\_  
 (TANDATANGAN PENULIS)

\_\_\_\_\_  
 (COP DAN TANDATANGAN PENYELIA)

Alamat Tetap: LOT 1756 KG BUKIT BATOR,  
 16390 GUNONG, BACHOK,  
 KELANTAN.

“I hereby declare that this report is the result of my own work except for quotes as cited  
in the references.”

Signature : .....

Author : SITI NOR HASIMA MAT JUSOH

Date : 30 APRIL 2009

“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours”

Signature : .....

Supervisor's Name : EN. AZAHARI BIN SALLEH

Date : 30 APRIL 2009

## **DEDICATION**

Special to my father and my family, thanks a lot for all your support.

For my friends, thank for helping and guide me for all this time.

Hope all of us will success and happy ever after.

## ACKNOWLEDGEMENT

First and foremost, I would like to praise the Almighty Allah for blessing me with strength and capability to provide the final year report successfully for the 2008/2009 session. One more course to go, but I hope that this blessing will continually giving me the nurture that I need. I am so glad that I have given an opportunity to carry out this project, which exposes the actual system of evaluation process.

Furthermore, I would like to express my deepest appreciation to my final year project's supervisor En.Azahari Bin Salleh for his advise, precious guidance, advices, support and all the countless help during finish my project. Under his guidance, I have developed, improved and achieved the completion of this project. Besides that, I would like to express my gratitude to both of my parents for the encouragement and financial support throughout my studies.

At last but not least, to all my friends, lecturers and colleagues whom I have not mentioned by name in here, thank you very much. May all thou sacrificial will blessing and guidance from Almighty Allah SWT.

## ABSTRACT

The primary purpose of this report is more to brief to the reader with a detailed and comprehensive study of theory, design, fabrication, result and problem encountered in the designing bandpass filter. This filter design is operate at frequency center of 5.8 with bandwidth is 20% of frequency center. The approaches used to achieve this project are through literature review of microstrip filter including calculation, computer software simulation and fabrication process using FR4 board. Microstrip technology is the best technique because it is can give accurate value and economical. This technology is design to reduce the cost compared to conventional filter that had been used before. The bandpass filter has several types and design but this project is focused on the parallel-coupled bandpass filter to determine the suitable parameters. Microwave Office Software is used to analyze the characteristic parameter and determine the insertion loss and return loss of frequency response that has been used to analyze performance quality. The bandpass filter contributes to the application of Wireless Local Network Area application. This thesis exposes to the evaluation process of designing parallel-coupled microstrip bandpass filter.

## ABSTRAK

Tujuan utama laporan ini adalah untuk memberikan maklumat secara terperinci kepada pembaca mengenai teori, rekabentuk, proses fabrikasi, keputusan dan permasalahan yang mungkin wujud dalam proses mereka bentuk. Reka bentuk turas ini beroperasi pada frekuensi tengah 5.8 GHz dengan jalur lebar pada 20% daripada frekuensi tengah. Pendekatan digunakan bagi mencapai projek ini adalah melalui kajian latar belakang termasuk pengiraan, simulasi perisian computer dan proses fabrikasi menggunakan papan FR4. Mikrostrip teknologi adalah teknik terbaik kerana ia adalah boleh memberikan nilai yang tepat dan jimat. Teknologi ini dapat mengurangkan kos berbanding dengan turas konvensional yang telah digunakan sebelum ini. Penapis lurus jalur mempunyai beberapa jenis dan reka bentuk tetapi menumpukan perhatian pada rekabentuk penapis lurus jalur ganding selari. Perisian Gelombang Mikro digunakan untuk menganalisa ciri-ciri parameter dan menentukan kehilangan sisipan dan kehilangan balikan bagi gerak balas frekuensi telah digunakan untuk menganalisa prestasi kualiti. Sementara itu, kaedah kehilangan penyisipan yang digunakan untuk menganalisis kualiti pelaksanaan. Penapis turas ini adalah digunakan dalam aplikasi Rangkaian Kawasan Setempat Tanpa Wayar. Laporan ini mendedahkan proses merekabentuk penapis lurus jalur ganding selari.



