

THE MINIMIZATION OF 5.75 GHZ CHEBYSHEV BAND PASS FILTER

OTHMAN ABDULLATIF JUSSAB

**This report is submitted in partial fulfillment of the requirement for the award
of Bachelor of Electronic Engineering (Telecommunication Electronic) With
Honours**

**Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka**

June 2012



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : The Minimization of 5.75 GHz Chebyshev Band Pass Filter

Sesi Pengajian :

1	1	/	1	2
---	---	---	---	---

Saya OTHMAN ABDULLATIF JUSSAB

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 (\checkmark) :

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)

Tarikh:

Tarikh:

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

Signature :

Author : OTHMAN ABDULLATIF JUSSAB

Date : 15th JUNE 2012

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

Signature :

Name : **PROF. MADYA DR. ABDUL RANI BIN OTHMAN**

Date : **15th JUNE 2012**

Dedicated to my beloved family

ACKNOWLEDGEMENT

First, I am highly thankful and indebted to Allah Subhanahu Wata'ala for providing me peace of mind, ability and will to complete this work.

Peace and Rahmah be upon my father Mr. Abdullatif Jussab Saddique who had inspired me to strive for excellence. May Allah bestow him with Al Firdaus. I am grateful to my mother, Mrs. Khairon, my grandmother Mrs. Hawa and Aunty Safia for their spiritual support and Dua'as. I am also thankful to all my siblings; namely, Asif, Layla, Nasreen, Muzammil, Mukhtar, Nadir, Rubeena, Nadia, Fatma, Juneid, Nabel, Rukhsaar, Naypheen, Ayman, and Nawaf for their caring and dua'a.

I am very grateful to PM. DR. Abdul Rani bin Othman, who has served for a year as my supervisor for my study towards Bachelor Degree. PM. Dr. Abdul Rani provided invaluable guidance and support throughout the work on this thesis. Without his support and patience I would not have completed my degree.

I would like to express my gratitude to the Faculty of Electronic and Computer Engineering (FKEKK) for giving me a chance to take part on a project which is a requirement to fulfilling the bachelor degree where I had gained great experience and knowledge.

Last but not least, I would like to thank everyone who has made this project possible especially my friends; Jason Danial, Mohd Nasruddin, Teh Chee kang, Sam, my lecturer, Mr. Mohammad Zoinol, Final Year Project Lab technicians and Microwave Lab technicians. This project would not have seen the daylight without their help.

ABSTRACT

This project presents the minimization of Chebyshev 9th order band pass filter with a center frequency of 5.75GHz and a bandwidth of 100MHz. The minimization of the band pass filter has taken considerations on the same design specifications and performances. This thesis will compare the simulation results of two substrates, TLY-5A and FR4. The designed circuits were simulated using Ansoft SV software. The fabrication of the miniaturized band pass filter was realized using the FR4 dielectric substance by using parallel coupled method. The minimized filters were named as Ω -Type and W-Type. The insertion loss of the Ω -Type filter was – 20.01 dB with a bandwidth of 460 MHz operating at 5.75 GHz. The W-Type had an insertion loss of -23.03 dB with a bandwidth of 260 MHz operating at 5.75 GHz. With this research, smaller band pass filter can be used in applications such as RF front end receiver and other communication systems in the future.

ABSTRAK

Projek ini membentangkan tentang pengecilan saiz penapis lulus jalur pertengahan jenis Chebyshev pada tahap 9 dengan frekuensi pertengahan pada 5.75GHz dan jalur lebar seluas 100 MHz. Pengecilan pada penapis lulus jalur pertengahan ini mengambil kira spesifikasi dan prestasi dari reka bentuk asal. Tesis ini membincangkan perbezaan dari segi keputusan simulasi dari dua jenis bahan yang berbeza iaitu TYL-5A dan FR-4. Perisian Ansoft SV digunakan bagi ujian simulasi bagi reka bentuk ini. Kemudian, bahan FR-4 dengan teknik pemasangan selari digunakan untuk memfabrikasi reka bentuk ini. Penapis ini dilabel sebagai Jenis- Ω dan Jenis-W. Nilai kehilangan sisipan bagi Jenis- Ω ialah -20.01 dB dengan nilai jalur lebar sebanyak 460 MHz beroperasi pada 5.75 GHz. Manakala, Jenis-W pula mempunyai nilai kehilangan sisipan sebanyak -23.03 dB dan nilai jalur lebar sebanyak 260 MHz beroperasi pada 5.75 GHz. Melalui kajian ini, penapis lulus jalur pertengahan yang telah mengalami proses pengecilan ini dapat digunakan untuk sesetengah aplikasi seperti penerima akhir frekuensi radio dan lain-lain sistem komunikasi di masa akan datang.