**TABLE OF CONTENTS**

<b>CHAPTER</b>	<b>TITLE</b>	<b>PAGE</b>
	<b>PROJECT TITLE</b>	i
	<b>CONFESSION</b>	ii
	<b>DEDICATION</b>	v
	<b>ACKNOWLEDGMENT</b>	vi
	<b>ABSTRACT</b>	vii
	<b>ABSTRAK</b>	viii
	<b>TABLE OF CONTENT</b>	ix
	<b>LIST OF TABLES</b>	xiv
	<b>LIST OF FIGURE</b>	xv
	<b>LIST OF ABBREVIATIONS</b>	xvii
	<b>LIST OF APPENDIX</b>	xviii

<b>I</b>	<b>INTRODUCTION</b>	
1.1	PROJECT BACKGROUND	1
1.2	PROJECT OBJECTIVE	2
1.3	PROBLEM STATEMENT	3
1.4	SCOPE OF WORK	3
1.5	THESIS OUTLINE	4
<b>II</b>	<b>MICROSTRIP BANDPASS FILTER</b>	
2.1	OVERVIEW	6
2.1	FILTER DESIGN	8
2.2	TYPES OF FILTER	9
2.2.1	Basic Low Pass Filter	9
2.2.2	Basic High Pass Filter	10
2.2.3	Band Pass Filter	10
2.3	FREQUENCY RESPONSE TYPES OF FILTER	11
2.3.1	Butterworth Filter (equal-ripple amplitude)	11
2.3.2	Chebyshev Filter	12
2.3.3	Bessel Filter	13
2.3.4	Gaussian Filter	13

2.4	SCATTERING PARAMETER	13
2.4.1	Definition of S-parameters	14
2.5	MICROSTRIP FILTER	15
2.5.1	Parallel-Coupled Microstrip Bandpass Filter	18
2.5.2	Hairpin-Line Bandpass Filters	20
2.5.3	Interdigital Bandpass Filter	21
2.6	SUBSTRATE MATERIALS	22
2.6.1	Flame Resistant 4 (FR4)	23
2.6.2	Ceramic Substrates	24
2.6.3	Softboard	24
2.6.4	Sapphire substrate	25
2.6.5	Plastic	25

### **III PROJECT METHODOLOGY**

3.1	PROJECT METHODOLOGY	26
3.1.1	Dimensional Calculation	28
3.2	SIMULATION	34
3.3	FABRICATION	36
3.3.1	Layout Printing	36

3.3.2	UV Process	37
3.3.3	Developer	37
3.3.4	Etching Process	37
3.3.5	Stripper	38
3.3.6	Cutting and Soldering	38
3.4	TESTING	38
3.4.1	Network Analyzer	38

## **IV RESULT AND ANALYSIS**

4.1	INTRODUCTION	40
4.2	SIMULATION RESULT	44
4.2.1	Actual Layout (Corel Draw 12)	45
4.2.2	Simulation Result Analysis	46
4.2.3	Comparison Simulation Result Between FR4 Board and Roger Board	49
4.3	MEASUREMENT RESULT	52
4.3.1	Comparison Result	55
4.2.2	Fabrication Result Analysis	57

<b>V</b>	<b>CONCLUSION AND FUTURE WORK</b>	
5.1	CONCLUSION	58
5.2	FUTURE WORK	60
	<b>REFERENCES</b>	61
	<b>APPENDIX</b>	63

**LIST OF TABLES**

<b>NO</b>	<b>TITLE</b>	<b>PAGE</b>
3.1	Bandpass Filter Design Specification	29
3.2	FR4 Substrate's Properties	29
3.3	Element values for Chebyshev lowpas prototype filters.	31
4.1	Filter Design Result	41
4.2	Parameter of Parallel-Coupled Filter	43
4.3	Physical Dimension of Coupled Line	43
4.4	RT5880 Substrate's Properties	49
4.5	Physical Dimension of Coupled Line from ADS Software.	49
4.6	Comparison simulation result between FR4 Board and Roger Board	52
4.7	Measurement result of parallel-coupled microstrip filter	55
4.8	Comparison of simulation result and measurement result	55