CONTENTS

CHAPTER	TITLE	PAGES
	PROJECT TITLE	i
	STATUS CONFIRMATION FORM	ii
	DECLARATION	iii
	DEDICATION	vi
	ACKNOWLEDGEMENT	vii
	ABSTRACT	viii
	ABSTRAK	ix
	CONTENTS	x
	LIST OF TABLES	xiii
	LIST OF FIGURES	xiv
	LIST OF ABBREVIATIONS	xvi
	SYMBOLS	xvii
	LIST OF APPENDIX	xix
I	INTRODUCTION	
	1.1 Introduction	1
	1.2 Project Objectives	2
	1.3 Project Background	2
	1.4 Project Scope	3
	1.5 Methodology	4
	1.6 Thesis Structure	5
II	LITERATURE REVIEW	

2.1	Introduction	6
2.2	Filters	6
2.2.1	Type of Filters	7
2.2.2	Passive Filters	8
2.2.3	Classification of Filters	8
2.2.4	Band Pass Filters	10
2.3	Literature Survey on Miniaturized Band Pass Filter	11
2.4	Filter Designing Methods	13
2.4.1	Image Parameter Method	13
2.4.2	Insertion Loss Method	15
2.5	Low Pass Filter Prototype	16
2.5.1	Butterworth Low Pass Filter Prototype	18
2.5.2	Chebyshev Low Pass Filter Prototype	21
2.6	Scaling and Conversion	24
2.6.1	Scaling	24
2.6.1.1	Impedance Scaling	24
2.6.1.2	Frequency Scaling	24
2.6.2	Conversion	25
2.7	Filter Realization	27
2.7.1	Microstrip Transmission Line	27
2.7.2	Parallel Coupled Band Pass Filter	28
2.7.3	Glass Epoxy (FR-4)	31
2.8	Summary	32

III METHODOLOGY

3.1	Introduction	33
3.2	Project flow	33
3.3	Chebyshev Band Pass Filter Design	36
3.3.1	Chebyshev Low Pass Filter Prototype	36
3.3.1.1	Graphical Method	36
3.3.1.2	Calculation Method	38
3.3.2	Frequency Scaling and Conversion	40

	3.3.3 Filter Implementation	41
	3.4 Simulation Process	43
	3.5 Hardware Fabrication Process	45
	3.6 Measurement Process	46
	3.7 Summary	46
IV	RESULTS AND ANALYSIS	
	4.1 Introduction	47
	4.2 Simulation Results of Conventional 9 th Order Band Pass Filter	47
	4.3 Simulation Results of Ω -Type 9 th Order Band Pass Filter	55
	4.4 Simulation Results of W-Type 9 th Order Band Pass Filter	59
	4.5 Measurement Results	64
	4.5.1 Measurement Results of Ω -Type 9 th Order Band Pass Filter	64
	4.5.2 Measurement Results of W-Type 9 th Order Band Pass Filter	64
	4.5.3 Comparison of Measurement Results	65
	4.6 Summary	67
V	DISCUSSION AND CONCLUSION	
	5.1 Introduction	68
	5.2 Discussion	68
	5.3 Recommendation	69
	5.4 Conclusion	70
	REFERENCES	71
	APPENDICES	74

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Element Values of Butterworth Filter	20
2.2	Element Values of Chebyshev Filter	22
3.1	Specifications for Chebyshev Filter	36
3.2	9 th Order Element Values Equal Ripple Low Pass Filter Prototype	39
3.3	Calculation of Even and Odd Impedances	43
4.1	Conversion of Dimension W, S and P for Substrate TLY-5A	48
4.2	Conversion of Dimension W, S and P for Substrate FR4	48
4.3	Comparison of Target and Simulation Results for Conventional 9 th Order Band Pass Filter Design for TLY-5A and FR4	51
4.4	Optimized Values of W, S and P for TLY-5A	42
4.5	Optimized Values of W, S and P for FR4	53
4.6	Comparison of Target and Optimized Simulation Results for Conventional 9 th Order Band Pass Filter using Substrate TLY-5A	54
4.7	Effect of Varying the Parameters W, S and P	55
4.8	Results Comparison of Ω -Type Chebyshev 9 th Order Band Pass Filter	58
4.9	Comparison Between Conventional and Ω -Type Band Pass Filter	59
4.10	Results Comparison of W-Type Band Pass Filter	62
4.11	Comparison of Conventional Ω -Type and W-Type Band Pass Filter	63
4.12	Comparison of Measurement Results	65
4.13	Comparison of Simulation and Measured Results for Ω -Type Band Pass Filter	66
4.14	Comparison of Simulation and Measured Results for W-Type Band Pass Filter	66

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Designing Process	4
2.1	Filter Responses	9
2.2	Block Diagram of Image Parameter Method	14
2.3	Block Diagram of Insetion Loss Method	15
2.4	Low Pass Filter Prototypes for even and odd orders	17
2.5	Characteristics of Butterworth Filter	18
2.6	Attenuation v/s Normalized for Butterworth Filter Prototype	19
2.7	Characteristics of Chebyshev Filter	21
2.8	Attenuation v/s Normalized for Chebyshev Filter Prototype	22
2.9	Low pass to band pass transformation	25
2.10	Conversion of Inductor	26
2.11	Transformation of capacitor `	27
2.12	Microstrip Transmission Line	27
2.13	Microstrip Parallel Coupled-line Coupler	29
2.14	Layout of Cascaded Coupled Bandpass Filter	30
2.15	Even and Odd modes of Electrical Fields	30
3.1	Project Flow Chart	35
3.2	Determining Number of Orders Using Graphical Method	38
3.3	Schematic Diagram of 9 th Order Lumped Element Circuit	39
3.4	Conversion of Series Inductor and Parallel Capacitor	40
3.5	Schematic Circuit after Conversion	41
3.6	Transformation of Low Pass to Band Pass Response	41
3.7	Substrate Settings For FR4	44
3.8	Conversion of Even and Odd Impedances to Microstrip	45

4.1	Schematic Circuit of Conventional 9 th Order Band Pass Filter	49
4.2	Layout of Conventional 9 th Order Band Pass Filter for TLY-5A	49
4.3	Layout of Conventional 9 th Order Band Pass Filter for FR4	49
4.4	Frequency Response of TLY-5A Band Pass Filter	50
4.5	Frequency Response of FR4 Band Pass Filter	51
4.6	Optimized Frequency Response of Band Pass Filter for TLY-5A	53
4.7	Optimized Frequency Response of Band Pass Filter for FR4	54
4.8	Schematic Circuit of Ω -Type Chebyshev 9 th Order BandPass Filter	55
4.9	Layout of Ω -Type Chebyshev 9 th Order Band Pass Filter for TLY-5A	56
4.10	Layout of Ω -Type Chebyshev 9 th Order Band Pass Filter for FR4	56
4.11	Frequency Response of Ω -Type Chebyshev 9 th Order Band Pass Filter for TLY-5A	57
4.12	Frequency Response of Ω -Type Chebyshev 9 th Order Band Pass Filter for FR4	58
4.13	Schematic Circuit of W-Type Chebyshev 9 th Order BandPass Filter	60
4.14	Design Layout of W-Type Chebyshev 9 th Order Band Pass Filter for TLY-5A	60
4.15	Design Layout of W-Type Chebyshev 9 th Order Band Pass Filter for FR4	61
4.16	Frequency Response of W-Type Chebyshev 9 th Order Band Pass Filter for TLY-5A	61
4.17	Frequency Response of W-Type Chebyshev 9 th Order Band Pass Filter for FR4	62