## LIST OF FIGURES

NO	TITLE	PAGE
2.1	Frequency response for a low pass filter	9
2.2	High Pass Filter	9
2.3	Frequency response of a Band Pass Filter	11
2.4	Frequency Response of various filters	12
2.5	Generalized two-port network, characteristic impedance $Z_0$	14
2.6	Stripline transmission line (a) Geometry (b) Electric and magnetic field lines.	16
2.7	Microstrip line and stripline	18
2.8	General Structure of parallel (edge)-coupled microstrip bandpass filter	19
2.9	Layout of a 5-pole of hairpin-line microstrip bandpass filter	20
2.10	General Configuration of interdigital bandpass filter	21
2.11	Physical dimension of microstrip line	23
3.1	Project Methodology	27

3.2	Attenuation versus normalized frequency for 0.5 dB ripple low-pass filter prototype	30
3.3	Coupled line filter configuration	32
3.4	The coupled line filter with admittance $Y$ , and the equivalent circuit	32
3.5	Linecalc ADS Software	34
3.6	AWR Software	35
3.7	Network Analyzer Measurement Set	39
4.1	Attenuation versus normalized frequency for 0.5 dB ripple low-pass filter prototype	42
4.2	Schematic layout of the 6 <sup>th</sup> -order bandpass filter.	44
4.3	Actual Layout of Parallel Coupled bandpass filter	...45
4.4	Filter response before optimize coupled line	46
4.5	Optimization coupled length filter response	47
4.6	Optimization coupled line width result	47
4.7	Optimization coupled line space result	48
4.8	Em Structure of Schematic Layout of 6 order bandpass filter	50
4.9	The result of frequency response.	50
4.10	Return Loss of different substrate	51
4.11	Insertion Loss of different substrate	51
4.12	Fabrication Circuit	52
4.13	a). Return Loss ( $S_{11}$ ) and b). Insertion Loss ( $S_{21}$ )	53
4.14	a). Return Loss ( $S_{11}$ ) and b). Insertion Loss ( $S_{21}$ )	54



## LIST OF ABBREVIATIONS

BW	-	Bandwidth
BPF		Bandpass Filter
PCB	-	Printed Circuit Board
WLAN	-	Wireless Local Area Network
$f_c$	-	Center frequency
$f_L$	-	Lower Cut-off Frequency
$f_H$	-	Higher Cut-off Frequency
$Z_{in}$	-	Input Impedance
$Z_0$	-	Characteristic Impedance
$\epsilon_r$	-	Relative Dielectric Constants
$\epsilon_{eff}$	-	Dielectric
$h$	-	Substrate Height
$t$	-	Thickness
$l$	-	Length
$w$	-	Width
$s$	-	Space

**LIST OF APPENDIX**

<b>NO.</b>	<b>TITLE</b>	<b>PAGE</b>
A	Smith Chart for Schematic Design	63
B	RT/Duroid <sup>f</sup> 5870/5880 High Frequency Laminates	64

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 PROJECT BACKGROUND**

This project provides the reader with the detail and comprehensive study of theory, design, fabrication, result and problem encountered in the designing bandpass RF microwave filter. This project will develop bandpass filter by using microstrip technology. The approaches used to achieve this project are through literature review, dimensional calculation and computer software simulation. The characteristic and the required specification are analyzed before fabricating the microstrip bandpass filter. It is impossible to transmit an infinite signal through an infinite electromagnetic spectrum, electromagnetic spectrum is very limited, hence there is a need have a filter that will confined the desired Radio Frequency (RF) or microwave signal within the limited bandwidth.

Computer simulation is the best technique to get the solution because it can give the accurate value and it also economical. Microwave Office 2004 is the software that use to analyze the characteristics of the microstrip bandpass filter and to determine the suitable parameters.

This project methodology had been divided into three stages. The first stage is survey of literature review and the second stage is dimensional calculation followed by software simulation and lastly fabrication, testing and analysis of the results. The filter design is concentrated on the parallel-coupled bandpass filter operating at 5.8 GHz by using FR4 as a substrate.

## **1.2 PROJECT OBJECTIVE**

Microstrip technology of filter in microwave is widely used and become one of the important technologies in the new era. This project will develop a bandpass filter by using microstrip technologies applications which is one of the ways to upgrade the communications system. The filter will be used in high speed and big capacity data transmission such as video in Wireless Local Area Network application. In developing this project, objective was the main concern to make sure that all process in this project will completely in the duration that given.