LIST OF ABBREVIATIONS

RF	-	Radio Frequency
MIC	-	Microwave Integrated Circuit
LAN	-	Local Area Network
WLAN	-	Wireless Local Area Network
Op-amp	-	Operational Amplifier
FFT	-	Fast Fourier Transform
IIR	-	Infinite Impulse Transform
FIR	-	Finite Impulse Response
DC	-	Direct Current
BW	-	Bandwidth
P_{LR}	-	Power Loss Ratio
IL	-	Insertion Loss
L_A	-	Attenuation Characteristics
TEM	-	Transverse Electromagnetic Wave
FR4	-	Flame Retardant Type 4
TLY-5A	-	Taconic TLY model 5
PCB	-	Printed Circuit Board
UV	-	Ultra Violet
UWB	-	Ultra Wide Band
IEEE	-	Institution of Electrical and Electronic Engineer
MHz	-	Mega Hertz
GHz	-	Giga Hertz
FYP	-	Final Year Project

SYMBOLS

%	-	Percentage
ϵ_e	-	Effective Dielectric Constant
ϵ_r	-	Dielectric Constant
Δ	-	Fractional Bandwidth
C	-	Capacitance
dB	-	Decibel
g	-	Element Values
d	-	Substrate Thickness
E	-	Electrical Phase
J	-	Inverter Constant
K_0	-	Wave Number
M	-	M-Derived Constant
N	-	Number of order
n	-	Number of Order
L	-	Inductance
P	-	Physical Length
W	-	Width
S	-	Spacing
P_{inc}	-	Incident Power
P_{load}	-	Load Power
R	-	Input Termination Resistance
R_0	-	Source Impdance
S_{11}	-	Return Loss
S_{21}	-	Insertion Loss
V_p	-	Phase Velocity
Z_{0e}	-	Even Impedance

Z_{0o}	-	Odd Impdance
Z_0	-	Characteristic Impedance
βl	-	Electrical Length
Ω	-	Ohm
β	-	Propagation Constant
λ	-	Wavelength
π	-	Pi

LIST OF APPENDIX

APPENDIX	PAGES
A. Design Layout for Ω -Type 9 th Order Chebyshev Band Pass Filter	74
B. Design Layout for W-Type 9 th Order Chebyshev Band Pass Filter	74
C. Fabricated Conventional Band Pass Filter Implemented on TLY-5A	75
D. Measurement Results for the Fabricated Conventional Band Pass Filter	75
E. Fabricated Design of the Ω -Type Band Pass Filter Implemented on FR4	75
F. Measurement Results for Ω -Type Band Pass Filter	76
G. Fabricated Design of the W-Type Band Pass Filter Implemented on FR4	76
H. Measurement Results for W-Type Band Pass Filter	77

CHAPTER I

INTRODUCTION

1.1 Introduction:

Microwave filter is a two-port network used to control the frequency response at a certain point in a microwave system by offering transmission at frequency range for pass band of the filter and attenuation in the stop band of the filter. Normal frequency responses include low-pass, high-pass, band-pass, band reject characteristics and all pass characteristics [1].

Nowadays, filters play important roles in several RF and microwave communication systems. The present developments in RF and microwave filter are mainly based towards better performance, integration and smaller, lighter weight, and affordable cost. Unfortunately, smaller size can be crippling towards a microwave engineer, since it is often suitable to utilize the properties of structures which have dimensions comparable to the signal wavelength. When the design area becomes comparable to or smaller than the signal wavelength, such structures can be difficult or impossible to incorporate [2].

1.2 Project Objectives

The main objective of this project is to design a minimized size of the conventional Chebyshev band pass filter at 5.75 GHz while maintaining the specifications desired.

1.3 Project Background

Filter networks are vital building elements in many ranges of microwave engineering. Such systems are used to select, reject, separate or even combine signals at different frequencies in a number of microwave systems and equipment. Though the physical realization of filters at microwave frequencies may vary, the circuit network topology is mutual to all [3].