The objective for the microstrip bandpass filter is:

- To design a bandpass filter at 5.8 GHz by using microstrip technology. A simulate will be done by using Microwave Office Software 2004 and the circuit will be fabricate by using FR4 as a substrate.

### **1.3 PROBLEM STATEMENT**

In this project, microstrip technology will be used. As we know, the cost for a bandpass filter is expensive. Originally, filters were designed using inductors, capacitors, and transformer and were terminated by resistors representing the load and the internal resistance of the source. This technology is design to reduce the cost compared to conventional filter that had been use before. There is no use the active devices such as capacitor and the whole circuit will fabricate using this technology, but the mathematical of filter approximation was being advanced independently of these devices. Bandpass filter is take time to build and this technology is try to make faster and simple way to design microstrip bandpass filter. The bandpass filter is working on 5.8 GHz based on IEEE802.11a standard for wireless LAN application. This frequency is becoming more widely recognized as an economical alternative for short distance voice and data communication.

### **1.4 SCOPE OF WORK**

In this new era technology, all the application of communication system widely used the microwave radio frequency such as Japan, United State America, Great Britain and others. Malaysia is one of the countries that try to reach the technology.

This project is to develop a 5.8 GHz Chebyshev bandpass filter by using microstrip technologies. This project is focus on super high frequency (SHF) which the electromagnetic spectrum between 3 MHz to 300 MHz and the specification frequency at frequency 5.8 GHz. The scope of this project is divided to three stages which is study of literature review, simulation and fabrication of the circuit. A scope of work is:

- Analysis the type of filters and a significant set of parameters  $S_{11}$  and  $S_{21}$  known as ‘scattering parameters’ or more briefly S-parameters embody the effects of reflection or through transmission of power for any network.  $S_{11}$  is referring to return loss and  $S_{21}$  is the insertion loss of frequency response.
- By using software such as Microwave Office, the expected result for the filter can be determined which simulation process is one of the engineering methods to get the expected result.
- The last part of this project is fabricating filter circuit using FR4 board after do the simulation and the result will be compare with the expected result from simulation.

## 1.5 THESIS OUTLINE

Chapter 1 provides a first glimpse at the basic aspects of the research undertaken which is introduction, project objective, problem statement, and scope of work in the designing parallel-coupled microstrip bandpass filter.

Chapter 2 gives a literature review on parallel-coupled microstrip lines and overview of the fundamentals of parallel-coupled bandpass filter design. Coupling effect will be discussed. It also shows how a parallel coupled can be used for the filter design, based on the given specification how to obtain the  $Z_{oe}$  and  $Z_{oo}$  from lowpass filter prototype elements.

Chapter 3 shows the detail of designing a Chebyshev parallel-coupled bandpass filter. Flowcharts and sequence of the filter design will be presented. It is starting with dimensional calculation to analyze the order of filter and the physical dimension of the coupled-line. Careful and detail studies were carried out on chapter to obtain a right design equation. Finally an appropriate design equation was achieved and used for

further design of the parallel coupled bandpass filter. Filter design parameters are presented for bandpass filter center frequency 5.8 GHz with operation bandwidth of 20 %.

Chapter 4 is about the result and analysis microstrip bandpass filter. Based on the design equation from chapter 3, the design modification was introduced on the parallel coupled bandpass filter and simulated. The complete results are given for non modified and modified filters. From the results and analysis on this chapter, further modification has been done on the filter design parameter to achieve the actual design specification proposed in this research. Finally, the results are presented and analyzed.

Chapter 5 concludes the thesis followed by recommendations for future work.

## **CHAPTER II**

### **MICROSTRIP BANDPASS FILTER**

#### **2.0 OVERVIEW**

We are living in age of information of information technology. Most of this technology is based on the theory of filter design and its applications are supported by other disciplines such as computer science and engineering, and advances in technologies. Filter plays important rule in many radio frequency or microwave applications. It is used to separate or combine different frequencies.

In the early days of microwave engineering (1940), most components were manufactured as highly precise mechanical elements. There is no semiconductor processes were available such as any practical planar circuit board technologies at hand for industrial scale network. Active devices were mostly electron tubes which it is required the extreme capabilities of the mechanical workshop [3].