Filter is the most vital passive element used in microwave subsystem which is also the narrowest bandwidth components in the system. Filter limits such system parameters as gain and group delay flatness over frequency [4]. The development of microwave filter had begun since 1937, during the age of World War II, where the microwave filter had been extensively developed. A lot of researches demonstrated on variety of filter arrangements to realize both filter compactness and selectivity improvement. The most common band pass and band stop filter configurations are parallel coupled line, comb line, inter digital and hairpin line [5].

Andrew Elvis Simon and Lim Kuang Yaw specified that although traditional filter structures, like hair pin filters, inter digital filters and coupled lines do have good response over the microwave frequency range, however, a more robust and efficient filter structure search is still preferred [2]. This implies filter size reduction, selectivity improvement and spurious response control are the most innovative research purposes. Over the years, the rapid development of Microwave Integrated Circuit (MIC) in radar, satellite, and mobile communications tends to progress in terms of bandwidth, cost and size. Wideband applications requires coupled line microstrip and stripline filters because the demand on selectivity is not severe. On

the other hand, wireless applications need miniature filters due to space and cost constraints [4].

According to Othman A. R., the advance and demand of WLAN technology have emphasized enhancement of low cost, less power and small size transceiver by using microstrip technology. A filter design of 5.75GHz 9th order Chebyshev band pass filter can be used for the purpose of WLAN application which is an alternate economical method for small distance voice and data communication. The design parameters are 100MHz bandwidth, insertion loss less than 10dB and equal ripple of 0.5dB [6]. Thus, the filter design of Dr.Abdul Rani is used as a reference for this research work.

1.4 Project Scope

The prime scope of the project is to decrease the size of the conventional Chebyshev 9th order band pass filter while retaining the specifications. The design specifications remained the same where the center frequency of filter is 5.75GHz. The bandwidth of the filter is 100MHz and the insertion loss, S_{21} is less than 10dB. The equal ripple of the filter is 0.5dB. This project is simulated using the An-soft Designer SV2 simulation tool. Simulation and analysis are done on the minimized filters based on the objective of the project. In additional, the prototype is fabricated and measured to obtain the frequency response of the band pass filter. Simulation and measurement results are compared in order to verify the objective in this research work.

1.5 Methodology

The designing process is divided into three stages:

In the first stage, a literature review will be done regarding the Chebyshev filter designing and the architecture of microstrip bandpass is selected. The dimensions, characteristic impedance and relative permeability of the material for bandpass filter will be calculated according to the design specifications.

In the second stage, the bandpass filter will be modeled by using Ansoft Designer according to the design specifications. The bandpass is then simulated for the system characteristic such as insertion loss, center frequency etc.

In the third stage, the fabrication of the simulated filter will commence. Tests will be done where by the individual parameters of band pass filter will be measured for verification with the parameter value that are specified in the filter.

Figure 1.1 below shows the flow of the designing process discussed above.

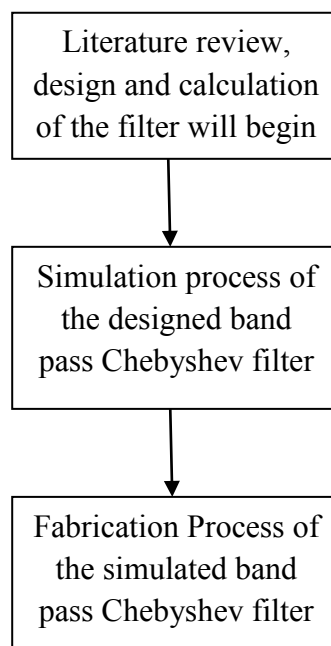


Figure 1.1: Designing Processes

1.6 Thesis Structure

This thesis consists of five chapters which are categorized as below to discuss on the project of Chebyshev band pass filter design. Chapter 2 is the literature survey of the RF filter designs, which covers the background study on the miniaturized band pass filter design and literature review on filter design theory. These will influence the selection of the filter design method and the techniques in the project. Chapter 3 discusses the methodology of the project. The methods and procedures to design and minimized the Chebyshev band pass filter are covered in this chapter. Chapter 4 illustrates the simulations and measurement results of the band pass filter. Result analysis will be covered in this chapter. Chapter 5 describes the conclusion of this thesis and it also includes the discussion and recommendations of this project.